ANALYSIS OF ALTERNATIVE PROCEDURES FOR THE EVALUATION OF AGRICULTURAL FLOOD CONTROL BENEFITS

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Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits

Volume II

A Report Submitted to the
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FOREWORD

A. Purpose

This research is devoted to evaluating alternative methodologies for estimating agricultural flood control benefits. One methodology utilizing land values as an indicator of differential returns to land related to flood risk has been published as IWR Report 69-4. The immediate report is primarily concerned with the evaluation by the Economic Research Service, U. S. Department of Agriculture, of the analytical capabilities of a regional linear programming model to estimate the narrowly defined national efficiency benefits due to the reduction of flooding on agricultural crops.

B. Findings

This research extends the Regional Linear Programming (RLP) model developed by Economic Research Service for river basin planning purposes to estimate the potential "efficiency" agricultural crop benefits from specific flood control projects. The feasibility of using the RLP model for this purpose was tested by applying the model to projected 1980 agricultural conditions. The RLP model was used to estimate the on-farm costs for producing the basin's projected 1980 level of agricultural output that is consistent with the nation's food and fiber needs. Potential "efficiency" benefits are estimated by comparing the basin-wide on-farm production costs with no flood control development, with six operating reservoirs and with eight reservoirs (assuming operating levee development in place under all conditions).

Procedures for estimating the flow of benefits over the life of the project were described.

A critical assumption of the RLP approach is that of infinitely inelastic demand conditions, i.e., the quantity of the product demanded is unaffected by variations in price. Therefore, as output per acre is increased through flood control measures, there is a corresponding reduction in production on marginal lands elsewhere in the basin. The relatively inelastic properties of demand for agricultural commodities at the national level have been confirmed by numerous studies.

If evaluation procedures concentrate on the gains in production of flood plain producers valued at going market prices, national gains are overstated, to some extent, since there is inevitably some offsetting reduction in output by producers outside the flood plain. Regional Linear Programming offers a method for computing both flood damage reduction benefits and "net" enhancement benefits (those benefits attributable to increased land use, such as idle land shifting into crop production, since offsetting reductions in production on other lands are internalized at the regional level.

One of the advantages of the RLP model is the potential for estimating future growth in agricultural flood damages. The method utilizes independent projections of demand for farm commodities and anticipated changes in crop yields and costs to generate production costs at various points in time.

C. Assessment

The utility of the RLP model for estimating agricultural crop benefits from the national economic efficiency viewpoint has been carefully explored. As the report cautions, there are several limitations to its immediate widespread use. Four types of information are needed: (1) acreage by soil class; (2) estimates of crop yields and production costs at present and selected future time periods; (3) flood hazard information; and (4) the degree of protection afforded by flood control measures. The Conservation Needs Inventory (CNI) is utilized to estimate acreages of various soil classes both on and off the flood plain. There are several serious statistical limitations to the use of CNI data on relatively small areas. The procedure for adjusting productivity estimates to reflect with and without flooding conditions appears to be subject to legitimate criticism. The only practical source of this information appears to be agricultural crop damages calculated by the frequency-damage method, therefore substantial additional study costs are entailed. For these reasons, it is recommended that substantial additional work be initiated before the procedure is utilized widely for project evaluation use.

On the other hand, there are several uses where the data limitations do not appear to be as serious. The basin planning version can be utilized very effectively as a tool for assessing alternative programs--that is, the various means by which agricultural crop productivity can be altered, such as irrigation, drainage and flood control. Future growth in productivity obtained from the RLP model can be utilized to project agricultural crop damages with much more credible results than can be estimated by the damage-frequency method.

The estimated regional benefit presented in the report should be interpreted with care. A "regional" agricultural flood control benefit was described as the difference between the estimated benefit derived by the conventional frequency-damage method (based on an assumed perfectly elastic demand for products from the flood plain) and the national economic efficiency benefit derived from the linear programming analysis. This "regional" benefit has a specialized meaning. It does not accrue on a widespread basis to residents throughout the region, but rather, it accrues to the occupants of the flood plain. Hence, it is only a regional benefit to the extent that the flood plain beneficiaries are residents of the region.

D. Status

This research represents the findings, conclusions, and independent judgment of the team of researchers. Their conclusions are not to be construed to necessarily represent the view of the Corps of Engineers. Policy and procedural changes which may result from this research will be implemented by directions and guidelines provided by the Chief of Engineers through command channels.

PREFACE

This report, Analysis of Alternative Procedures for Evaluation of Agricultural Flood Control Benefits is the result of a contract between the Corps of Engineers, U. S. Department of the Army, and the Economic Research Service, U. S. Department of Agriculture. The research conducted under this contract was to examine problems associated with estimating agricultural flood control benefits and to develop an improved analytical basis for a variety of policy and planning issues confronting the Corps of Engineers in meeting their responsibilities for flood control programs. The project was designed to identify means of improving estimates of the economic benefits resulting from reducing the flood risk on agricultural flood plains.

The investigation focused on two means of improving the analytical basis of flood-control project evaluation procedures. First, agricultural land market prices were analyzed for use as a check or a proxy for benefits calculated by conventional flood hydrograph-flood damage integration methods. Second, a regional linear programming model was used to evaluate expected national and regional agricultural benefits from flood control. The study of the two evaluation methods was conducted concurrently but is reported in two volumes.

Volume 1 consists of two parts: (1) A discussion of the theoretical framework for estimation of flood control benefits; and (2) an analysis of agricultural land market prices used as a proxy for flood control benefits computed by conventional flood hydrograph-flood damage integration methods. This volume (Volume II) also consists of two parts: (1) An application of a regional linear programming model to evaluate national agricultural benefits from proposed flood control projects; and (2) development of a composite model for a more complete evaluation of flood control benefits.

TABLE OF CONTENTS

TABLE OF CONTENTS - continued

PAGE

APPENDIX A

APPENDIX B

ANALYSIS OF ALTERNATIVE

PROCEDURES FOR THE EVALUATION

OF

AGRICULTURAL FLOOD CONTROL BENEFITS

PART III

APPLICATION OF A REGIONAL

LINEAR PROGRAMMING MODEL

CHAPTER I

INTRODUCTION

The central purpose of the research in this part is to examine and test the feasibility of utilizing a regional linear programming (RLP) model of the agricultural sector, as developed for river basin planning, as an analytical device to estimate agricultural benefits of specific flood control projects proposed by the Corps of Engineers. Regional linear programming models provide an analytical framework for evaluating economic need for and the consequences of water resource investments in a specified region. Operational RLP planning models have required the assembly of extensive information about projected demand for agricultural commodities and of crop production data reflecting both flood prone and flood free conditions. Cost and yield information of both flood plain and upland soils in a region for selected years are projected. The model, with its informational base, thus provides a potential for estimating agricultural flood control benefits resulting from a proposed project.

The availability of operational regional planning models does not automatically assure their application to the task of estimating benefits from a specific flood control project(s). Several problems must be resolved prior to adapting the planning model to a project evaluation assignment. In this report, we will first present a brief review of the major factors to consider in establishing methods and techniques for flood control benefit evaluation and indicate how linear programming relates to these factors; second, describe the features of the Wabash Basin RLP planning model; third, discuss the major empirical problems in modifying the planning model to a project evaluation model; fourth make the empirical application test; and fifth, draw conclusions to indicate the theoretical and empirical advantages and shortcomings associated with applying a RLP model to evaluate agricultural flood control benefits.

Attributes of Benefit Evaluation Methodology

As discussed in Volume I, there are four principal desiderata to consider in an ideal formulation of flood control benefit evaluation procedures: (1) effect on the productivity of flood plain resources; (2) the viewpoint taken--resource owner's or society's; (3) projection of future benefits; and (4) adverse effects (if any) of the proposed projects. 1/ The rationale for these points was presented in Volume I and are briefly summarized below.

The productivity of or returns to flood plain resources can be increased by any action that shifts the supply curve downward and/or to the right. Flood control may reduce the costs of inputs used in agricultural production; e.g., reduction in soil preparation and replanting costs. Increased productivity of inputs used on flood plain lands may result by reducing or eliminating direct loss of agricultural output, and by eliminating yield reductions due to delayed planting. Flood control may also contribute to more efficient utilization of flood plain land either in its present use by allowing more intensive production practices to be adopted (e.g., heavier fertilizer applications) or by enabling land use shifts to higher value crops or to commercial, industrial, or residential uses. The first two effects--reducing input costs and reducing yield losses--are considered direct damage reduction. Benefits arising from more efficient utilization or from shifts to higher value uses are considered enhancement benefits.

1/ Economic Research Service, Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, Vol. I, U. S. Department of Agriculture, August 1969.

Flood control benefits can be evaluated from two different viewpoints. First, from the viewpoint of what the flood plain occupants would suffer due to flooding or what they would receive as flood protection benefits; and second, from the viewpoint of society as a whole. It is important to distinguish between these two viewpoints because the societal benefits are not necessarily equal to the sum of the benefits obtained by individual flood plain occupants. An individual may benefit greatly from a flood control project yet society as a whole may be no better off. This is particularly true when the demand for the additional output produced on the protected flood plain is inelastic. In this case, the increased net returns to flood plain occupants may be offset either by equivalent reductions in production elsewhere or by increased costs of price support and production control programs.

In addition to determining estimated benefits under current conditions, we also need to know whether the benefits can be expected to increase or decrease over time. A sound analysis will require projection of future rates of flood plain development that are likely to occur in the absence of flood protection.

An ideal benefit evaluation framework should also consider the negative effects that may result from the installation of a flood control project. For example, the release of flood waters from a reservoir may cause streams to have bankful conditions for prolonged periods, resulting in impaired drainage to adjoining land.

The RLP model developed for river basin planning is constructed in a way that explicitly recognizes the first three flood control benefit evaluation desiderata mentioned above. Detailed information on production costs and yields for flood plain soils are obtained for both with and without flooding conditions. A national viewpoint is adopted by recognizing the inelastic demand for most agricultural crops. 2/ And future flood plain land use is systematically projected, based on cost and yield conditions that are expected to prevail in the future.

Selection and Features of Linear Programming

Linear programming offers a means by which a broad range of production possibilities for flood plain soils can be considered simultaneously with similar possibilities for upland soils. Production costs and yield responses for a variety of crops on specified soil groups, under with and without flooding conditions, can be analyzed via computer to determine likely changes in land use as a result of providing flood protection. Associated with these land use changes are reductions in the costs of producing the necessary food and fiber in the region, which can be interpreted as a saving due to flood protection. This system offers the possibility of analyzing more detailed information regarding the agricultural effects of flood protection than is possible through the use of the "composite acre" approach that is used in conventional agency methods. The adoption of linear programming as a tool of analysis, however, should not be made without recognizing the underlying basic assumptions of this technique.

The linear programming model, like any other model, is an abstraction of reality. According to Swanson, "The researcher who uses an LP model abstracts those features of a problem which are believed to be most crucial and places

2/ A study by Brandow indicates the following elasticities of demand at the farm level of selected commodities: Feedgrains, including corn, oats, barley, sorghum grain and feed wheat, -.36; soybeans -.61; potatoes and sweet potatoes -.11; wheat for food -.02; rice -.04; and corn for food -.03. Brandow, G. E., Interrelations among Demands for Farm Products and Implications for Control of Market Supply. Bul. 680. Pennsylvania State University, College of Agriculture, University Park, Pennsylvania, 1961.

them in a systematic framework. The LP model assumes that the production processes may be broken down into elementary processes or activities tied together by a set of linear relations." 3/

These activities, together with the specified stock of available resources, define the production possibilities or opportunities. Numerical estimates of resource availability, production coefficients, and activity weights must then be obtained.

Four postulates of linear programming have been listed by Dorfman--linearity, divisibility, additivity and finiteness. 4/

> "(1) Assumption of Linearity - demands that for each activity the ratios between the two inputs and the product are fixed and hence independent of the level at which the activity operates. Thus inputs are combined in technically fixed proportions." 5/

The production function that is represented by an LP model is assumed to be homogeneous in the first degree, that is, there are constant returns to scale in any one process. This implies that the same quantity of output is obtained from each given set of inputs, regardless of the number of input sets used.

> "(2) Assumption of Divisibility - given the process or activity, all non-negative levels of the process are considered as possibilities. Since activity levels are not forced to take integral values (and can thus assume fractional levels), neither are the resource requirements required to take integral values."

This assumption should not cause any problem if the units of inputs and outputs can be defined in small quantities so that any rounding of fractional inputs or outputs in the final solution can be made without significantly altering the values of the numbers in the solution.

3/ Earl R. Swanson, "Programming Optimal Farm Plans," in Farm Size and Output Research, Southern Cooperative Series, Bulletin No. 56, June 1958, p.47.
4/ Robert Dorfman, The Application of Linear Programming to the Theory of the Firm, Univ. of Calif. Press, Berkeley, 1951. Chapter IV.
5/ Swanson, op. cit., p. 47.

"(3) Assumption of Addivity - this implies that with the simultaneous operation of two or more activities, the total product (TP) produced is equal to the sums of the products produced by the individual processes. The quantities of inputs required are sums of the requirements of each individual activity." 6/

"(4) Assumption of Finiteness - means that of all possible processes, only a few are considered as alternatives." 6/

In the Wabash RLP planning model, a maximum of five resource management alternatives were considered for a given soil group--flood protection, flood protection plus drainage, drainage, irrigation, and existing resource condition. Within each management group only one process (input combination) was considered for the production of each of nine crops. In actuality, however, a broad range of input combinations could be considered for producing a given crop on a given soil group. The effect of the finiteness assumption may be reduced by increasing the number of alternative processes. As computational facilities become more adequate, finiteness is less of a problem.

As indicated in Volume I, the efficiency benefits to society of providing flood protection to agricultural land could be estimated by "...either summing the individual benefits after netting-out all income transfers and cancellations, or by directly estimating the shift in the aggregate supply curve." 7/ Regional linear programming models provide a direct estimate of the shift in the supply curve. A cost-minimizing LP model is constructed which specifies the least-cost method of achieving a predetermined level of agricultural output from a region given the capability of the land and water resources in the region and the level of production technology utilized by farmers in the region. The model consists of (1) a set of demands (point estimates) of commodities expected to

6/ Swanson, op. cit., p. 49.
7/ Economic Research Service, "Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, Vol. I, U. S. Dept. of Agriculture, August 1969, p. 31.

be produced in the region; (2) an inventory of acres (aggregated into soil groups) within the region that have similar yield and cost-of-production characteristics; (3) crop yields obtained on each soil group; and (4) variable production costs associated with each crop for each soil group.

Yields and costs of the specified soil groups are derived to reflect average conditions as experienced by farmers in the region with these soil groups in their current state of development. A second set of yield and cost estimates are derived to reflect the productive capacity of the soil groups under average farm management conditions if the water problem is eliminated. In the case of flood plain soils, the first set reflect yields and costs under existing flooding conditions and the second set reflect changes in flood risk after installation of flood control structures. These two sets of data thus provide the basis for calculating "without development" and "with development" solutions. Separate models can be constructed for selected time periods that incorporate the anticipated technical and economic conditions for each respective selected time period. Target years of 1980, 2000, and 2020 have been used in the river basin planning studies.

Comparisons of the total cost-of-production under "without" and "with" development, when aggregated over the planning period, provides an estimate of the savings to society that would be realized as a result of the flood control project. This saving is equivalent to the efficiency benefit (including both crop damage reduction and net enhancement) that would accrue to the flood control project. Once the basic models are constructed for a region, they can be used to examine the effect of alternative sites or sizes of structures, and to analyze alternative configurations of a system of flood control structures.

In addition to estimating the efficiency gains, the model can be used to indicate the land use changes that are likely to occur as a result of the flood control project. Land use changes are identified on both flood plain areas and upland areas, as the proposed project alters the relative comparative advantage of different soil groups in different locations. The upland land use changes represent the offsets that are expected to occur in the long run as a result of the project, in response to forces operating in the private market. By specifying the model to represent three points in time, e.g., 1980, 2000, and 2020, a dynamic perspective can be obtained of the land use pattern as farmers would respond to changes over time in commodity demand and technology of production under "with" and "without" project situations.

An operational planning model has been developed for the Wabash River Basin. This basin will be used for all subsequent analyses of this study to indicate the composition of the model, the type of adjustments that are necessary to convert a planning model to a project evaluation model, and to interpret the information from the solution output.

CHAPTER II

FEATURES OF THE WABASH BASIN RLP MODEL

Components of the Wabash RLP planning model are discussed briefly in this chapter to indicate the general format of the model and the type of data required for its implementation. This discussion is not intended to be a critical review of the assumptions and rationale underlying the various components of the model.

Determination of Regional Commodity Demand Levels

The first step in the process of determing future agricultural demands on a riverbasin, such as the Wabash Basin, is to estimate national output of food and fiber for selected time periods. Estimates of the national demand levels for the major commodities produced in the Nation were provided by commodity specialists of the U. S. Department of Agriculture, based on domestic and foreign export demands. Estimated domestic demand levels are based on projections of the population for each of the three target years 1980, 2000, and 2020, and on projections of per capita consumption rates for the major commodities. The summation of domestic demands and projected export demand, by commodities, determines the expected total national food and fiber output. The identification of the Ohio Basin's expected output was based on extrapolation of past regional trends in crop and livestock production. Adjustments were made to reflect the judgment of commodity specialists regarding probable shifts in production among the country's water resource regions. Domestic and export demands for livestock and livestock products were translated into requirements for feed and forage for each water resource region.

The level of crop output for the Wabash Basin was derived indirectly from the national projections of output for the Ohio River Basin. This was done through a detailed evaluation of the Wabash Basin's historical contribution to the total Ohio Basin production.

As indicated on page 3, a national viewpoint toward estimated flood control benefits is obtained by adopting a model which is based on inelastic demands for agricultural commodities. Given the highly inelastic nature of most crops that are likely to be grown on the flood plain after flood protection is provided, the assumption of fixed demands in the model is not unrealistic. 1/

An analysis of historic trends in the geographic location of the Nation's output of food and fiber and judgment of commodity specialists regarding future shifts among region, provide a basis for indicating probable future levels of agricultural production in various regions. By assuming that the Nation's food and fiber requirements will be produced in the various regions at the projected levels, an analysis of resource use in a given region, with and without flood protection, will provide an indication of "national efficiency" benefits from the proposed flood control project. This does not necessarily mean that estimates of land use adjustments resulting from provision of flood protection to a region will actually occur entirely within the study region. To the extent land shifted out of production within the region has lower marginal unit costs of production than cropland that remains in production elsewhere in the Nation, the national efficiency gains will be underestimated. If the production adjustments occur outside the region, this implies an increase in the relative share of agricultural commodities produced

1/ In this study, the analysis will be confined to a single point estimate of demands for the various commodities, i.e., a completely inelastic demand. In actual practice, however, it may be desirable to use two or more point estimates of demand to reflect different points on the demand curve. Selection of relevant alternate points will depend on the nature of the supply curve and the probable shift in the supply curve associated with the proposed flood protection.

within the region. Because a study region is likely to contain a wide array of soils with different productivities, including some "marginal" soils, it is reasonable to assume that marginal unit costs on low productivity soils within the region are similar to marginal unit costs on soils outside the region. Hence, the potential basis toward an under-estimate of the national efficiency gain is small, and for all practical purposes, the efficiency gains calculated within the region can be regarded as national efficiency gains.

Land Resource Availability

The basic units of the RLP model are groupings of soils with similar yield and cost-of-production characteristics. These groupings are derived from an examination of the Land Resource Area/Land Capability Unit (LRA/LCU) classification of soils in consultation with soil scientists. Specific acreages of soils in each LRA/LCU for a given area are estimated from information in the USDA Conservation Needs Inventory (CNI). The agricultural land base, including cropland and pasture, is the residual land area of the Wabash Basin after deducting urban, forest, and other land use needs. Urban land is projected to expand over the period to reflect growth in population and the accompanying increased demands for land. The demand for urban land use was obtained from projections of expected additional land requirements for an increased population. Forest lands in the Wabash Basin are expected to remain relatively stable in the foreseeable future. Thus, the land area available for crop and pasture land is expected to decline. Table 1 indicates estimates of the availability of cropland for the period 1958 to 2020. Pasture land was permitted to transfer to cropland at a specific cost per acre if its soil characteristics were suitable for crop production and the RLP model determined the transfer would be advantageous. In each projection year, a relatively small amount of pasture land was transferred to cropland in the Wabash Basin RLP planning model.

Table 1.--Cropland Withdrawal, Wabash River Basin, 1958-2020
(Index 1958 = 100)

Subarea	1958 cropland	Index 1980	Index 2000	Index 2020	Percent change 1958-2020
	1,000 acres				Percent
1	1,999	92.6	89.1	86.4	-13.6
2	2,783	94.3	89.0	85.5	-14.5
3	1,378	96.1	95.8	95.4	- 4.6
4	2,733	97.6	96.8	95.9	- 4.1
5	1,409	97.2	96.6	96.4	- 3.6
6	3,891	96.3	94.5	93.2	- 6.8
Total	14,234	95.7	93.4	91.8	- 8.2

Sources: (1) 1958 Conservation Needs Inventory for Ohio, Indiana, Illinois.
(2) Wabash Basin Type II Comprehensive Survey data.

In addition to specifying the land use capability of the various LRA/LCU's in the Wabash Basin, the investigators also identified the LRA/LCU acreages which had a water problem--flood hazard, impaired drainage, or droughty condition. This information, in conjunction with appropriate cost and yield information, serves as basic data for subsequent identification by the model of water resource development opportunities.

Production Costs

On-farm production costs associated with producing the nine major crops grown in the Wabash Basin were necessary inputs to the Wabash RLP planning model. The sum of the four main production cost categories--preharvest work, materials, plant nutrients, and harvesting costs--provides an estimate of input costs associated with each potential crop activity. Data from the Midwestern State agricultural experiment stations were used to derive the cost coefficients.

The preharvesting costs included all charges for land preparation, spraying, planting, cultivating, and other preharvest activities. This category included labor charges, depreciation of equipment, taxes, insurance, and repairs, service, fuel, and lubricants for equipment. The materials category covered such items as twine for baling, herbicide spray for corn, and seed costs. The plant nutrients included fertilizer and lime applications sufficient to sustain soil productivity at the level specified in the RLP model. The harvesting costs were computed on a per acre basis for field operations such as combining, mowing, picking, and chopping. Annualized capital costs for fixed investments such as barns, fences, machine sheds, silos, and fences and the maintainence and repair costs of such items were not included in the production cost estimates. Also, average annual costs of maintaining tile and ditches on presently drained lands were not included as a separate production cost item. These capital improvement costs were not included because they generally are not considered by farmers as a variable cost in decisions regarding cropland use.

The specification of the RLP model required all cost estimates to be based on out-of-pocket costs incurred at the farm gate. An opportunity cost for the land input was not included in the calculations, since land is a residual claimant and its value is a function of the value of its output. Transportation costs also were not included under the assumption that most of the output produced would be consumed on the farm or delivered to nearby handlers. Bulky, perishable commodities such as fruits and vegetables, which have high transportation costs, are of very limited importance in the Wabash Basin, and were not included in the planning model.

Two sets of cost of production crop budgets were made for those LRA/LCU's which were identified as having a water problem. The water problems included inadequate drainage, flood hazard, and a drought hazard (potential for irrigation). The first set represented the costs associated with the LRA/LCU in its current state of development. The second set represented the production costs that would be incurred after the water problem was eliminated. In the case of flood plain lands, the first set included average annual crop production costs incurred with the existing flood hazard; the second set represented average annual costs incurred under flood free conditions.

Projected Technology

One of the principal features of the RLP analytical system is the explicit manner by which it evaluates future conditions. In addition to the projected commodity requirements for 1980, 2000, and 2020 discussed above, the analytical system also requires specific estimates of yields that are anticipated in the projection years. Crop and pasture yields utilized in the Wabash Basin RLP planning model were projected on the basis of historical yield trends and potential future yield increases based on findings of current agronomy research.

Both crop and soils specialists were consulted in developing yield projections for the soil groups in the Wabash Basin. Average farm management capabilities and average weather conditions were assumed for the target years. The yield estimates represent increased levels of inputs over time, such as improved seed, insecticides, fertilizer, and improved timeliness of farm operations. Specific crop yield changes were estimated for the various LRA/LCU soil groups in the Basin. The general anticipated trends in crop yields, as derived from regression analyses of past trends and judgment of crop specialists, are presented in Table 2.

Table 2.--Projected Yield Increases Per Year, Wabash River Basin

Crop	Per acre yield increases per year	
	1964 to 1980	1980 to 2020
	Bushels	Bushels
Corn	1.00	.67
Soybeans	.33	.26
Wheat	.50	.33
Oats	.50	.33
Barley	.12	.12

Constraints Built into the Model

The use of a linear programming model to determine land use allocation in a river basin for future time periods will provide a solution based on the comparative advantage of the various soil groups. Analysts conducting river basin studies have observed that certain economic and institutional rigidities of the agricultural economy may prevent achievement of an economic optimum based wholly on comparative advantage in crop production of soil groups in different parts of the basin. Because of this, certain constraints were built into the RLP model. Upper limits are placed upon the rate at which shifts in river basin cropping patterns can occur.

Another way to view these constraints is to recognize that a decision made during the current time period affects the opportunities and choices during subsequent time periods. In an effort to better correlate the RLP model's predicted farmer behavior with historically observed behavior, these limitations on changes in cropping patterns are imposed. This approach enables some specification on limits of changes in the acquisition and accumulation of resources.

Six economic subareas were delineated in the Wabash River Basin Survey to facilitate the analyses by the participating agencies. These subareas generally encompass major trade centers having similarities in industrial, manufacturing, and retail trade activities and also approximate the major hydrologic areas. These subareas were used in the RLP model. Constraints were imposed upon the model by specifying a minimum percentage of each geographical subarea's historic share of the crop output to be produced in that subarea. The use of these constraints assure that cropping patterns in a subarea will not consist of only one or two crops in which it has a high comparative advantage. The constraints also reflect the historical fact that farmers in the Wabash Basin generally have found it desirable to have a certain crop mix to enable maintenance of a balanced operation. The implication of employing the constraints is that crops will likely continue to be grown in areas where production has occured historically.

The constraints employed in the Wabash model specified that for those crops that are expected to decline or remain constant in total output, at least 50 percent of the historic output of each crop would continue to be produced in the respective subareas. These crops included oats, wheat, barley, and hay. For crops in a relative rising demand situation, the subarea output minimums for 1980 were 50 percent of the 1959 base; for 2000--40 percent of the 1980 base; and for 2020--30 percent of the 2000 base. Crops in the rising demand category include: corn, soybeans, corn silage, and pasture. Limits on the extent of crop pattern change were based on criteria established by NRED analysts using the Wabash Basin planning model. Restrictions on extent to which crop adjustment within each subarea could occur were arbitrarily set at levels indicated in Table 3 so that acreage of crops decreasing would only approach zero asymptotically by target year 2020. The limits were applied only at the subarea level. No constraints were placed on particular groups of soils, such as flood plain soils.

Table 3.--Production Minimums for Selected Crops by Subarea, Wabash River Basin

Base year	Target year	Production as percentage of base year: Decreasing crops a/	Production as percentage of base year: Increasing crops b/
		Percent	Percent
1959	1980	50	50
1980	2000	50	40
2000	2020	50	30

Source: Wabash River Basin Type II Survey data.
a/ Oats, wheat, barley, and hay.
b/ Soybeans, corn, corn silage, and pasture.

CHAPTER III

MAJOR ISSUES AND PROBLEMS IN MODIFYING THE WABASH RLP MODEL FOR PROJECT EVALUATION

Much of the information required by a RLP project evaluation model (RLP-PE) can be drawn directly from the RLP basin planning model (RLP-BP). However, since the project area will generally be smaller than the basin planning area, it is desirable that the RLP-PE model be based on more detailed data. There are three major problems or issues associated with adapting a RLP-BP model to a RLP-PE model that must be resolved prior to moving ahead with the empirical test. The first and most critical problem is concerned with the reliability of land resource data for the specific flood plain areas to be protected. Several potential sources are available. A second problem is concerned with the derivation of accurate estimates of crop and pasture yields of flood plain land under with and without flood protection. The third problem is associated with a modification that is required in adapting a RLP-BP model to a project situation. This problem involves the development of procedures to reflect yields associated with partial protection actually afforded by a project, in lieu of yields based on assumed 100 percent protection in the RLP-BP model.

Obtaining Land Resource Data for Project Flood Plain Areas

One of the inputs necessary in any flood control benefit estimation study is reliable productivity data regarding the flood plain acreage subject to inundation. Land resource data for many flood plain areas has not been systematically collected. If the productivity information is to be evaluated in a RLP model, it must be compatible with the data format of the model in order to be incorporated into the analysis.

There were three relevant alternative data sources to consider in this study. First, the Conservation Needs Inventory data, which served as the source of land inputs for the Wabash River Basin Type II Survey. Second, the soil survey reports published by the Soil Conservation Service, USDA, in cooperation with the State agricultural experiment stations. Third, land use data from Corps of Engineers project justification studies. These studies evaluated crop yields and land use for all project impact areas downstream from proposed Corps flood control reservoirs. A discussion of the features and limitations of each of these sources is presented below.

The Conservation Needs Inventory

The initial national CNI land use and land capability classification data were collected and evaluated between 1957 and 1961. Soils with a flood hazard were identified in this inventory. Two yield estimates were derived to reflect average annual flooding conditions and flood-free conditions. The CNI is not a complete inventory of all lands but rather, a two percent random sample of quarter sections (160 acres) from each county in the United States.

A two percent sampling rate was used in the CNI in order to provide an acceptable rate of statistical reliability for counties containing between 250,000 and 500,000 acres. Since the impact area for a given flood control project frequently will either traverse more than one county or be less than 250,000 acres, it was necessary to evaluate the extent to which CNI data could be used in determining the composition of flood plain lands. Statistical tests were conducted in an effort to determine the acceptability of CNI data for use in a flood control project evaluation study.

An evaluation of the CNI's reliability in estimating the true proportions of flood plain soil types was made by applying chi-square tests to the CNI data and soil survey information for ten Indiana counties for which modern soil survey reports were available. These soil survey reports were assumed to contain the true or population parameters of flood plain soil since the soil surveys consist of on-site inspection of the entire area. Flood plain information for the ten counties is summarized in Table 4.

In order to test the effect of increased size of the sampled area, flood plain lands from the ten counties were combined serially. Five different orderings of the counties were made--alphabetic, reverse alphabetic, size of flood plain--large acreage to small, size of flood plain--small acreage to large, and by county chi-square agreement--smallest to largest. In each ordering the flood plain lands were summed, starting with the first county. A record was kept of the statistical agreement between the CNI and soil survey (SS) as the counties were aggregated serially. Composite information from the five orderings of counties is presented in Table 5. The second column of the table, "Number of Observations," indicates the number of times a particular class interval of flood plain acreage was found among the five different orderings.

As indicated in Table 5, the CNI/SS probability agreement became progressively higher as the size of the CNI sampled area increased. The outcomes indicate that an acreage level of approximately 200,000 acres is generally necessary for an agreement to exceed .90. However, in one ordering, the agreement at the 224,000 acre level was only .55. The findings indicate that in order to be on the safe side, the CNI may be used as the sole source of flood plain land resource data for projects having impact areas exceeding 200,000 acres. If this rule of thumb is followed, the CNI estimate will be equivalent with the population parameters approximately 80 percent of the time.

Table 4.--Chi-Square Test of Agreement between Soil Survey and CNI for Selected Soil Types, Ten Indiana Counties a/

County	County number	County soil survey acreage	Chi-Sq. SS/CNI agreement
Bartholomew	1	53,504	.049
Carroll	2	18,330	.001
Cass	3	14,326	.620
Fountain	4	18,232	.410
Gibson	5	99,200	.600
Knox	6	72,064	.200
Miami	7	19.968	.036
Owen	8	30,589	.001
Parke	9	31,398	.815
Tippecanoe	10	27,629	.407

a/ For 3 flood plain soil types: well-drained, fair drainage, poorly drained.

Source: (1) U.S. Department of Agriculture. Soil Conservation Service
(2) U.S. Department of Agriculture. Conservation Needs Inventory, State of Indiana, 1958.

Table 5.--Composite Test of CNI Reliability for Estimating Flood Plain Acreage, Ten Indiana Counties

Flood plain Acreage	Number of observations	Class average	Average CNI/SS agreement	Range of CNI/SS agreement
(thousands)		Acres	Chi-Square	Chi-Square
14.0 - 25.0	2	16,328	.310	.001 - .620
25.1 - 50.0	3	36,369	.180	.001 - .407
50.1 - 75.0	6	62,449	.337	.001 - .790
75.0 - 100.0	4	93,365	.319	.050 - .600
100.1 - 150.0	4	116,360	.396	.100 - .840
150.1 - 200.0	4	176,960	.704	.308 - .927
200.1 - 250.0	5	220,947	.873	.550 - .990
250.1 - 300.0	7	282,881	.834	.690 - .990
300.1 - 350.0	6	326,605	.936	.880 - .990
350.1 - 375.0	4	358,687	.986	.980 - .990
Over 375.0	5	385,240	.990	all .990

Soil Survey Reports

Modern soil survey reports would serve as an excellent source of information concerning the acreage of various soils found on the flood plain, and would also indicate current or potential use of flood plain soils. If soil survey reports exist, flood frequency lines from flood plain maps could be superimposed on the soil classification maps. Unfortunately, however, modern soil survey reports do not exist for all counties of the United States nor those in the Wabash Basin.

Twenty-two Indiana counties and seven Illinois counties in the Wabash Basin have flood plain acres affected by the six operational and two proposed flood control reservoirs being evaluated by the RLP planning model. Of these 29 counties, only 10 have soil survey reports that are adequate for flood control benefit evaluation purposes. Soil surveys for the remaining 19 counties are either based on obsolete classification schemes, have a scale too large for accurate acreage assessment, or have not yet been published.

Since full coverage of modern soil survey reports for all 29 counties was not available, this source of flood plain soils information was rejected for use in the study. If such information had been available, however, it would have been used in place of estimates of flood plain soils as derived from the Conservation Needs Inventory.

Project Justification Studies

The Corps of Engineers undertakes a detailed study for each flood control reservoir. In the Wabash Basin, 15 flood control reservoir justification studies had been completed by mid-1967. 1/ In the course of the Corps' study, a systematic strip sample is made of agricultural areas that are to be protected. This sample is designed to include from 15 to 25 percent of the total area in the protected stream reach. 2/ The sample is used to determine crop

1/ U.S. Army Engineer District, Louisville, Corps of Engineers, Interim Report No. 3, Wabash River Comprehensive Study, March 1967.
2/ Interim Report No. 3, op. cit., p. C-67.

distributions and yields, as well as to gather non-crop agricultural damage information. In each completed project justification study, data that were current at the time the study was conducted were used for crop distribution, yield, and commodity price levels.

The crop distribution data are used to derive a composite land use acre for estimating flood damage reductions. The simplifying assumption made by the Corps is that the crop distribution for a given stream reach will hold for each acre of land in the reach.

Use of the Corps' land resource data, in effect, implies that there is one flood plain soil type for each stream reach, with an accompanying set of crop yields. By contrast, the Wabash River Basin Type II Survey identified 17 flood plain soil groups. The present average corn yields for these 17 soils range from 41 to 89 bushels per acre.

If the Corps' land resource data are used, they will provide a single weighted average figure representing the contribution of all the soil types found in that reach. The task of converting the Corps' average reach figure into the LRA/LCU soil groups system used in the RLP is an impossible one. If the single Corps figure for each reach is introduced into the RLP analysis as an output, the model may specify that whole reaches should be used entirely for a single crop. This is due to the fact that in the LP model, comparative advantage in crop production is largely responsible for the optimal cropping pattern in the basin.

Another major problem in using the Corps' data for this particular study is that much of the information is out of date. The flood damage surveys used in project justification studies for the six operational Corps reservoirs in the Wabash Basin were completed prior to 1956. As studies are completed and projects are authorized by Congress, no resurveys are attempted on stream reaches affected solely by authorized projects.

Since the Corps project justification land resource data are not delineated by LCU soil groups and are not consistently updated, they were rejected as a source of information about the productivity of flood plain land soils for this study and CNI data were used instead. Since the impact areas for the six operational reservoirs and the Big Pine-Lafayette reservoir complex include 654,687 and 412,814 acres, respectively, statistical reliability problems are not considered to be an issue in the study because both figures well exceed the minimum 200,000 acres.

Estimating Flood Plain Crop and Pasture Yields

In the Wabash RLP planning model, cost and yield coefficients for flood plain soil groups were estimated without regard to upstream or downstream location. 3/ If there is a significant difference between upstream and downstream flooding conditions, then the use of average upstream and downstream crop yield data could cause a significant bias in the results of the investigation. There appear to be two types of potential differences between upstream and downstream flooding conditions that could contribute to differential yields: First, variation in natural flooding conditions due to flood frequency, seasonality, depth, and duration; and second, the variation in the degree of protection currently afforded.

Characteristics of Wabash Basin Flooding

A recent report issued in connection with the ongoing Wabash River Basin Type II Survey gives an indication of the seasonality of flooding in the basin:

3/ Upstream and downstream designations are institutional delineations which satisfy the agreement between the Corps of Engineers and Soil Conservation Service. Upstream drainage areas, those tributaries containing up to 250,000 acres, are of special concern to the Soil Conservation Service.

Of the various types of meterological disturbances which produce storm rainfall in the Wabash River Basin, those storms having a quasi-stationary front oriented from west-southwest to east-northeast across the basin have produced the most serious floods on the Wabash River and its tributaries. Storms of this type usually occur from late winter to early spring when ground conditions are conducive to high runoff. Convective storms, which are productive of the greatest rainfall intensities, generally occur during the summer season, but these storms seldom cause major flooding since their aerial extent is usually limited and they happen at a time when the ground is highly absorptive. Although storms are more frequent during the months of October to April, records show that they may occur at any time during the year. 4/

The hydrological data necessary for establishing flood frequency are much more readily available for downstream flood plain areas than for upstream watersheds. The Corps relies primarily on historical stream discharge data to establish the probabilities of flood occurrence. The flood history from gaging station records furnishes the basis for establishing the expected frequency of flood occurrence. Using historical records, the Corps utilizes paired series of damage values and frequencies based on hydrological analysis of historical peak flood water discharge data.

In the Wabash Basin, the period of historical record for some gaging stations is quite long. For example, the station on the Wabash River at Mount Carmel, Illinois, has records dating from November 1, 1874. In general, the larger the drainage area above a gaging station, the longer the period of record. 5/ In contrast, the comparatively small tributaries evaluated by Soil Conservation Service (SCS) seldom have gaging stations. Because of this

4/ U.S. Army Engineer District, Louisville. Wabash River Basin Comprehensive Study: Indiana, Illinois, and Ohio. Interim Report No. 3., Vol. II, Appendix B, pp. B-1,2 (mimeographed).

5/ See U.S. Department of the Interior. Geological Survey and State of Indiana cooperating. Floods in Indiana: Magnitude and Frequency, by A. Rice Green and Richard E. Hoggatt. Open-file report. Indianapolis, Indiana, 1960 (mimeographed).

deficiency in hydrologic data, the SCS utilizes Weather Bureau intense rainfall event data in order to establish frequency of flooding. 6/ In both the historical method used by the Corps and the intense storm method used by SCS, the damage done by a particular flood is simply the product of the acreage inundated and the composite acre value (typical acre-loss value).

The SCS's use of the intense rainfall data in the Wabash Basin gives a storm pattern which centers on the middle of the growing season (Table 6).

Table 6.--Monthly Probability Distribution of Intense Precipitation of 24-Hour Duration: Great Lakes Region Data a/

Month	Monthly probability b/	Growing season probability	Month	Monthly probability b/	Growing season probability
Jan.	0.013	-	July	0.156	0.180
Feb.	0.011	-	August	0.170	0.203
Mar.	0.047	-	Sept.	0.145	0.173
Apr.	0.058	0.049	Oct.	0.086	0.084
May	0.102	0.099	Nov.	0.033	0.024
June	0.164	0.188	Dec.	0.015	-
			Sum	1.000	1.000

a/ Area of 400 square miles lying between 80° and 90°W. longitude and north of 40°N. latitude.

b/ Based on the monthly probability of rainfall for 1-year return period storms. The annual probability of such storms is 1.0 or 100.0 percent and thus the sum of the monthly probabilities is also 1.0 or 100 percent.

Source: U.S. Department of Commerce. Weather Bureau: Rainfall Intensity-Frequency Regime: Part 5-Great Lakes Region. Technical Paper No. 29. Washington, D.C.: GPO, February 1960.

An evaluation of both the Weather Bureau data used by the SCS in their Wabash Basin project investigation studies and the gaging station data used by the Corps indicates a high probability of flooding during the growing season (Table 7). In either case, there is a high probability of one or more

6/ For a general discussion of the methods used by SCS to estimate crop-enterprise flood damage reduction benefits, see Department of Agricultural Economics, Michigan State University. Estimating Small Watershed Project Benefits: A Computer Systemization of SCS Procedures, by John Vondruska. Agricultural Economics Report No. 120. East Lansing, Mich., February 1969.

damaging floods during the growing season on both upstream and downstream flood plain lands. The flood stage of 14 feet at the Montezuma station indicates the stage at which damage begins, minor flooding of unimportant low areas adjacent to the stream were not considered in specifying the flood stage. 7/

Table 7.--Monthly Probability Distribution of Damaging Floods, a/ Wabash River at Montezuma, Indiana b/

Month	Monthly probability c/	Growing season probability	Month	Monthly probability c/	Growing season probability
Jan.	.294	-	July	.177	.177
Feb.	.412	-	August	-0-	-0-
Mar.	.382	-	Sept.	.059	.059
Apr.	.500	.500	Oct.	.059	.059
May	.353	.353	Nov.	.059	.059
June	.206	.206	Dec.	.206	-
			Sum	----	1.413

a/ Flood stage - 14 feet (U.S. Weather Bureau)
b/ Drainage area, 11,100 square miles (approx.)
c/ Based on 98 floods in 34 years of record (1924-57)

Source: U.S. Department of the Interior. Geological Survey and State of Indiana cooperating. Floods in Indiana: Magnitude and Frequency, by A. Rice Green and R. E. Hoggatt. Open-file report. Indianapolis, 1960 (mimeographed).

Comparison of Upstream and Downstream Flooding

An empirical test was undertaken in an effort to determine whether differences do in fact exist in the crop yields that upstream and downstream farmers obtain. Corps and SCS project justification reports were evaluated in the test. Two evaluations of the data were made. First, an evaluation was made of the differences in average annual crop damages for a representative sample of Corps projects and SCS upstream watershed projects. Second, the the damage factors for corn and soybeans under upstream and downstream flooding conditions were evaluated.

7/ Green and Hoggatt, op. cit.

The first test was made by comparing average annual crop damages on soils with similar productivities in the upstream and downstream areas. These comparisons revealed that average annual crop damages reported for downstream acres exceed upstream crop losses by only 4.3 percent (Table 8). Although the same set of commodity prices was used in making the comparison, two other key variables, land use and per acre crop yield, were not evaluated. Corps of Engineers project justification studies are conducted independently of SCS studies to determine yield and land use, but are coordinated through inter-agency reviews. Therefore, differences are likely to be unimportant.

Table 8.--Comparison of Average Annual Crop Losses Upstream vs. Downstream Areas, Wabash River Basin

Category	Upstream areas	Downstream areas
No. of reaches	8	12
Acreage a/	42,437	634,910
Sampling rate b/	3.7%	42.2%
Average annual damage	$13.12	$13.68
Range	($5.47-$19.05)	($7.14-$23.24)
Price set used c/	AN	AN

a/ Flood plain defined by acreage innundated by 50-year recurrence interval storm for upstream and 100-year storm for downstream areas, **respectively.**
b/ Based on total upstream acreage of 1,142,800 and total downstream acreage of 1,504,800 as reported in U.S. Army Corps of Engineers, Ohio River Basin Comprehensive Survey Appendix M, "Flood Control". U.S. Army Engineer Division, Ohio River, Cincinnati, Ohio: December 1967. Table WA-1, p.11-147.
c/ The 1957 USDA adjusted normal price set (AN).

Sources: (1) SCS Preliminary Watershed Investigation Reports.
(2) U.S. Army Corps of Engineers, Louisville District project justification data.

The second comparison revealed differences in damage factors for specific agricultural crops grown on the flood plain. Data for the upstream flood plain soils used in the Wabash River Basin Type II Survey were compared with data from the same set of Corps studies used in the first evaluation. The Corps stream reach studies used in this evaluation were the most recent available and were located in four of the six economic subareas of the Wabash Basin. This comparison indicated that there is virtually no difference (less than 1 percent) between Corps and upstream data of the weighted average damage factor for corn (Table 9). In contrast, there was a significant difference in the damage factors for soybeans, the second most important crop grown on flood plain lands. The Corps damage factor on the sampled downstream reaches was larger by 6.8 percentage points than the weighted average damage factor used in the upstream areas. This implies that there is a significant difference between upstream and downstream losses from flooding for soybeans, assuming that the Corps sample used is representative of downstream conditions.

The second major difference between upstream and downstream flooding is the variation in the degree of existing protection. There are 145 named levees in the Wabash Basin; most of the levees protect downstream flood plain lands. The Corps has supplemented small private levees with an extensive system of levees, particularly along the lower reaches of the Wabash River. In contrast, upstream flood plain lands are seldom leveed. This is probably due to the fact that the narrower upstream flood plains do not have a ratio of area protected to levee miles favorable enough to permit economic justification. The net effect of this difference in the extent of levees is that the flood control increment for leveed downstream flood plain lands will be small relative to unleveed flood plain lands, all other things being equal. This is particularly true for Corps constructed levees along the lower Wabash, such as the Lyford Levee.

Table 9.--Comparison of Flood Damage Factors by Crop, Corps and Wabash Basin Planning Model Data, Wabash River Basin

Category	Wabash planning model	Corps projects
Acreage	357,200 a/	735,900 b/
Average annual corn loss	15.1%	15.0%
Corn yield (aver.)	84.0 bu	92.0 bu
Average annual soybean loss	9.3%	16.1%
Soybean yield (aver.)	31.6 bu	34.6 bu

a/ Includes all upstream flood plain acreage for economic subareas 1-4.
b/ Represents a sample of 18 Corps of Engineers stream reaches drawn from economic subareas 1-4.

Sources: (1) U.S. Army Corps of Engineers, Louisville District project justification data.
(2) Wabash River Basin Planning Model data.

The Lyford Levee, when completed in 1943, was designed to protect against all floods of 15-year or more frequent recurrence interval. With the addition of four Corps reservoirs upstream, this levee will now protect against all floods of 50-year or more frequent recurrence. As upstream protection is added to supplement Corps reservoirs, it is likely the Lyford will never be topped.

The Corps' project justification reports do not explicitly state the extent to which existing levees affect proposed projects since this would require estimating crop damages that would occur under natural (unleveed) conditions. This requires that the investigator recompute the average annual damages for the reaches affected by the project, and is an extensive undertaking. In order to do a precise job, all the available Corps data are necessary, plus information pertaining to private levees in the area. Since this is a highly technical, time-consuming, and costly procedure, it was not done for the individual stream reaches in this study.

Since the vast majority of these private levees were constructed prior to the assembly of crop yield data, the effect of these levees are reflected in the projected yields under the "without" development condition. Additional protection to be provided by the proposed reservoirs is reflected in the projected yields under the "with" protection condition, through the application of the damage reduction factors obtained from the Corps analysis of these stream reaches. This procedure results in consistency between the Corps evaluation and the RLP-PE analysis with respect to considering the effect of the private levees.

Pasture damages were found to be insignificant in the Wabash River flood plain evaluated in this study. Specifically, there are only 7,250 acres of pastureland out of a total of 525,800 acres of Wabash River flood plain below the Big Pine reservoir. Since less than two percent of the flood plain is in pasture and its value is so low, pasture damages can effectively be ignored. 8/

In summary, the examination of crop yields and the crop damage factors employed for downstream vs. upstream soils did not reveal differences that were felt to invalidate the use of basin-wide cost and yield data, as compiled for the RLP planning model, in the project evaluation model. The large difference between upstream and downstream areas in the damage factor for soybeans may have some effect on the estimated efficiency benefit to flood control as derived from the project evaluation model; however, it will not be a significant factor in testing the general application of the proposed model to flood control benefit evaluation.

8/ Gross cash rent per acre of pasture for the State of Indiana ranged between $9 and $10 per acre in 1964-66. U.S. Department of Agriculture, Farm Real Estate Market Developments, CD-67 (August 1965) and CD-71 (December 1968).

Partial Flood Control Protection

In the Wabash RLP model, the with flood protection condition was based on total or 100 percent protection against all crop flood losses. This specification was adopted in the RLP model because the objective of the Wabash River Basin Type II Survey was to measure the maximum potential societal gains from the water and related land resource development activities.

In the application of the project evaluation RLP model, the purpose will be to evaluate only the societal gains from the level of additional flood protection provided by that project. The protection level downstream from a given flood control project will be less than 100 percent for at least some portion of the protected flood plain. This is true for several reasons. First, there is no way to specify with absolute certainty the maximum possible flood. The ultimate size limit of a flood for an area is approximated by the Corps' maximum probable flood used in the design of a spillway to insure the area's safety. 9/ Without exception, such a flood is considerably in excess of the design flood--the one against which the given area is to be protected,--which reflects a balance between maximum net benefits and engineering safety and integrity standards. Second, the level of flood protection afforded downstream is, to a large extent, related to uncontrolled drainage agea. Therefore, the level of protection decreases with distance downstream from the reservoir (Table 10).

9/ See Department of the Army, Corps of Engineers, Survey Investigations and Reports. Engineering Manual 1120-2-101 (1964), p. 49. The maximum probable flood is the largest flood for which there is any reasonable expectancy in this climatic era. Its recurrence interval is unspecified but most infrequent.

Table 10.--Indices of Flood Protection to Cropland on the Wabash River Flood Plain

Reach	Miles below Big Pine site	Index	
		Present conditions a/	After project b/
W-6	2.5 - 32.8	.397	.598
W-5A	32.8 - 52.3	.427	.619
W-5B	52.3 - 75.5	.395	.562
W-4	75.5 - 166.1	.371	.553
W-3	166.1 - 195.8	.401	.516
W-2	195.8 - 250.3	.161	.269
W-1	250.3 - 290.3	.127	.216

a/ Protection index is the reduction in average annual dollar crop damages over a no protection condition, expressed in decimals. Present condition (1969) includes Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, Mansfield reservoirs.

b/ Includes existing reservoirs plus authorized Big Pine and Lafayette reservoirs.

Source: Louisville District Corps Data.

The Wabash River Basin Type II Survey data utilized in the RLP model expressed crop yields and associated costs for flood plain soil groups in terms of 100 percent flood protection. These flood-free yield and cost yield coefficients were computed for all flood plain soil groups identified in the Wabash Basin. In order to estimate the effect of a specific flood control reservoir which will not provide 100 percent protection throughout the affected flood plain, it was assumed that the effect could be expressed as some fraction of the yield increase associated with complete protection. The portion of the yield increase associated with providing additional flood protection is designated as the flood control increment. This increment for a given soil group reflects the single basin-wide estimate for average annual flooding condition. This figure represents the judgment of State soil scientists as they evaluate the particular soil group in the context of the flooding conditions under which it is found.

Project justification data for the downstream reaches being evaluated in the empirical investigation were obtained from the Louisville District Corps office. These data evaluated the average annual dollar crop damages, under both natural conditions and the flooding conditions anticipated following the installation of a flood control reservoir.

The percentage reduction in average annual crop and pasture damages following the installation of the flood control reservoir was used as an estimate of the effect of the project in this empirical investigation. This impact was incorporated into the analysis by way of increasing the yields and associated costs of the flood plain lands affected by the project.

For example, if the Big Pine and Lafayette reservoirs were added to the existing levels of flood protection, average annual crop damages for Wabash River stream reach W-6 would be reduced by $92,679 (1960 values). Since the Corps estimated average annual crop losses for this reach to be $275,862 (1960 values) following the completion of the upper three Wabash reservoirs (Salamonie, Mississinewa, Huntington), this is a reduction in average annual crop losses of 33.6 percent. Each flood plain soil group in the reach has an associated flood control yield increment which represents the difference between present flooding conditions and flood-free conditions. The simplifying assumption was made that all affected flood plain soil groups in the reach will respond to this reservoir's partial flood protection to the same extent. Operating under this assumption, the flood control increment for each soil group was then obtained as a product of the damage reduction factor and the flood control yield increment. The sum of the crop yield increase attributed to the particular reservoir and the present average soil group crop yield gives an estimate of the expected yields following the project.

The use of Corps dollar damage data contains two key implications which may or may not have an effect on the outcome of the empirical investigation.

First, the reach-wide dollar damage reduction factor (computed from Corps data) was used to adjust upward the flood-prone yields for corn and soybeans. The resultant yields for corn and soybeans reflect the estimated effect of the additional flood protection provided by the set of Corps flood control project which was evaluated in the empirical investigation (see Section IV). Since a single coefficient reflects the effect on both corn and soybean yields, this implies that the damage factors for corn and soybeans are identical. The Corps estimates of yield reductions (Table 9) appear to bear this out for the downstream flood plain of the Wabash Basin. The estimates derived from the Wabash planning models in table 9, however, imply that soybean losses are understated by 6.8 percentage points.

The second key implication of using the Corps reach-wide dollar damage index is that the relationship between corn and soybean valuation per acre in the base year (1960) will also apply to the target year 1980.

Variations in crop valuation over time, due to relative changes in market price and per acre yield of these two crops, were examined by comparing the effect of both proportional and nonproportional per acre valuation increases for corn and soybeans (Table 11). Three simplifying assumptions were made in this hypothetical example. First, the prices paid for No. 3 corn and No. 2 soybeans at Chicago are the relevant market prices. Second, the statewide yield averages for Indiana are the relevant per acre output coefficients. Third, the average annual damage factors for the corn and soybean crops are identical at the level of 15 percent per year.

The data in Part B, Table 11, represent a 20 percent increase in both the 1960 corn and soybean values reported in Part A. The data in Part C represent the actual trends in soybean and corn values during the past 8 years. A comparison of Parts A and C reveal that corn value per acre has increased 27.6 percent, whereas soybeans have increased only 19.9 percent. A comparison between Parts B and C indicate that the reachwide dollar damages would only be underestimated by 3.1 percent if constant valuation relationships are assumed between corn and soybeans. This result indicates that the projection of a constant valuation relationship between corn and soybeans does not cause a significant bias during the 8 year period 1960-68. Therefore, the projection of a constant valuation relationship for the period 1960-80 appears to be a reasonable one.

In summary, the use of the percentage reduction in stream reach dollar crop damages as the coefficient to adjust present flood-prone yields upward appears statistically acceptable. The bias involved in assuming that the soybean and corn damage factors are equal and the bias associated with assuming a constant valuation relationship between these two crops do not appear to be significant in this application.

Table 11.--Variations in Crop Loss Estimates due to Relative Change in Crop Valuation Hypothetical Reach

Crop	Value per acre a/	Land use	Damage factor	Contribution to composite acre
	(A) Estimate for 1960			
Corn	$74.80	.50	.15	$ 5.61
Soybeans	58.59	.50	.15	4.39
Composite acre	$66.70	1.00	.15	$10.00
	(B) Estimate for 1969, with 20 percent valuation increase but no change in relative crop valuation			
Corn	$90.00	.50	.15	$ 6.75
Soybeans	70.80	.50	.15	5.31
Composite acre	$80.40	1.00	.15	$12.06
	(C) Estimate for 1969, using current crop valuations			
Corn	$95.45	.50	.15	$ 7.16
Soybeans	70.22	.50	.15	5.27
Composite acre	$82.84	1.00	.15	$12.43

a/ Statistical Reporting Service, USDA. Crop Production Annual Summaries, for the years 1960-69. USGPO. Washington, D.C.

CHAPTER IV

EMPIRICAL INVESTIGATIONS

Selection of Study Area

Four primary criteria were considered in selecting the downstream flood plain area to be evaluated in the empirical investigation. First, the agricultural flood plain lands in the project impact area must have been evaluated recently both with respect to the hydrological characteristics and the damage estimates due to flooding. Second, the acreage of the impact area must be sufficiently large so that the statistical difficulties associated with using Conservation Needs Inventory (CNI) land use data will not bias the outcome. Third, the flood control project must cause a significant reduction (5 percent or more) in average annual crop losses for all areas to be included in the evaluation. Fourth, the reduction in flood frequency due to the flood control project will likely cause enhancement benefits through the conversion of idle land to productive use and through the more intensive use of existing cropland.

Hydrologic and economic data were collected and reviewed for a number of Corps flood control projects which were either completed or in advanced stages of planning. The projects considered in Illinois included the authorized Lincoln reservoir and the proposed Louisville and Helm reservoirs. In Indiana, 12 proposed reservoir projects located on the Wabash River or its major tributaries were considered. These included the Big Pine, Lafayette, Patoka, Downeyville, Big Blue, Big Walnut, Annapolis, Eel River, Danville, Tippecanoe, Clifty Creek, and Shoals reservoirs.

As single alternative sites were considered, it became readily apparent that no single reservoir project authorized or considered by the Corps was able to exert a statistically significant effect over a sufficiently large impact area to meet the CNI minimum area requirement of 200,000 acres (see

Chapter III). As noted in Chapter III, the effects on crop yields decrease as the distance from the flood storage increases. For a small reservoir such as the Clifty Creek, which controls a drainage area of only 140 square miles, the reservoir's effect is dissipated quite rapidly as a function of distance downstream. Even though the Clifty Creek's impact area is potentially large, 157,600 acres from the site to Mount Carmel, Illinois, the reservoir's effect was immeasurable below EW-4. Thus, the Clifty Creek reservoir exerted a statistically significant effect over only 90,600 acres.

The authorized Big Pine and Lafayette reservoirs, located on the Wabash River, were considered jointly in Corps hydrologic and economic computations and were selected for this study. This set of reservoirs was found to satisfy all four selection criteria. First, the project impact area has been evaluated since 1960. Second, the downstream flood plain contains 412,814 cropland acres. Third, the hydrologic effect of the Big Pine-Lafayette project is sufficient to reduce damages in Wabash River reach W-1, the most distant impact area evaluated, by over 9 percent (1960 values). Fourth, there is a reasonable expectation that enhancement benefits will be realized if the Big Pine-Lafayette project is installed. This is particularly anticipated in the lower reach of the Wabash River, as indicated in the Congressional document containing the justification for the Big Pine-Lafayette project:

> Below the White River, the flood plain contains many large tracts...which are uncultivated or cultivated only intermittently because of frequent flooding or prolonged inaccessibility. Cultivated lands in flood free years yield high crop returns; however...some of these lands are cultivated only one or two times every five years. 1/

1/ U.S. Congress, Senate. Committee on Public Works, Lafayette and Big Pine Reservoirs, Wabash River Basin, Indiana. S.D. 29, 89th Congress, 1st Sess., p. 30.

These two reservoirs, in combination with the six operational reservoirs on the Wabash River, are expected to have a major effect in reducing flood damages from the Wabash River. 2/

Although the major focus of the empirical analysis in this study is on the Big Pine-Lafayette reservoirs, data for the entire set of eight reservoirs were analyzed. The six operational reservoirs were included for two reasons. First, the Wabash RLP planning model did not explicitly consider the total effect of this set of projects. Yield data used in the model were collected in 1963, which meant that the effect of the four largest and most recent structures was not evaluated at all. In addition, the effect of the Mansfield reservoir on flood plain yields was not likely incorporated because the reservoir had been operating only two years prior to collecting the yield data, and it was doubtful that its effect on yields was incorporated in the yield estimates. Second, the sequential analysis of the effect of the six operational reservoirs, followed by the two authorized reservoirs, provided a firm base for analyzing the separate or incremental effect of adding the Big Pine-Lafayette reservoirs to the flood control system.

The analyses of these 8 reservoirs proceeded on the basis of first analyzing the effect of the partial protection provided by the 6 reservoirs which were undertaken prior to the Big Pine-Lafayette project. This provided a new base situation to reflect a "without development" condition with respect to the Big Pine-Lafayette project. By applying the damage reduction factors to the crop yield coefficients of soil groups in flood plain impact acres below the Big Pine-Lafayette, the separate effect of these two reservoirs can be determined.

2/ The six operational reservoirs include Cagles Mills, Mansfield, Monroe, Salamonie, Mississinewa, and Huntington.

Modifications to the RLP Planning Model

The Wabash RLP-BP model was formulated to provide general basin-wide information on the economic need for and effects of river basin development projects and programs. Adapting the planning model to a project evaluation model requires some refinement in the formulation of the model. More detailed information about the anticipated effect of flood protection on specific acres to be affected by the proposed project must be incorporated in the model. Four modifications in data format and specification were made to convert from a planning model to an evaluation model: (1) Identification of project-affected flood plain acres by soil groups, as used in the planning model; (2) estimation of yield effects on project-affected land resulting from the reduction in flood hazard; (3) revision of cost of production estimates for project-affected land; and (4) separation of flood control and drainage increments on inadequately drained flood-plain soils.

Identification of Project-Affected Soil Groups

As noted in earlier discussion, the flood plain lands evaluated in the Wabash RLP-BP model included all land capability units (LCU) subject to flood loss, without regard to their geographical location within the basin. An estimate of the acreage of the LCU's affected by the two levels of flood protection was required as an input to the linear programming model. Guidance was obtained from Indiana and Illinois State soil scientists with regard to those flood plain LCU's likely to be found in the Corps project impact areas. The following procedure was followed in order to obtain an estimate of the LCU composition of these downstream flood-plain soil groups.

a. The Corps project flood-plain cropland acreage was determined by county, based on Corps data.

b. Total cropland acres on flood plains in upstream areas were determined for the counties having Corps flood-plain land.

c. Upstream and downstream cropland acreages were summed.

d. The total Corps project impact area was subdivided into geographical subareas, each having over 200,000 cropland acres.

e. The CNI totals of flood plain soils by LCU, by county, were determined for each of the subareas.

f. Within each subarea, the upstream acreage was subtracted from the CNI flood plain total.

g. The LCU proportions present in the remaining CNI acreage was then computed. These proportions represented the LCU composition for the Corps project impact lands in each subarea.

h. The LCU proportions thus obtained were multiplied by the Corps cropland acreage in each of the respective subareas.

The LCU acreages thus obtained for project impact areas were introduced into the RLP-PE model as project flood-plain land resource inputs with their associated cost and yield coefficients.

Yield Estimates for Project-Affected Flood Plain Lands

In the Wabash River Basin Type II Survey, the flood protection alternative was approached under a slightly different set of assumptions than desired in this investigation in three respects.

First, the Type II Survey's "no development" evaluations for 1980, 2000, and 2020 represent the outcome if present flood protection levels persist into these target years. The cost and yield coefficients for flood plain soils reflect the average of all flooding conditions experienced by each particular soil group in upstream areas. Second, the flood protection alternative in the

Type II Survey was provided only on the basis of total protection against all cropping losses. Third, the cost and yield coefficients used in the Type II Survey for flood plain soils reflect optimal drainage conditions, as well as total flood protection, for these soil groups. Since 77 percent of all the downstream flood-plain lands require additional drainage, the coefficients for these soil groups will require modification to permit the economic impact attributed to flood control only to be evaluated in this study.

The first problem noted above concerns the comparability of yields on upstream flood-plain soils versus downstream flood-plain soils under present flooding and flood-free conditions. In the RLP planning model the flood-control yield increment was defined as the expected yield difference between present flooding conditions and flood-free conditions. A comparison of downstream and upstream damage levels on flood plain lands, reported in Table 9, indicates that there is little difference in the flood control increment for corn (less than 1 percent). This implies that the potential bias in using Type II upstream flood-control corn-yield increment data as an estimate of the corn yield increment associated with additional flood protection on downstream flood plain lands will be negligible.

On the other hand, the comparison of Type II and Corps-sampled reaches indicates a difference of 6.8 percentage points in the flood control increment for soybean yields--9.3 percent and 16.1 percent, respectively, for the Type II survey and the Corps project study. (See table 9.) A possible explanation for this discrepancy may relate to the Corps' use of the composite acre concept. The composite acre concept implies that the reach-wide crop distribution holds for each acre of land in the reach regardless of location on the flood plain. Soybeans are much more susceptible to flood damages than corn during the bulk of the growing season (Table 12). If flood damage calculations assume that soybeans are typically grown in high-risk zones, when in fact they are grown in low-risk zones, average annual damages will be overstated. 3/

Table 12.--Sample Unit Crop Damages as Percent of Total Crop Value Per Acre, Wabash River Flood Plain a/

Time of flood	Soybeans	Corn
	Percent	Percent
1-15 June	30.5	41.0
16-30 June	51.8	64.0
1-15 July	66.1	38.5
16-31 July	67.3	26.5
1-15 August	67.3	18.0
16-31 August	67.3	21.0
1-15 September	66.1	8.2
16-30 September	58.2	5.9
1-15 October	37.3	4.2
16-31 October	14.6	2.8

a/ Crop damages were estimated on the basis of an inundation up to two feet and a duration of flooding up to 48 hours.
Note: Maximum damage is total value of crop minus labor and expenses not expended at time of flood.
Source: U.S. Army Engineer District, Louisville, Corps of Engineers, Wabash River Basin Comprehensive Study. Interim Report No. 3, Vol. III. March, 1967. Table 53, p. c-70.

After weighing the evidence regarding the flood-control yield increments for corn and soybeans, it was determined to use the estimates developed for the RLP-BP model without further adjustment, recognizing that the use of the upstream soybean flood-control increment could subject the findings to downward bias. This could bias both estimates of the extent to which the project impact areas would grow soybeans, and of the production cost savings associated with the eight flood-control projects evaluated.

3/ The assumption of homogeniety is modified in crop damage calculations to reflect distribution of crops by flood-hazard zones in normal Corps procedures. While soybean damages in Table 12 indicated considerably higher losses in July-September periods, it should be noted that flood probabilities are much lower for this period (see Table 6). River bottom farmers also shift almost entirely to soybeans after May-early June floods, thereby planting soybeans in apparently high-risk flood zones.

The second major modification regarding yields was to select a methodology to adjust flood-prone yields upward to reflect the partial protection afforded by the six operational and two authorized Corps flood-control reservoirs (Table 13). The first set of projects, affording the additional flood protection designated as Flood Control 1, includes all currently (1969) operational Corps reservoirs. The second set of reservoirs, affording the flood protection designated as Flood Control 2, includes the two reservoirs with which the empirical investigation is primarily concerned.

The methodology selected to obtain an index of additional flood protection provided by these two sets of reservoirs was straightforward. The percentage reduction in average annual dollar crop damage attributed to each level of protection was derived from Louisville District Corps data (1960 values). For flood plain LCU's not requiring additional drainage, the partial-protection crop yields for project impact areas were calculated in a two-step procedure. First, the flood-control yield increment for each impact area LCU was multiplied by the protection index for the particular stream reach and set of reservoirs (Table 13). Second, this adjusted yield increment was added to the "no development" yield which reflects current flooding conditions.

As noted earlier, a third difficulty in using RLP planning model yield data resulted from the inclusion of both drainage and flood control yield increases in the flood control yield increment for imperfectly drained flood plain LCU's. In the planning model, the flood control development alternative

Table 13.--Crop Acreage and Flood Protection Index, by Selected River Reaches, Wabash River Basin

Stream	Reach	Total acreage	Crop acreage	Protection index a/	
				Flood Control 1	Flood Control 2
Wabash River	W-1	108,000	70,848	.1265	.2157
	W-2	114,000	89,376	.1609	.2694
	W-3	99,700	79,062	.4007	.5164
	W-4	154,500	117,111	.3705	.5528
	W-5A	19,700	17,099	.3953	.5619
	W-5B	13,700	11,892	.4271	.6185
	W-6	16,200	14,110	.3972	.5997
	W-7	14,600	13,316	.6185	.8035
	W-8	3,800	3,165	.6766	.8309
	W-9	19,500	16,965	.8804	.8804
	W-10	11,600	10,451	.9300	.9300
	W-11	3,600	3,243	.9500	.9500
Raccoon Creek	RC-1	2,450	2,050	.6000	.6000
	RC-2	5,050	4,100	.9500	.9500
Lower Eel	LE-1	45,000	43,335	.3500	.3500
White River Main Stem	WE-1	24,200	17,593	.1193	.1193
White River	WW-1	121,000	102,972	.1163	.1163
East Fork White River	EFW-1	30,200	24,999	.2500	.2500
	EFW-2	9,200	7,500	.3500	.3500
Salt Creek	SC-1	7,350	5,500	.8000	.8000
Total acreage		823,350	654,687		

a/ Protection index is the reduction in average annual dollar crop damages expressed in decimals (1960 prices). Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, and Mansfield reservoirs. Flood Control 2 includes Flood Control 1 plus Big Pine and Lafayette reservoirs.

Source: Unpublished data, Corps of Engineers, Louisville District.

on inadequately drained flood-plain land was derived on the basis that drainage would accompany the higher level of flood protection. Thus, the costs and yield coefficients were calculated to reflect a "flood control plus drainage" condition. This was done for the planning model because it is generally held by soil scientists that the full benefit of flood control on inadequately drained soils will only be realized if drainage is also provided. In the project evaluation model we are first interested in determining the effect of flood control as the initial effect on agricultural production; and secondly, the effect of adding drainage as a development alternative. This approach will allow an evaluation of the efficiency benefits of providing additional flood protection under the "flood control only" and "flood control plus drainage" development assumptions.

The following procedure was used to estimate the yield increment on inadequately drained soils resulting from the partial protection provided by the flood control project, in lieu of seeking field estimates of the effect of flood protection considered by itself. This procedure provides crop yield estimates for the "flood control only" analysis.

a. Obtain the yield increment between the optimally drained flood-free yield condition and the yield associated with optimal drainage under existing flood-protection levels.

b. Determine the percentage yield increase due to flood control only, by dividing the flood-control increment by the optimally drained flood-prone yield.

c. Multiply the present "flood-prone inadequately drained" yield by the percentage derived in step b to obtain the "flood control only" yield increment.

d. Multiply the flood control yield increment from step c by the flood protection index for the particular level and stream reach (Table 13).

e. Add the adjusted yield increment to the "flood-prone inadequately drained" yield to obtain the partial protection "flood control only" yield.

Estimates of yields and costs for the analysis, based on the assumption that drainage and flood control must be a joint development to achieve optimum yield increases on flood plain soils, were derived by the steps outlined below. This procedure provides partial-protection crop-yield estimates under the condition of the joint development, "flood control plus drainage" resulting from the installation of the two sets of flood control reservoirs. 3a/

a. Obtain the yield increment between the optimally drained flood-free yield condition and the yield associated with optimal drainage under existing conditions.

b. Multiply the flood control increment derived in step a by the flood protection index for the particular level and stream reach (table 13).

c. Add the adjusted yield increment derived in step b to the optimally drained yield to obtain the partial protection "flood control plus drainage" yield.

Cost of Crop Production Estimates for Project-Affected Flood Plain Lands

In the RLP planning model, the cost coefficients were stated in terms of the per-acre on-farm production costs for growing a particular crop on the respective LRA/LCU soil groups. The additional per-acre costs associated with the provision of additional flood protection include only those out-of-pocket costs incurred by the average flood-plain farmer. Thus, the additional costs include the cost of the increased inputs (fertilizer, seed, lime, etc.)

3a/ Analysis of the flood control benefit under the "flood control plus drainage" assumption is presented in the Appendix A.

necessary to raise the additional crop output, plus the additional harvesting costs associated with the flood control crop-yield increment. No allocation of flood control project costs was made in either the RLP-BP model or this study.

Revised per-acre costs for project impact lands were obtained by multiplying the flood control yield increment by the marginal cost per unit of output for each crop. This additional cost was added to the per-acre base cost for the project-affected LCU's, in order to obtain the partial development cost intermediate between flood-prone and flood-free costs.

Summary of Input Revisions

The costs, yields, and acreage of flood plain LCU's affected by the two sets of flood control projects were adjusted to reflect partial protection and to separate flood control effects from drainage effects. These data were prepared in a format for computer analysis that would enable the partial-protection flood control alternatives to be evaluated as revisions to the 1980 Wabash RLP-BP model "no development" solution.

There were four sets of cost, yield, and associated land resource coefficients representing two levels of flood control and two assumed levels of drainage.

(1) Flood Control 1 under the "flood control only" conditions.

(2) Flood Control 2 under the "flood control only" conditions.

(3) Flood Control 1 under the "flood control plus optimal drainage" conditions.

(4) Flood Control 2 under the "flood control plus optimal drainage" conditions.

Application of the RLP Evaluation Model

In previous discussion, production efficiency gains were identified as one of the primary benefits from flood control investment. The RLP-PE model provides a direct estimate of these gains by calculating the reduction in total cost of crop production as a result of the flood protection. Two computer runs--without flood-control project and with flood-control project--are required for each target year. The difference in the total cost of production between the two runs provides a point estimate of the savings that accrue to society as a result of the flood control project in each target year. An estimate of the total efficiency gains that are expected to occur is derived by extrapolating the three target year efficiency gains over the life of the project to determine the annual flow of benefits, and discounting them to a present value. In this study we were primarily concerned with determining whether a river basin planning model could be modified to serve as a project evaluation model. Therefore, only one target year was selected to test the model conversion.

1980 was selected as the target year, and the "no development" run completed for the Wabash River Basin Type II Survey was used to estimate total cost of production without the flood control project. Since we had chosen to test our model conversion procedures on the authorized Big Pine and Lafayette reservoirs, two "development" runs were necessary. One "development" run was based on revised yield and cost coefficients for flood plain lands affected by the six operational flood-control reservoirs in the Upper Wabash Basin--this is referred to as Flood Control 1. 4/ The information on total costs of production and land use patterns resulting from Flood Control 1, provides a new base to represent the "without development" situation for the

4/ Cagles Mills, Mansfield, Monroe, Salamonie, Mississinewa, and Huntington.

analysis of the effect of the Big Pine and Lafayette reservoirs. The second "development" run included yield and cost coefficients which reflect the additional flood protection provided by the Big Pine and Lafayette reservoirs --referred to as Flood Control 2.

In the analysis below, it was assumed that no additional on-farm drainage costs would be required or installed by flood plain farmers in order to realize higher levels of output associated with the reduction in flood risk. Additional analysis was made, however, based on an alternative assumption that additional on-farm drainage would be necessary to realize the flood protection benefits. This assumption implies that inadequately drained flood plain lands will not respond to flood control alone and that the joint development of flood control plus drainage is necessary to realize the full potential of reducing the flood hazard. Analysis based on this assumption is presented in Appendix A.

Cost and yield modifications which were associated with the project-protected lands were introduced as revisions to the input matrix used in the 1980 Wabash RLP-BP model. In order to lower total basin on-farm costs, the unit costs of crops grown on the soil groups in the development alternatives must be lower than unit costs of soil groups utilized in the "no development" solution. Thus, soil groups having cost and yield coefficients reflecting partial flood protection which enter the 1980 land-use allocation will displace lands on which it is more costly to grow the same quantity of total basin output.

Efficiency Gains

The "no development" total on-farm costs which would be incurred in producing the estimated levels of agricultural commodities for 1980 is $471,126,000 (Table 14). This assumes that no Corps flood-control reservoirs would be operational in the Wabash Basin. An analysis of the effects of the six operational Corps reservoirs indicate that the same quantity of agricultural output can be met with annual total on-farm costs of $470,822,000--a reduction of $304,000. Adding the Big Pine-Lafayette project would provide further cost-reduction gains of $218,200 in the 1980 target year. These gains represent the net enhancement to the Big Pine-Lafayette flood-plain acres after considering offsetting effects elsewhere in the Wabash Basin.

Efficiency gains resulting from the Big Pine-Lafayette project are associated with a flood-plain impact area of 540,400 acres. Of these acres, only 68,494 were converted from a nonproductive use to cropland or were utilized more intensively for crop production. Efficiency gains to the entire flood plain represent an annual return of about $0.40 per acre. If the efficiency gains are attributed only to the 68,494 acres that were enhanced by the project, the annual return would be about $3.20 per acre. Capitalizing these annual returns at 8 percent indicates an increase in land value of $5.00 per acre for the entire flood plain or $40.00 per acre for the "enhanced" acres.

Table 14.--Effect of Flood Control Reservoirs on Agricultural Production Costs, Wabash River Basin, 1980

Status of flood protection	Total on-farm costs	Incremental difference	Incremental percent change
No development	$471,126,000	--	--
Flood Control 1 a/	470,822,000	$304,000	.064
Flood Control 2 b/	470,603,800	218,200	.047

a/ Flood control only with six reservoirs--Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, and Mansfield.
b/ Flood control only with eight reservoirs--Flood Control 1 plus Big Pine and Lafayette.

The efficiency gains attributable to the Big Pine-Lafayette reservoirs represents the net societal cost savings for the agricultural sector in the Wabash Basin associated with investing in these two reservoirs. Total production costs of meeting the demand for commodities from the Wabash River Basin are lowered, because output losses due to flooding are reduced substantially. This cost reduction is offset somewhat by slightly higher input costs, especially plant nutrients, because a higher level of inputs is anticipated to be applied to flood-protected lands in order to more fully realize their full production potential. In addition to estimating efficiency gains accruing to a reservoir, the RLP-PE model can also provide estimates of probable land-use changes.

Changes in Land Use

The 1980 "no development" solution obtained in the RLP-BP model indicates that there is excess capacity in the agricultural sector for 1980. As indicated in Table 15, approximately 17 percent of the cropland would be idle, assuming no Corps reservoirs would be operational by 1980.

Table 15.--Major Land Use,Wabash River Basin, 1980

Category	Available land a/	Land used b/	Share of land
	Acres	Acres	Percent
Cropland	13,626,800	11,316,200	83
Pasture	2,087,500	1,969,400	94
Total	15,714,300	13,285,600	85

a/ Based on 1958 CNI data, less land withdrawn for urban expansion.
b/ Based on the 1980 Wabash Basin "no development" solution.

Source: Wabash River Basin Type II Survey Data.

The extent to which the two levels of flood-control protection affect the Wabash Basin land-use pattern for 1980 is indicated in Table 16. A comparison of the "no development" land-use pattern and the pattern associated with the

Table 16.--Adjustments in Land Use due to Big Pine-Lafayette Reservoirs, Wabash River Basin, 1980

Category	Flood Control 1 a/	Flood Control 2 b/
	Acres	Acres
Flood Plain:		
Total acreage	823,350	540,400
Cropland	654,687	412,814
Land Use Adjustments		
Flood Plain:		
Idle to cropland	44,189	8,293
Cropped more intensively	490,909	60,201
Basin-wide:		
Reduction in cropland	19,096	1,505
Cropland to idle	63,285	9,798

a/ Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, and Mansfield reservoirs.
b/ Flood Control 2 includes Flood Control 1 plus Big Pine and Lafayette reservoirs.

installation of the six reservoirs of Flood Control 1 indicated a 19,096-acre reduction in the cropland required to meet anticipated 1980 Wabash River Basin agricultural demands. On the project flood plain, however, land enhancement occurred through the conversion of 44,189 acres of idle land to cropland because of the additional flood protection. In addition, land enhancement occurred on 490,909 acres of cropland through more intensive use. This represented approximately three-fourths of the 654,687 cropland acres on the impact area flood plain. These lands, which produced corn and soybeans in the base situation, would continue to raise these crops, but with higher applications of inputs (fertilizer, seed, and lime). While land enhancement occurred on flood plain land, a total of 63,285 upland acres were idled because of the increased economic efficiency associated with producing on the flood protected lands below the six reservoirs.

The addition of Big Pine and Lafayette reservoirs resulted in a relatively small net reduction of 1,505 acres in the basin-wide cropland requirement. On the flood plain itself, an additional 8,293 acres would be converted from idle to productive agricultural use, and 60,201 acres of impact area lands would be cropped more intensively. In the upland area, however, 9,798 more acres of croplands would be idled.

Comparison of RLP Benefits with Corps Benefits

As noted in Part I, Chapter II, the conventional Corps procedures evaluate flood control benefits from the point of view of what the individual flood-plain occupants receive as flood protection benefits. If benefits are evaluated in this manner, the increase in net income due to reduced production costs and the additional crop output produced by flood-plain farmers is viewed as the relevant measure of flood control benefits. Using the Corps' assumption, the reduction in average annual crop damages expected for 1980 was estimated.

The crop-damage reduction benefits for the Big Pine and Lafayette reservoirs were obtained from Corps stream-reach studies. 5/ In order to obtain an estimate of the average annual benefits by 1980, they were projected to grow in a linear fashion at the rate of .76 percent per year from 1969 to 1980. (The Corps initially estimated the reservoirs would be completed in 1969.) This was the growth rate implied in the projected increase in output used in the RLP-BP analysis. Use of this rate, rather than the 3 percent annual growth used by the Corps to project the increase in total flood-control benefits, provides a common basis for comparing reductions in crop damages by the conventional Corps procedures and the RLP-PE procedures.

5/ U.S. Army Engineer District, Louisville, Review of Wabash River Basin Covering Reservoir Sites on Wildcat, Big Pine and Sugar Creeks, Indiana. Interim Report No. 1, Vol. II Louisville, March 1963 (mimeographed).

A comparison of the 1980 estimated agricultural annual benefits to the Big Pine-Lafayette project as derived by the RLP-PE model and by conventional Corps method indicates that the benefit calculated by the Corps method was 2.4 times larger than the RLP-PE method (Table 17). The basic data (yields, costs, and damage-reduction factors) for both methods were very similar. The major reasons for the observed difference in estimated flood-control benefits are the different conceptual foundations upon which the two methods are based. The national efficiency (inelastic demand and net enhancement) concept underlying the RLP-PE estimated annual benefit of $218,100 provides a measure of the gain to society from decreased costs of producing agricultural commodities in the Wabash Basin made possible by the Big Pine-Lafayette project. In contrast, the resource-owner viewpoint (perfectly elastic demand, gross enhancement) concept underlying the Corps' estimate of $510,900 provides a measure of the income gains to the flood-plain occupants. This estimate implicitly includes the $218,100 national efficiency gain; hence, $292,800 difference may be interpreted as a regional income gain accruing to the flood-plain occupants. It represents an income transfer from the farmers whose land loses its relative comparative advantage for the production of corn and soybeans.

Table 17.--Estimation of Annual Flood Control Benefits Under Alternative Benefit Evaluation Procedures, Big Pine-Lafayette Project, 1980

Evaluation procedure	Dollar benefits
RLP-PE Model	$218,100
Corps Procedure a/	510,900

a/ Benefits based on Interim Report No. 1, Vol. II., op.cit. Share of benefits attributable to agricultural crop losses avoided were based on unpublished project justification data, Louisville District, Corps of Engineers.

Methods of Estimating Enhancement Benefits

The Corps Approach

The provision of flood protection to an area can cause increased utilization of property, as well as prevention of flood damages. The nature of these enhancement benefits pertaining to agricultural lands is indicated by the following excerpt from a Corps of Engineers' engineering manual.

> Enhancement benefits [are] the benefits attributable to the increased or higher utilization of property made possible through provision of flood control. [These benefits] consist of the increase in earning power [net earnings] of land... that was formerly undeveloped or only partially developed due to the hazard of floods. Evaluation of this benefit will require consideration of past use of the affected property and the probable future uses of the property, both with and without flood control. 6/

In the Wabash Basin flood-control project justification studies made by the Corps, land enhancement benefits were calculated as a separate step in the benefit estimation procedure. In the revised project justification of the Salamonie, Mississinewa, and Huntington reservoirs, higher land-utilization benefits were computed for agricultural lands as indicated in the following paragraph.

> The Upper Wabash River Reservoirs will considerably reduce flood stages and flood damages in the upper reaches of the Wabash River overflow area. Less frequent flooding will permit land cultivated intermittently at present and waste land to be converted to a higher use and allow more profitable use of other land not now used to its potential. It is considered that these areas benefited lie in reaches near to the reservoirs and between a present and a future four year flood as modified by reservoir operations. It is estimated that higher land utilization benefits to the Upper Wabash River Reservoir System will be $60,000 annually, 7/ at the end of the first 10 years of project operation. With an interest rate of 5 percent and a 100-year project life, the average annual compound interest factor is 0.8093. Higher land utilization benefits to the reservoir system distributed through the project life are $49,000, annually. 8/

6/ Dept. of the Army, Engineering Manual 1120-2-101 (1964), op.cit., p.59.
7/ Based on 1955 data adjusted to 1960 prices.
8/ U.S. Army Engineer District, Louisville. Huntington Reservoir Design Memorandum, revised January 25, 1962. p.82.

The Corps' evaluation procedure utilizes a gross enhancement approach that does not consider lands and productive resources that are idled elsewhere in the region or nation. The Corps approach also implies that flood-plain agricultural lands are inherently more productive than other lands and if they are afforded a sufficient degree of additional flood protection they will be utilized more intensively. 9/

The Wabash RLP Approach

In contrast to the gross enhancement concept employed by the Corps, the RLP-PE is a net enhancement concept. In comparing the RLP "no development" solution with the solutions resulting when flood-control development alternatives are introduced, the flood-plain land enhancement which occurs is offset by disenhancement of other lands. This is due to the specification of a fixed agricultural demand for the basin. Because of this requirement, shifts of crop production to the project-protected flood plain are offset by reductions in crop activity elsewhere. Unlike the Corps approach, the RLP-PE model assumes that project-protected flood plain lands will be enhanced only if the cost and yield coefficients change sufficiently to alter the comparative advantage in crop production of these flood plain lands relative to all other lands in the basin.

As noted in Chapter 2, one of the chief attractions of the RLP-PE is that it provides an appropriate measure of social benefits from flood control under conditions of inelastic demand. Since the demand for most agricultural commodities continues to be quite inelastic, a model such as the RLP, which considers this condition, provides more realistic estimates of the societal benefit

9/ No enhancement benefits are attributed to the Big Pine-Lafayette reservoirs of the Corps, apparently because only a limited land area could be provided with significantly reduced flood hazards sufficient to induce higher land uses.

of agricultural flood protection than one that is based on an assumption of perfectly elastic demand.

In the empirical analysis reported in Table 16, the net enhancement feature of the RLP-PE model is indicated. The provision of the 8 reservoirs by 1980 would cause a net reduction in cropland required of 20,601 acres. Although 52,482 flood-plain project impact acres would be converted from idle to cropland use, 73,083 upland acres would be idled. Approximately four-fifths of the project-protected flood plain lands, or 551,110 acres, would continue to be utilized in the same manner, producing either corn or soybeans. These latter lands would be utilized more efficiently than previously; this would be possible because a reduction of direct flood losses would encourage expansion in the application of fertilizer, higher seeding rates, and adoption of generally more-intensive production practices.

Future Flood Plain Growth

The Corps Approach

In making the final estimates for the project benefit-cost ratio, the Corps makes projections of expected flood plain growth over the planned life of the project (100 years), and adjusts expected average annual benefits accordingly.

The procedures used in Interim Report No. 3 to estimate expected growth were:

> Average annual flood damage projections to 2066 were determined by applying flood plain growth indices to current damage estimates for the following categories: agricultural crop and non-crop, transportation routes, urban residential, commercial, industrial, and facilities for public transportation, communication and utilities.
>
> The indices of future change in average annual flood damages were developed on the basis of projected population, employment, industrial output, personal and per capita income and other economic

indicators. Agricultural crop and non-crop flood damage projections were based on indices derived from studies by the Economic Research Service, U. S. Department of Agriculture projecting regional changes in farming operations, including future land use, crop yields and the addition of farm improvements....

Growth indices for subareas, counties, and SMSA's were applied to specific flood plain areas after modifications of the indices to reflect the anticipated future relationships of flood plain and upland developments in the immediate area of study .... Projections beyond 2020 to 2066 were extensions of 1960 to 2020 projections using the same patterns and rates of change.

Future flood plain growth indices were developed...for each damage category at different levels of development and flooding frequencies and depths. 10/

In the benefit-estimating process the individual stage-damage curves, and growth factors are consolidated into a single future damage multiplier. For Reach EW-4 the damage multiplier was 3.02. 11/ In this reach, the present average annual damages from all sources were estimated at $1,159,000, based on 1966 values 12/, and were projected to increase 200 percent to reach $3,500,000 by 2066. Growth over the intervening years was postulated to be a straight-line function of time.

One of the problems underlying the Corps' projection of damage values is the assumption that growth projections for regions, counties, or SMSA's imply a parallel growth in flood plain values-at-risk (and a cooresponding one-for-one growth in damages). A three-fold growth over 100 years implies that physical growth (residences, transporation, etc.) must be primarily new construction, but it is not clear why this growth must occur on the flood plain or why it cannot be planned to withstand flooding. Similarly, the projected increases in crop yield imply that crop values at risk (at the same relative price level) will be higher. On the other hand the projected yield

10/ Interim Report No. 3, op. cit., pp. C-79, C-80.
11/ Ibid., p. C-82.
12/ This estimate is residual to damages prevented by the Clifty Creek Reservoir (proposed in Interim Report No. 2).

increases could also imply that the need for flood plain cultivation should be reduced, ceteris paribus, because the uplands can also contribute more toward fulfilling national food and fiber needs.

The Corps assumption that the future expansion of agricultural production in the project-protected flood plain will grow at the same rate as the composite regional growth index is subject to question. This composite index is based primarily on four factors, namely population, employment, per capita income, and industrial output. National data pertaining to these factors was collected for the years 1957-68 (Table 18). The average percentage increase per year for these four factors is 3.05 percent for the period 1957-68. This corresponds closely to the damage factor of 3.02 used in Reach EW-4.

In order to assess whether the growth in the agricultural sector should correspond to the 3 percent per year composite growth used by the Corps, national data were obtained for the agricultural economy for the period 1957-68. As reported in Table 18 the average percentage increase in feed grain output and gross farm product is only 1.6 percent per year over the 11 year period. This indicates that if the protected agricultural flood plain increased output is similar to national agricultural production increases, the use of a composite index will cause upward bias in estimating agricultural crop damages on the project-protected flood plain. 13/

The RLP Approach

The agricultural economy need not grow at the same rate as other economic sectors; therefore, a procedure providing an independent estimate of the future agricultural economy appears highly desirable.

13/ Current Corps procedures reflect an attempt to disaggregate damage categories and develop individual indices to project future damages. For instance, the final report of the Wabash Type II survey utilizes indices of about 1 percent per year on agricultural crop damages, and are in essential agreement with the results implied by the RLP model.

Table 18.--Growth Indices for Selected Economic Indicators - U.S. 1957-68

Year	Population (1957=100)	Civilian employment (1957=100)	Industrial output (1957-59=100)	Per capita disposable personal income (1957=100)	Feed grain production (1957-59=100)	Gross farm product, 1958 prices (1957=100)
1957	100.0	100.0	100.7	100.0	93	100.0
1958	100.7	98.4	93.7	99.3	101	102.5
1959	103.4	100.9	105.6	102.0	106	103.9
1960	105.5	102.7	108.7	102.1	109	107.9
1961	107.3	102.6	109.7	103.5	99	109.4
1962	109.0	104.1	118.3	106.7	100	108.9
1963	110.6	105.8	124.3	109.2	108	112.3
1964	112.2	108.2	132.3	115.1	95	109.9
1965	113.6	111.0	143.4	121.2	111	116.7
1966	115.0	113.8	156.3	126.5	110	109.4
1967	116.3	116.1	158.1	130.2	124	118.7
1968	117.5	117.5	165.3	134.1	118	117.7
Average percent per year	1.6	1.6	5.9	3.1	1.6	1.6

Source: Council of Economic Advisors, Economic Report of the President, January 1969. Washington, D.C. U. S. Government Printing Office, p. 237, 238, 245, 254, 268, 318.

The RLP model is based on systematically projected changes in the demand for farm commodities, and anticipated changes in crop yields and costs due to adoption of new technology. The best judgment of specialists regarding the level of consumer demand, state of agricultural production technology, and availability and cost of regional resources can all be considered in the RLP-PE model. The growth in the agricultural economy using the RLP-PE model need not be a simple linear function of time.

The projected national needs for food and fiber were prepared by the Economic Research Service, USDA, and Office of Business Economics, Department of Commerce under an Interdepartmental Agreement dated March 6, 1964, through the Water Resources Council. These projections develop an interregional framework of economic projections which are internally consistent with other sectors of the economy, compatible with the other regions and capable of being aggregated to the projected national requirements.

These national projections provide a basis for deriving a set of baseline projections for the Wabash River Basin that are consistent with national market forces and that recognize interregional competition in meeting the national market demand.

In this analysis, the magnitude of future demand was determined through consideration of numerous forces which influence this demand. The major forces include:

1. Population growth.
2. Rising per capita disposable income.
3. Changes in consumer tastes and their influences on per capita use.
4. Industrial and other uses of agricultural commodities.
5. Livestock feeding efficiencies.
6. Imports and exports.

Increased domestic requirements for the major farm commodities are a function of population growth and projected per capita consumption. The estimates of domestic consumption requirements are derived from the population estimates for each time period and the assumed per capita consumption rates.

By application of the RLP evaluation model under "with" and "without" alternative water-resource development conditions, it is possible to trace out the time path of agricultural flood-plain development which is warranted on the basis of future conditions.

RLP Estimated Growth in Benefits for Life of Project

As indicated in the previous section, the RLP-PE model provides a method for estimating growth in benefits from flood control projects based on a careful examination of probable future agricultural conditions. In this study, attention was focused on the conceptual difficulties and empirical problems that would be encountered in adapting a river basin RLP-BP model to a project evaluation model. With this orientation of the study, data for only one target year (1980) were used to obtain a point estimate of agricultural flood control benefits. Estimates of the benefits that would be realized in 2000 and 2020 could be obtained by applying the same modifications to the RLP-BP data for these target years, and making computer runs for these years. Total agricultural efficiency gains expected over the life of the project could be calculated from the estimated benefits of the three projection years. These calculations would provide a careful estimate of the annual stream of benefits for the projection period. Beyond the projection period (50 years), the trend in benefits could be extrapolated to cover the entire project life. Errors in estimating benefits during the last half of the project life would not be critical because discounted values of future benefits are relatively small. This is especially true when discount rates of five percent or more are used.

Simulated values of the RLP estimated benefits for 2000 and 2020 were calculated from relationships identified in the 1980 evaluations instead of making specific computer runs for these years. An assumption was made that the flood control projects (Flood Control 1 and Flood Control 2) would reduce agricultural production costs in the Basin in 2000 and 2020 by the same proportion as achieved in 1980. The "no development" production costs were derived from the Wabash RLP-BP model for each target year. Simulated values for annual flood-control benefits expected in 2000 and 2020 indicate that these benefits will increase by 14 percent from 1980 to 2000, and by 9.7 percent from 2000 to 2020. By 2020 the efficiency gains from flood protection provided by the reservoirs of Flood Control 2 would be $273,000 (Table 19). 14/ If the estimated rate of growth in benefits from 2000 to 2020 is extrapolated to 2069, the anticipated flood-control efficiency gains from Flood Control 2 would be $337,000.

The expected annual flow of benefits can be derived from these point estimates from computer runs by interpolating the benefits between target years and extrapolating the benefits from the last target year to the last year of the project life. Discounting this stream of benefits to a present value will provide an estimate of the flood control benefits to society in national efficiency terms. This procedure was applied to the simulated values of agricultural flood-control benefits presented in Table 19. Present-value average annual benefits of $241,300 were estimated (Table 20). This represents the annual net saving to society resulting from the more efficient use of resources made possible by the installation of the Big Pine-Lafayette project. In contrast, the conventional Corps method of estimating benefits resulted in

14/ These dollar estimates represent proxy numbers for illustrative purposes and should not be interpreted as approximation of actual dollar estimates that would be derived from computer runs.

Table 19.--Projection of 1980 Agricultural Crop Benefit Proportion to 2069, Big Pine and Lafayette Reservoirs, Wabash River Basin

Target Year	Production costs		Efficiency gains from Flood Control 2 c/
	Flood Control 1 a/	Flood Control 2 b/	
1969	$434,802,000	$434,601,000	$201,000
1980	471,013,000	470,795,000	218,000
2000	536,855,000	536,606,000	249,000
2020	588,701,000	588,428,000	273,000
2069	727,971,000	727,634,000	337,000

a/ Includes Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, and Mansfield reservoirs.
b/ Includes Flood Control 1 reservoirs, and also Big Pine and Lafayette reservoirs.
c/ Additional cost savings attributed to addition of Big Pine and Lafayette reservoirs to Flood Control 1.

Table 20.--Estimated Present Value of Average Annual Flood Control Benefits from Alternative Evaluation Procedures, Big Pine-Lafayette Project

Formulation	Dollar Benefits a/
Wabash RLP-PE Model	$241,300
Corps Conventional Model b/	609,500

a/ Based on 100-year project life (1969-2069), $3\frac{1}{4}$ percent interest rate, and 48.5 percent crop benefits portion of total benefits.
b/ Total benefits based on Interim Report No. 1, Vol. II., op.cit. Share of benefits attributable to agricultural crop losses avoided were based on unpublished project justification data, Louisville District, Corps of Engineers.

damages as derived from the RLP-PE evaluation. 15/ As mentioned earlier, the major reason for this difference is that the RLP-PE model is based on a net enhancement concept and the conventional Corps method is based on a gross enhancement concept.

15/ Present-value average annual damages were $1,080,000 when based on the 3 percent rate of growth of damages that was used in the project justification report.

CHAPTER V

SUMMARY AND CONCLUSIONS OF THE RLP-PE MODEL

Regional linear programming basin planning (RLP-BP) models have been designed and applied in river basin planning surveys to identify the economic need for water resource development as it relates to the production of agricultural commodities. With appropriate modification, these models present a potential for utilizing their analytical framework and data base to evaluate the agricultural benefits of proposed flood control projects. A project evaluation model (RLP-PE) can be formulated to provide estimates of the cost of producing a specified output from an area under conditions of present flood hazards and with flood protection afforded by the proposed reservoir. The difference between these two estimates provides a single measure of the efficiency gain which reflects both the direct damage reduction and the net enhancement effect to agricultural lands protected by the reservoir. The analysis can be repeated for each year in which data were assembled for the river basin survey (e.g., 1980, 2000, and 2020), to obtain point estimates of expected future benefits of the flood control project. By extrapolating the estimated agricultural production-cost savings over the life of the project and discounting them back to a present value, an estimate is derived of the agricultural crop benefit component of the proposed flood control project.

This method of estimating agricultural crop benefits offers three main conceptual advantages as a method for determining the national benefit of providing flood protection to an area. First, the RLP-PE model provides information about the effects of a proposed project from a national efficiency point of view. Inelastic demand for farm commodities is assumed; thus, the efficiency gains resulting from the proposed project represent savings to the nation by meeting its food and fiber needs at less cost. Second, this approach provides a means by which the net enhancement of the project can be estimated. The RLP-PE model operates on the basis of utilizing land for the production of various crops for which the land has a comparative cost advantage. Improvement of the productive capacity of flood plain lands as a result of flood protection will increase production on the flood plain and, in the long run, will be offset by loss of production elsewhere. The RLP-PE model calculates these offsets and thus estimates the net enhancement effect. To the extent that the relative comparative advantage of lands that shift out of production within the study are similar to the comparative advantage of land elsewhere in the nation that would actually shift out of production, the estimated efficiency gains represent an unbiased estimate of the national gains. If the marginal lands within the basin have a comparative advantage, the model will underestimate the national efficiency gain. The third conceptual advantage of the RLP-PE model is the manner and detail in which future benefits are estimated. Instead of projecting future benefits on some assumed growth rate, they are calculated on the basis of separate estimates of changes in the demand for farm commodities and changes in technology which affect the yield and cost information in the model.

Three major issues or obstacles to converting the RLP-BP model to a RLP-PE model were examined and resolved. Sample data of the land base on which the planning model is based were found to be adequate for evaluating the effects of a single project if the flood plain to be protected includes at least 200,000 acres. The RLP-PE model can evaluate flood protection effects on smaller areas; however, supplemental information describing the land characteristics of the flood-plain impact area must be obtained. The problem of deriving accurate yield estimates for downstream flood-plain soils as compared to all flood-plain soils in the basin, upon examination, turned out to be an insignificant problem. Comparisons between crop yields and damage factors employed for upstream and downstream areas were not sufficiently different to invalidate the use of basin-wide yield and cost data of the RLP-BP model, in the RLP-PE model. Even if there were unique crop-yield and damage factors associated with a proposed project flood plain, this would not preclude the application of the RLP-PE model. Additional information specific to the flood plain would have to be derived from outside sources and introduced into the model as yield and cost revisions. The third conceptual difficulty in converting the RLP-BP model to a RLP-PE model was to devise appropriate means to adjust flood-free yield estimates of the RLP-BP model to reflect the actual partial protection to be provided by the project. This was accomplished by applying the Corps estimate of percent reduction in flood damages to the RLP-BP model "flood-free yield increment" and adding this "partial increment" to the existing flood-prone yield to derive the partial-protection yield. This operation was completed on a reach by reach basis since the level of protection varies by reach.

An empirical test of the RLP-PE model was conducted, utilizing information from the RLP-PB model that was constructed for the Wabash Comprehensive River Basin Survey and data supplied by the Louisville District Office of the Corps of Engineers. The effect of adding the Big Pine-Lafayette reservoir complex to the existing six reservoirs in the Upper Wabash Basin was evaluated. Only one year (1980) was selected to test the procedures for converting the RLP-BP model to a RLP-PE model. The conversion was successful, and estimates were obtained of the efficiency gains and changes in land use patterns that would be expected to result from the project.

Comparisons of the estimated production cost of achieving specified target demands for food and fiber in the Wabash Basin with and without the proposed Big Pine-Lafayette project revealed an annual saving of $218,100 as a national benefit. Associated with this efficiency gain was a land enhancement on the flood plain of 8,300 acres of land conversion and 60,200 acres cropped more intensively. In other parts of the basin, however, 9,800 acres were idled.

The significance of estimating national agricultural flood-control benefits by this approach is readily seen in a comparison of estimated benefits for the year 1980 derived from the RLP-PE model and the benefits calculated by the Corps using conventional methods. The RLP-PE model and the conventional methods provided estimated benefits of $218,100 and $510,900, respectively. Similar yield and damage reduction factors were used in both analyses. Therefore, the difference can be largely attributed to the different underlying concepts between the two approachs. The RLP estimate represents a net enhancement of land within the whole basin as farmers in the basin efficiently manage their resources to meet an inelastic demand for farm commodities. On the other hand, the Corps procedure represents a gross enhancement on the flood plain without offsetting reductions elsewhere and an expansion of output in response to a perfectly elastic demand for farm commodities.

Calculations of production costs with and without the Big Pine-Lafayette project could be completed for 2000 and 2020, as was done for 1980, to derive point estimates of the expected efficiency gains for these years. This array of estimates could then be extrapolated over the life of the project to derive an estimate of total anticipated benefits of the project. The RLP-PE model was not applied to the 2000 and 2020 data for the Wabash River Basin to obtain separate estimates of flood control benefits for these years. However, simulated values of the 2000 and 2020 benefits were made by calculating the percentage reduction in production cost for the Big Pine-Lafayette project in 1980 and applying this percentage to the "no development" production costs of the 2000 and 2020 RLP-BP models. The set of flood control benefits, as estimated for 1980 and simulated for 2000 and 2020, were then extrapolated over the life of the project and discounted back to the present to indicate how the average annual benefits from the project could be calculated. An average annual benefit of $241,300 was obtained for the Big Pine-Lafayette project, which represent an estimate of national efficiency gains based on the RLP-PE model and the above procedures. The comparable estimate of average annual benefit by conventional methods used by the Corps is $609,500. This figure can be divided into a national efficiency gain component of $241,300 and a regional income gain component of $368,200.

A RLP-PE model adequately meets three of the four principal items that should be considered in an ideal flood-control benefit evaluation procedure. First, it provides an estimate of the productivity change of land due to flood protection by directly estimating the damage reduction and enhancement components of the benefits. Second, the analytical framework of the model enables the benefits to be estimated from a national efficiency point of view. And it provides an explicit method for projecting future benefits based on separate projections of future commodity demand and future resource capability (supply conditions). The model does not include any provision for estimating adverse effects of a proposed project.

Flood control benefits that arise from reduction in damage to real or personal property are not estimated by the RLP-PE model. Thus, the model does not represent a sufficient method of estimating the total agricultural benefits that may result from a flood control measure.

As additional comprehensive river-basin planning surveys are completed across the country, an expanding data base and basic RLP-BP models will be established that could be used to assist flood-control project planners in formulating plans. The application of RLP-PE models to this process would provide a continuity link between the comprehensive basin plans and the subsequent proposed flood-control projects. In addition, it could be used to provide a broader display of information about the consequence of a proposed project than can be obtained from conventional agency methods.

PART IV

AN INTEGRATION OF

BENEFIT-ESTIMATION MODELS

AND

SUMMARY

CHAPTER I

AN INTEGRATION OF BENEFIT-ESTIMATION MODELS

In Parts II and III of this report, two techniques were examined for estimating flood control benefits based respectively on the land market and on linear programming models. The essential features of both models and a summary of their applications to flood damage or benefit estimation problems within the Wabash River Basin are presented in the following chapter of Part IV. In this chapter, however, we wish to deal more specifically with the complementaries of the techniques, both vis-a-vis each other and relative to the "conventional" technique (the flood hydrograph-flood damage model).

In Parts II and III we were concerned with evaluating the land value and linear program models as <u>alternatives</u> to the conventional techique, in accord with objectives set out in the contract for this work. In addition, a further contract objective was to:

> Develop a system of evaluation, involving selected elements of one or more of (the) alternative approaches so as to enhance the validity of the evaluation process and to facilitate effective use of planning resources in the assessment of flood control needs and potential economic benefits in agricultural areas.

In approaching this objective of developing a <u>system</u> for benefit evaluation, we make the following assumptions or judgments:

1. Although we judge, on both theoretical and empirical grounds, the land value and the linear programming models show considerable promise as estimating techniques, further development and tests are desirable. In the case of the land value model, this would primarily consist of additional applications in other river basins and further experimentation with model specification, data-collecting techniques, and similar details. For the linear programming model, refinement of several features for the Wabash model, as discussed in

Part III, is required, as well as development of similar models for other river basins. For these reasons, neither approach can be considered fully operational at this time.

2. We assume that the conventional flood hydrograph-flood damage model will continue, at least for the foreseeable future, as the standard estimating technique of the Corps of Engineers. The conventional flood hydrograph-flood damage model will be needed to estimate flood control benefits to the non-agricultural sectors--and neither the land value model or the RLP-PE model evaluated in this study have this capability. In addition, the conventional model has the advantage of being an operational model familiar to both Corps personnel and reviewers of project justification studies.

3. The implicit criterion in the contract objective of developing a system of evaluation is improved accuracy of estimated benefits. Ideally, this too should be judged in a cost-benefit framework, but this is beyond the scope of this study. However, at the end of Part II, suggestions for reducing data-collection costs for a land value analysis were offered. And, for the major river basins of the United States, the major developmental costs of the RLP-BP models have already been incurred (although the marginal cost of adopting the regional model for specific benefit-estimation applications may still be high).

Setting for the Model

As previously discussed in Part I of this report, the relevant benefits from a national or social point of view for Federal investment in water resource development have been generally defined as economic efficiency benefits, measured as the net increase in "national income" resulting from the investment. But, as economists have long pointed out, 1/ measurement of efficiency gains

1/ M. M. Kelso, "Economic Analysis in the Allocation of the Federal Budget to Resource Development," In: Stephen C. Smith and Emery N. Castle (ed.), Economics and Public Policy in Water Resource Development, Iowa State University Press, 1965, p. 64.

defined in this manner is difficult and complex. In particular, we cannot expect to measure the effects of a single water project in the national income accounts, using the same concepts and measurement techniques employed by national income accountants. In practice, we are usually reduced to measuring benefits at the local project level. But frequently the gross benefits at the local project level will exceed the benefits at the national level because the investment tends to change the relative regional or area comparative advantage. This implies that the excess of local gains over national gains has been offset by losses elsewhere in the economy, due to the shift in comparative advantage. Thus, an estimate of national income gains compiled by aggregating regional or area gains from a specific project will be biased upward unless these regional losses (income transfers) are taken into account.

Even if comparative advantages are unchanged by the investment, society, given the choice of two water-resource investments that yield the same net national efficiency gains, might prefer one project over the other on the basis that the one region is disadvantaged or in greater need of employment and income opportunities stemming from the project. This suggests that regional or area development might also be a legitimate objective for Federal investment. However, there is still the need . . ."to spell out quite clearly, as separate questions, the efficiency considerations involved in each resource development project and its income redistributive consequences." 2/

Explicit recognization of regional economic development as an objective of water-resource investment was first made in Senate Document 97, and further recognition of this objective is implied in the Appalachian Regional Development Act of 1965. Most recently, a special task force of the Water Resources Council has recognized the separate objectives of national income and regional

2/ Ibid, p. 63.

development, as well as two additional objectives relating to environmental and social well-being criteria.

If the Task Force's recommendation is accepted as public policy, benefits from a specific water resource investment will need to be evaluated in terms of four broad objectives--national economic development, environmental quality, social well-being, and regional development. The actual task may be even greater since, for example, the regional development objective may contain a number of subobjectives (not necessarily mutually exclusive)--increased regional income, increased regional employment, improved regional economic base, improved income distribution within the region, and improved quality of services within the region. A similar set of subobjectives could possibly be developed for the environmental and social well-being objectives.

Recognization of the possible multiobjectives of a water-resource investment does not necessarily imply that a specific project can contribute equally to all objectives or that conflicts among objectives will not develop. From the standpoint of benefit-estimation methods, however, the implication is that the evaluation procedure will probably become even more complex. It is also unlikely that a single methodology can be developed to measure the contribution of a project to all objectives and subobjectives. This latter point applies especially to measurement of contributions to the environmental and well-being accounts, since these accounts include the complex problems of evaluating intangibles, human lives, and human well-being.

On the other hand, the problems of evaluating project contributions to national income and regional development objectives are closely related. In Part I of this report it was pointed out that both the conventional Corps technique and the land value approach adopt an essentially regional point of view in computing flood-control benefits, and that what is required is a technique for separating regional gains realized in the form of income transfers from national economic efficiency gains. The RLP approach, on the other hand, is based essentially on a national income criteria, although it also has implications for regional income distribution effects.

In our consideration of an integrated estimation technique (below) we will maintain the distinction between the national income and regional development accounts as suggested by the Task Force.

The Integrated Model

The land value and linear programming models, in their present state of development, are viewed as complements to conventional techniques. This suggests that a logical development of an integrated model would start with the conventional technique as the basic building block or "backbone." To this backbone, complementary features of the land value and RLP models are added with the purpose of either deriving more reliable (i.e., more accurate) estimates of expected benefits or of facilitating the allocation of benefits to the appropriate accounts, following the Task Force proposals.

Based on consideration of all three methods, we suggest a synthesis of techniques along the lines suggested in Table 21.

Stage one.--The benefit-estimation process has been divided into four broad steps or stages following the approximate steps now used by Corps offices. Previously, we have considered the methodology for a given site. In Table 21, however, we begin by recognizing that a combination of engineering, political, and general economic decisions precede the decision to consider a given investment in River Basin A rather than elsewhere; and within River Basin A, at site i as opposed to other potential sites within the Basin.

This stage provides the first point of contribution of the RLP-PE system. This use was not discussed in Part III because it is an implicit use of the

Economic Research Service river basin models currently operational for several areas of the United States. However, the present models are capable of identifying resource investment needs only on a broad regional basis. As the RLP-BP models are modified for specific project-evaluation purposes, decision makers should be able to pinpoint preferred investment points (inter- and intra-basin) with much greater specificity. For a given basin, a number of preliminary site-selection runs could be made to determine where in the basin the national income gains from a resource investment would be the greatest. This preliminary site selection may need to be modified, of course, on the basis of engineering and cost considerations which are not built into the model.

Table 21.--Stages in Estimation of Expected Agricultural Flood Control Benefits

Stage	Type of account	Actions
I Preliminary site selection	All	Formal or informal weighing of engineering, political, and economic a/ factors leading to selection of site i for project feasibility study.
II Estimation of expected benefits, present level of development	Direct (local)	Estimation of benefits from reduction of direct crop and non-crop agricultural damage b/, plus benefits from near-time land enhancement. a/ b/
	Regional	Summation of direct local benefits plus net secondary benefits to the region.
	National	Estimation of national income or efficiency gains. a/
III Estimation of expected benefits, future levels of development	All	Projection of expected future flood plain development as modified by regional and national growth projections. a/
IV Estimation of total	All	Summation of expected present and discounted future benefits.

a/ Entry points of the RLP model.
b/ Entry points of the land value model.

Stage two.--The second stage of the estimation process, using conventional estimation procedures, is the calculation of expected benefits from flood protection, given the present level of flood plain development and the expectations of immediate land enhancement likely to be induced by the project.

For the second stage we have identified three types of accounts. The direct or local account reflects the viewpoint implicit in both conventional estimating techniques and in the land value approach. The regional account is based on the direct account and takes into consideration any net secondary benefits to the region resulting from the project. If the Task Force recommendation to the Water Resources Council is adopted, this regional account, rather than the local account, will be the relevant account for computing regional benefit/cost ratios. If there are no net secondary effects, the definition of the two accounts would be synonymous and are so considered here.

Using conventional techniques, computation of benefits at the present level of development consist of calculating the expected benefits from reduction of direct crop and non-crop damages, including benefits derived from conversion of land to higher, more intensive uses. In the synthesized model, these calculations will be checked by comparing them to prevailing land values in the impact area. Generally, the primary gain sought from this modification is a higher level of confidence in the accuracy of the benefit estimate. This greater confidence would gain from the facts that each step in the conventional estimating procedure has been checked against the logic of capitalization theory and from the existence of an independent estimate of average expected flood damages obtained from the land value analysis.

The test of the land value model for the Wabash provides examples of how this portion of the integrated model might work. In both the Lower and Upper Wabash study areas, we observed statistically significant differences in the price of tracts subject to flooding compared to flood-free or protected tracts. Although, in very general terms, we were not able to derive a precise judgment of the absolute accuracy of the indicated land market discount for flood risk (at specific points on the flood plain, for example, or at a specific point in time for the Upper Wabash), we do judge that the land model results were consistent with the Corps' estimates of expected annual damages. Consistency between estimates from the two techniques was observed, both absolutely and relative to differences in damage magnitudes between the Upper and Lower Wabash, and between leveed and unleveed areas. We consider these results as confirming the damage estimates derived from the conventional technique.

In the White area, however, the land value model failed to yield a direct estimate of landowners' evaluation of the flood risk. We cannot say that the landowners consider the risk to be nil because it is possible that the relative desirability of the flood-plain lands was so high (relative to available upland tracts) that they commanded a price premium despite the flood risk. We do feel, however, that the estimate based on conventional techniques of expected annual damages of $16.89 per acre for agricultural crops and $4.21 per acre for agricultural non-crop damages to be inconsistent with prevailing land price relationships, both within the White area and relative to the other study areas. This suggests that some step or steps in the conventional technique led to an overstatement of expected annual flood damages for these river reaches.

The linear programming model contribution to the calculation of the direct or regional account in stage two is to provide an estimate of the types and extent of land enhancement activities that would be warranted by the project. Below the Big Pine-Lafayette project, for example, the RLP-PE model indicates that over 60,000 acres would be cropped more intensively and up to 8,300 acres could be converted to higher uses. Since these acreages can be identified by soil characteristics, it should be possible to identify with some specificity the location of the areas for which enhancement is expected.

Estimation of the project contribution to the national economic development account would be obtained from the RLP analysis and would represent the contributions of the project to the agricultural sector of the national economic development account. Under present project evaluation practices, decisions among competing water resource investments could be improved if this information were provided for each project under consideration. The test of the RLP-PE model in the Wabash Basin, for example, indicates that of the estimated total agricultural crop benefits of $609,500 from the Big Pine-Lafayette project, about $241,300 represents the net savings in producing the Wabash Basin share of the national food and fiber needs. The remaining $368,200 can be viewed as an income transfer to flood plain farmers under the assumptions of the RLP model.

Stage three.--The major task in stage three is the computation of the growth multiplier, used to estimate future flood plain development that can be expected over the planning period for a given project. Presently, expected future growth on the flood plains is estimated directly on the basis of several indices of expected state or area population growth, per capita income, future crop yields and technological advances; and with the assumption that the flood plain growth rate will be the same as the composite state or area growth rate. There is no a priori reason that the flood plain should experience the same growth rate as the uplands, but this assumption is necessary because there are no indices of expected future growth specific to the flood plains.

For the RLP model, many of the same indices are required to project future demands, yield levels, and production technology at specific points in time. However, the projections are made specific to the regional or subarea levels. The solution of the RLP model yields an estimate of flood plain use and output required to meet the projected regional and national demands at the selected points in time.

For the integrated model the expected, or warranted, growth at selected points in time would be obtained from the RLP model. The growth at the selected time points would then be extrapolated over the intervening years. The major advantages of this approach are the stronger conceptual base for estimating warranted development at each time point and the division of the projected period into discrete time units, permitting consideration of non-linear development paths.

CONCLUSIONS

The additions or modifications suggested for the integrated model have been tested or examined for a specific application within the Wabash River Basin but a full scale application of the total model has not been tried. Some of the suggested changes, such as the application of the land value model, need further empirical testing in other areas and other aspects, particularly for the RLP model, need further refinement and testing. However, none of the suggested modifications require extensive or immediate change in currently used techniques. Thus, the synthesized model might best be viewed, at the present level of development, as a goal for eventual development. This would suggest the sequential adoption of each suggested change (or modifications thereof) as the changes are further tested and developed.

CHAPTER II

SUMMARY: ALTERNATIVE PROCEDURES FOR BENEFIT EVALUATION

This study was undertaken to identify opportunities for improving the quality of estimated economic benefits resulting from the reduction of the magnitude and frequency of flooding on agricultural flood plains. Two specific alternatives for improving the analytical basis of project evaluation procedures considered in this report are: (1) The use of agricultural land market prices as a check or as a proxy for benefits computed by flood hydrograph-flood damage integration methods; and (2) the use of a regional linear programming model in evaluation of expected national and regional benefits. These methods are analyzed both theoretically and empirically, and compared with the conventional flood hydrograph-flood damage method. After analyzing the merits and shortcomings of the three procedures, a composite "system of analysis" is outlined which could serve as a foundation for possible changes in evaluation standards and practices.

Theoretical Framework

Benefit-cost analysis can be defined as seeking to maximize "public benefits" or "general welfare" within the area of investigation, e.g., a proposed flood control structure. Operational significance of the maximization principle is obtained by specifying that the ultimate aim of the development activity is to provide goods and services which satisfy human needs and desires. To the extent that the desired goods and services can be quantified, concepts of economic efficiency can be applied to determine when an efficient level of public benefits has been reached. An economic-efficiency gain is realized if, as a result of the development activity, either more goods and services are obtained with the same resources, or the same goods and services are obtained from fewer resources. Efficiency gains from water resource investments are ultimately expressed as gains in national income--additional wages, rents, and profits received by the aggregate households and firms as a result of the development.

Analysis of efficiency gains must be made with explicit recognition of the elasticity of demand for the products to be produced on the flood plain, and the nature of the supply functions of both flood plain and upland firms who compete in the production of these products. If the demand for flood plain products is inelastic, as is the case of most farm products, the efficiency gain to society is the saving in total variable costs of production realized in producing a given level of output. As output is increased on the flood plain as a result of flood protection, output on less productive lands will decrease, resulting in a reduction in variable costs required to achieve the output demanded by the market. Thus, calculation of the efficiency gain to society requires that the net reduction of returns to less productive lands be subtracted from the net increase of returns of flood plain firms. From the viewpoint of the individual flood plain firm, however, the efficiency gain is the increase in net returns resulting from lower unit costs and a higher level of output by the firm.

If the demand for flood plain products is perfectly elastic, the market will absorb all of the additional output that can be produced on the flood plain at the same price. The flood protection efficiency gain to society, in this case, is the net value of the incremental output plus the more efficient use of variable resources associated with the output obtained in the absence of the flood protection. Because no offsetting adjustments are made by upland firms, the benefit to society is equal to the sum of the increased returns to the individual flood plain firms.

The productivity of flood plain resources can be increased by any action that shifts the supply curve downward and/or to the right. Flood control may reduce the costs of inputs that would otherwise be required to remove flood debris or to replant crops. Increased productivity of inputs used on flood plain lands may result from the reduction or elimination of direct loss of agricultural output, and by eliminating yield reductions due to delayed planting. Flood control may also contribute to more efficient utilization of flood plain land, either in its present use by allowing more intensive production practices to be adopted (e.g., heavier fertilizer applications) or by enabling the land to be shifted to higher value crops or to commercial, industrial, or residential uses. The first two effects--reduction of input costs and yield losses--are considered direct damage reduction. Benefits arising from more efficient utilization or from shifts to higher value uses are considered enhancement benefits.

Flood control benefits can be evaluated from two different viewpoints: First, from the viewpoint of what the flood plain occupants would suffer due to flooding, or what they would receive as flood protection benefits; and, second from the viewpoint of society as a whole. It is important to distinguish between these two viewpoints because the societal benefits are not necessarily equal to the sum of the benefits obtained by individual flood plain occupants. An individual may benefit greatly from a flood control project, yet society as a whole may be no better off, particularly when the demand for the additional flood plain output is inelastic. In this case, the increased net returns to flood plain occupants may be offset either by equivalent reductions in production elsewhere or by increased costs of price support and production control programs.

In addition to determining estimated benefits under current conditions, we also need to know whether the benefits can be expected to increase or decrease over time. A sound analysis will require projection of future rates of flood plain development that are likely to occur in the absence of flood protection.

An ideal benefit evaluation framework should also consider the negative effects that may result from the installation of a flood control project. For example, the release of flood waters from a reservoir may cause streams to have bankful conditions for prolonged periods, resulting in impaired drainage to adjoining land.

Land Value Model

This portion of the study investigates the potential application of an evaluation procedure based on land value relationships as an alternative means of estimating potential flood control benefits. The general objectives are: (1) To develop a benefit-estimating model based on land prices in the Wabash River Basin; (2) to apply the land price model to areas currently considered for flood protection; and (3) to judge the feasibility of adopting the model as a part of required agency procedure.

Use of land value relationships to estimate expected flood control benefits has been frequently discussed in economic literature. The proposals are based on the theory of economic rent which implies that the market price, or value, of a fixed asset such as land is determined by its expected future earnings. Flood damages reduce the net returns to be expected from economic activity on the flood plain; it follows that flood plain land should command proportionately lower prices than otherwise comparable flood-free land. Since the prevention of expected loss of earnings is the major source of agricultural benefits from flood control, one should therefore be able to estimate these benefits directly from relative land price data.

This approach to benefit estimation has a strong inherent appeal among economists and a number of advantages have been claimed for a land value approach. For example, it has been pointed out that land value data are relatively accessible and easily interpreted. The land market provides a measure of value that is based on the experiences of those most directly affected by the flooding hazard and this factor is believed to lead to a more accurate estimate of expected benefits than the laborious and potentially error-prone estimating procedures currently used. In addition, land prices have already been discounted to a present value by an implicit long-term market rate that allegedly reflects an appropriate market-determined time preference rate for projection evaluation. Finally, it can be pointed out that the general feasibility of applying the principles of economic rent theory has been well established by studies of other exogenous changes in land rent which have effects on marketland values conceptually similar to Federally financed flood control projects.

The land value approach is conceptually equivalent to conventional estimating procedures, because both methods are based on calculating the changes in net income accruing to the land factor as a result of flood control and both reflect the viewpoint of the flood plain landowner. The Corps calculates the increases in net income by estimating the components of the income change stemming from the alleviation of direct damages and the enhancement benefits made possible by virtue of the project. Similarly, the land value approach provides a theoretical means of estimating the same income changes directly from relative land values.

A review of literature indicates that the most important questions regarding the model center around the accuracy of the land markets' evaluation of flooding hazards. One important consideration is the possibility that land buyers and sellers fail to fully recognize the flood hazard. This may lead to overpriced flood plain lands in the absence of recent or frequent flooding, but may also result in temporarily depressed flood plain values after severe flooding. Another major consideration is the problem of adjusting land values to a comparable price basis. This may create no serious problems in a wide range of cases in which the lands are physically similar or the noncomparable elements can be easily valued. However, if the physical differences of the land are extreme it may be impractical to make the value adjustments, or the adjustments may require so much data and be subject to so many uncertainties as to render the land value approach unusable. Evaluation may have to be decided on a case-by-case basis; but an accumulation of experience with the model should provide guides for determining the types of areas in which comparability problems are likely to be significant.

Three study areas with different flood plain characteristics were selected within the Wabash River Basin for the land value analysis. Carroll, Cass, Miami, and Wabash counties along the upper reaches of the Wabash were chosen to represent an area that has undergone a recent change in flood risk. These counties may also be representative of other areas where rivers and their tributaries have moderately narrow flood plains (approximately 500 acres per stream mile). Knox and Sullivan counties along the lower Wabash were chosen because they include reaches of the Wabash and White Rivers with extensive flood plains. Both counties contain extensive levees, which provide three types of land--unprotected flood plain, protected flood plain, and uplands. Bartholomew and Jackson counties along the White River were chosen for the third study area because this area provides a wide contrast in topography, type of farming, and nature of flood risk--both within the area and in contrast to other study areas.

Agricultural land prices within a local market area are postulated to be primarily a function of such variables as absolute size of tract, acres of cropland, acres of other land, quality of land, number and quality of farm buildings on the tract, type of financing, and whether the tract was purchased for expansion purposes. Information described above was assembled from records of the County Registrar of Deeds offices and County Assessors offices of the various counties under study. Multiple linear regression equations were formulated utilizing this information for both upland and flood plain lands in each of the three study areas.

The regression equation consistent with the postulated land model is of the form:

$$Y = b_o + b_i X_i + b_j X_j + E \quad \text{where } \begin{matrix} i = 1,2---n \\ j = n+1---m \end{matrix}$$

The dependent variable, Y, is sale price of land and buildings. The X_i's are the independent variables common to both uplands and flood plains that are believed to significantly affect land values. The X_j's are independent variables reflecting acres of land inundated at selected exceedence intervals. And E is the error term which represents random variation in the observations.

Initial investigations (in each area) were made with all observations combined (both upland and flood plain), in order to determine the general nature of the value relationships and to test if the average sale price of the flood plain tracts differed significantly from the upland tracts. The analysis of specific flood risk-land value relationships is limited in this type of analysis, however, because it is possible that some of the influence of flood risk may be picked up by other independent variables (such as proportion of cropland by grade), which are more strongly correlated with sale value in the combined regression analysis.

In order to separate the influence of flood risk from other factors influencing tract values, the following two-step procedure was adopted. First, the upland sales were analyzed as a class. The purpose of this step was to estimate the influence on sale value of all variables (except flood risk variables) for which data were available from the observations that were free of flood risk. The regression coefficients obtained, therefore, should be free of any discounting for flood risk.

In the next step of the analysis, the sale price of each flood plain observation was estimated on the basis of the values derived from the analysis of the upland sales. The assumption in this process is that in the absence of flood risk, those factors common to both upland and flood plain sales would influence price in the same way. The residual differences between the actual per acre sale price of the flood plain observations and the estimated price, given the above assumption, includes the component of flood plain land values attributable to flood risk. These residual differences provided the basis for additional investigations into flood risk-land value relationships.

Land Values and Estimated Flood Risk--Upper Wabash

The average flood plain tract in the Upper Wabash sold for $195.53 per acre, which was nearly $130 less than the price per acre of the average upland tract (Table 22). In comparing the average upland and flood plain farm, however, we noted that the tracts differed in several respects. Since the average tracts are not strictly comparable, it is not sufficient to simply take the difference between average prices as an indication of flood risk.

Correction can be made for differences of quality of land, size of tract, and farm improvements by assigning estimated upland values to the means of these variables for the flood plain sales, under the assumption that in the absence of flood risk the flood plain value components would be valued the same as the upland components (Part A, Table 22). If this is done, the estimated price of the flood plain sales would be $224.34. This indicates that about $100 of the $130 difference in average price per acre was due to quality and quantity differences, and about $30 represented the average discounting for flood risk.

Table 22.--Average land prices and flood risk calculations, Upper Wabash Area

A. Average price per acre analysis	Amount
1. Price per acre of average farm, 346 upland sales	$325.39
2. Price per acre of average farm, 45 flood plain sales	195.53
3. Unadjusted difference	-129.86
4. Estimated price of flood plain sales at upland values	224.34
5. Difference attributable to flood risk (4-2)	-28.81

B. Per acre residual analysis

Category	Mean residual	Standard error	t value	Significance
39 Wabash River observations	$-26.79	$11.44	2.34	0.025

Approximately the same conclusion can be reached if a "flood-free" sale price is estimated for each flood plain sale and subtracted from the actual sale price (Part B, Table 22). The difference of $26.79 represents the average discount per acre for the average flood plain farm. However, nearly all the observations overlapped the uplands to some degree and on the average, 45 percent of the total open land on the typical flood plain tract was actually free of flood risk. The estimated discount of $27, therefore, understates the actual per acre discount on the land subject to flooding. Additional statistical calculations indicated the flood risk on a tract entirely on the flood plain would reduce the value of the tract by about $50 per acre.

Total agricultural damages over all reaches in the four-county area were estimated by the Corps of Engineers to average $9.72 per acre under natural conditions. With completion of the three reservoirs the residual damages were estimated to be $2.01 per acre. The remaining damages capitalized at 5 percent represent a flood risk discount of $40 per acre as compared to a $194 discount under natural flooding conditions.

The land value data on which the residual analysis is based covers the years 1955 through 1966, a period during which the agricultural stretches of the flood plain changed from a no protection to nearly a complete reservoir protection status. This raises the question of when, in time, land values might be expected to respond to a prospective or actual change in flood risk. If price adjustments were discrete phenomena that followed completion of construction, the effects would not be fully reflected in the years sampled because only two of the three reservoirs were fully operational by January 1967. However, if price adjustments occur in anticipation of protection, the capitalization process may have been underway at the beginning of the sample period, since the reservoir investigations had already been made by 1955.

The analysis of the land-value data cannot establish that anticipatory capitalization did occur, but if some capitalization was already occurring during the early years of the study, then the estimated discount of around $50 per acre is not inconsistent with the capitalized Corps estimate of a $40 flood risk discount.

Land Values and Estimated Flood Risk--Lower Wabash

The difference in the simple average sale price per acre for the upland and flood plain farms was $49.37 ($303.33 - $253.96). Part A of Table 23 indicates that after correcting the 70 flood plain sale observations to a comparable basis with the upland sales they would command a price of $285.19 per acre. The difference between this estimated flood-free price and the actual price provides an estimate of an average discount for flood risk of $-31.23 per acre.

Table 23.--Average land prices and flood risk calculations, Lower Wabash Area

A. Average price per acre analysis	Amount
1. Average price, 260 upland sales	$303.33
2. Average price, 70 flood plain sales	253.96
3. Unadjusted difference	-49.37
4. Estimated price of flood plain sales at upland values	285.19
5. Difference attributable to flood risk (4-2)	-31.23

B. Per acre residual analysis

Category	Mean residual	Standard error	t value	Significance
70 flood plain sales	$-31.23	$12.01	2.60	0.01
38 levee protected sales	+3.83	16.31	1	NS
32 no levee sales	-72.86	114.91	4.89	0.0005
15 frontage	-117.84	16.53	7.13	0.0005
17 no frontage	-33.17	19.74	1.68	0.10

The average of the residual differences for all 70 flood plain observations was $31.23 (Part B, Table 23). However, the 70 observations were composed of 38 observations receiving protection from levees, and 32 observations outside or without levee protection. When residuals are calculated separately for these groups, the observations with levee protection had a positive residual of about $4.00. This residual was not significantly different from zero,which indicates that, with protection, the flood plains are valued comparably with upland farms.

Correspondingly, the residual for the 32 observations without levee protection was $-72.86. This group was further broken into two categories--those with river frontage (15 observations) and those without (17 observations). The corresponding residuals were $-117.84 which was highly significant (smaller than zero) and $-33.17 which was significant at the 10 percent level. The difference in the residuals for the frontage and no-frontage sales is partly a reflection of differing flood risk and partly the effect of averaging some upland values in the residual for the no-frontage observations.

The river frontage in Knox and Sullivan Counties include all or the major portion of reaches W-3 and W-4 along the Wabash and WH-1 and WW-1 along the White and West Fork of the White Rivers. Using conventional flood hydrograph-flood damage methods the annual total agricultural damages per acre with the existing modifications were estimated to be $6.81.

Applying a 5.0 percent capitalization rate, this composite damage estimate indicates that a differential of about $136 per acre between the uplands and unprotected flood plains should be expected. The most nearly comparable estimate from the land value investigation is the 15 sales of tracts of land with river frontage, which were almost completely embraced by the flood plains.

The mean residual for these 15 sales was $-117.84 per acre, with a standard error of $17. This differential is equivalent to expected annual damages of $5.89 based on a 5.0 percent capitalization rate. With a confidence limit of one standard error, a range of expected damages from $5.06 to $6.72 per acre is indicated. Therefore, at only a slightly higher degree of confidence, we could not say that the land value estimate differed significantly from the Corps estimate of $6.81. A 95-percent confidence interval, for example, would be from $4.11 to $7.67 per acre.

On the basis of the land value analysis, we can be relatively confident that the land value approach gives us no basis to question the accuracy of the Corps' estimate. Beyond this point, the analysis cannot specify which estimate is "best". The decision to accept the Corps estimate would depend partially on how critically the choice affected the benefit-cost ratio. If the choice were critical, a full-scale review of the entire Corps estimating procedure would probably be the logical next step.

Land Values and Estimated Flood Risk--White Subarea

In Bartholomew County the average prices per acre for upland ($349) and flood plain ($335) were quite close. However, the land quality of average upland and flood plain farm differs considerably. Sixty-five percent of the cropland on the flood plain farms was graded A or B by the tax assessors compared to 42 percent for the upland farms. When the average price of the flood plain sales is corrected for these differences the estimated average price is $370.68 per acre (Table 24). The difference between this estimated price and average sale value per acre for the flood plain sales is $35.39, or in terms of the average residual, $-35.90.

Although this residual provides an estimate of the discounting for flood risk on these sales, it is not significantly different from zero. As in the

Upper Wabash area, this residual probably understates the actual discounting that may occur on the flood plains since most of the observations overlap the flood plains and uplands. At an average of 113.2 acres per flood plain farm, a residual of $-35.39 per acre is equivalent to about $-64 per flood plain acre. However, the small number of observations and the low level statistical reliability precluded further meaningful analysis of the data.

Table 24.--Average land prices and flood risk calculations, Bartholomew County

A. Average price per acre analysis	Amount
1. Average price, 65 upland sales	$348.83
2. Average price, 16 flood plain sales	335.29
3. Unadjusted difference	-13.54
4. Estimated price of flood plain sales at upland values	370.68
5. Difference attributable to flood risk (4-2)	-35.39

B. Per acre residual analysis

Category	Mean residual	Standard error	t value	Significance
16 flood plain sales	$-35.90	$33.39	1.07	NS

Upland farms in Jackson County sold for an average price per acre of $110 <u>less</u> than flood plain land. The upland observations in the sample exclude sales from some of the poorest farming townships in the county, but there are still very large differences in the upland and flood plain farms.

A regression analysis was performed for the upland sales alone, but the results were unsatisfactory for adjusting flood plain sales for comparability. There was not enough grade A or B cropland on the upland farms to derive a reliable estimate of value, and the relative values for the different grades of cropland were inconsistent.

With the contrast between the upland and flood plain sales and the limitations of available data, there is no means of estimating the value of the higher grades of cropland under no-flood-risk conditions or of estimating the price this land would command in the absence of flooding. This does not mean that no discounting for flood risk occurs on the flood plain, but simply indicates that in the absence of flood risks, flood plain land prices would probably be even higher. The difficulty, however, is that there is no way to estimate the potential increment from the available upland price data.

The 36 flood plain sales for Jackson County are primarily within reach EW-4. About 91 percent of all cropland on the average flood plain farm would be inundated by the 100-year flood; 79 percent by the 5-year flood, and over 40 percent by the 1-year flood. Attempts were made to analyze the flood plain sales separately as a group but the analysis was unsuccessful. The basic problem with this type of analysis apparently can be traced to the fact that the basic units of observations are farms or tracts of land that lay across several flood risk zones. Logically, a land buyer might weigh his offer for the entire tract on the basis of the proportion of land in each flood risk zone but, if this occurs, the regression analysis was not able to pick it up.

The results in Bartholomew and Jackson Counties indicate that the regression analysis approach has very limted or no applicability in these or similar areas. The case in Bartholomew County is similar to the case in the Upper Wabash study area--the analysis does indicate that a price differential exists between flood plains and uplands but that the standard errors associated with the estimate are large, and relatively little confidence can be placed in a single-valued estimate derived from land values. In Jackson County the land value approach failed to yield an independent estimate of flood risk.

Conclusions on the Efficacy of the Land Value Model

The statistical limitations of the data for the three study areas do not permit strong statements about the precise relationship between land values and flood risk, except to note that the findings of the study are indicative of underlying regularities in the land market with respect to variations in flood hazards. Considering the results from the three areas jointly, it is noted that the analysis did not yield results in any area that are inconsistent with *a priori* expectations based on considerations of land rent theory. The results, particularly between the Upper and Lower Wabash areas and between leveed and nonleveed areas, are consistent in relative magnitude and in relation to degree of flood risk.

On the other hand, it is noted that even in the Lower Wabash area where the land value-flood risk relationships appeared strongest, the confidence limits that could be attached to the land value estimates are relatively wide. The standard errors are not necessarily an indication of wide variance in flood risk discounting, but stem from variance in all the factors determining land values--many of which cannot be adequately measured or included in an analytical technique. In addition, lack of precision is introduced into the estimate by the fact that the units traded in the market are sizeable tracts or whole farms that may overlap the flood plain or embrace a range of flood risk zones. Thus, even if it were possible to derive a precise estimate of the average discount per farm or per acre over a stream reach, we cannot expect to determine precisely how the price of a specific acre relates to the specific flood risk on that acre.

Nevertheless, the experiences in the Wabash Basin indicate that the land-value approach can provide a useful, independent measure of the reasonableness of the conventionally estimated agricultural benefits over a reasonable range of flooding conditions. As a land-value check, the analysis of the land market serves its purpose if it either (a) indicates that the benefit estimates are reasonable, or (b) it points out inconsistencies in the conventionally derived estimate.

To the extent that experiences in the Wabash Basin can be generalized, it appears that the efficacy of the land-value approach is closely related to topographic and flooding conditions. The land-value approach appears most likely to yield estimates with reasonable standard errors in regions with sufficiently broad flood plains so that an adequate number of sale observations over a relatively limited time period can readily be obtained, and where the flood plain and flood-free lands are closely "comparable." Areas of high comparability would probably include flood plains that are partially leveed (as in the Lower Wabash study area) or within wide river valleys in which the meanderings of the river have left a series of benchlands above the frequent inundation levels.

A second type of area (of which the Upper Wabash Area in this study is an example) we would view as creating moderate to large difficulties for application of the land value approach because (a) the relatively narrow flood plains create difficulties in obtaining an adequate number of observations at a reasonable cost, and (b) the contrast between alluvial flood plains and uplands requires more careful investigation of the need for comparability adjustments. Because of the difficulties of working with land-value data in this type of study area, one could not expect to obtain highly precise benefit estimates from land-value analysis. Although the relative land-price relationships and levels can still be of use in verifying the conventional estimates, a probable issue will involve the question of how much time and funds should be invested in refining the land-value estimates.

Areas least favorable to the land-value check would include areas similar to Jackson County, where the contrast between the flood plain and upland farming conditions favor flood plain production in spite of the risk. A likely result is a price structure which makes it difficult or impossible to estimate the expected flood plain land prices with protection. On the basis of the Wabash experiences, this type of area would not warrant extensive investigation of land-price relationships. Even in this type of area, however, a minimum of price data could provide the basis for a judgment evaluation of conventional damage estimates. Such a judgment evaluation cannot give definitive answers, but high damage estimates should be a signal for a careful review of the conventional techniques.

Recommendations

Based on the results of the Wabash analyses the following recommendations are offered:

(1) The application of land rent and capitalization principles should be made at the appropriate steps of each project justification study. The results should accompany the project report and any wide divergences explained. This recommendation is intended primarily as a procedural check to detect errors of logic or assumptions at each stage of the benefit estimation procedure before they become embodied (and perhaps hidden) in the next stage. This procedure would not require precise land-value data, but the values used should be consistent with prevailing land prices.

(2) Further studies of the relationship between land values and flood risk should be made in other areas presenting some variety in topographic, farming, and flood risk situations. Additional studies are recommended primarily to determine the transferability of relationships found in the

Wabash, and to accumulate a store of knowledge of land market-flood risk interrelationships which can provide the only means of making final judgments of the validity of the land market approach. Further experiences would also be helpful in developing specific procedural guides.

(3) If additional investigations are made in other areas, emphasis should be placed on reducing the costs of applying a land-value check, especially through systematizing land-data collection. For example, assuming that each district office knows approximately which reservoir or levee projects are likely to be considered over the next decade or so, sample counties could be selected and abstractors or the county recorder in each county could be contracted to supply the district office with farm sales data relevant to each agricultural sale occurring in a specified area on and bordering the flood plain. The district office could thus maintain a continuing, current file of data useful for general land price index purposes and would have available at the time of a land value analysis a stock of basic data, including grantor-grantee names, on which to base additional data collection.

Regional Linear Programming Model

This portion of the study investigates the potential of utilizing a regional linear programming model of the agricultural sector, as developed for river basin planning, as an alternative means of estimating agricultural benefits of specific flood control projects. The objectives are: (1) To examine the conceptual basis for regional linear programming models in relation to the features of an "ideal" flood control benefit evaluation procedure; (2) to examine empirical problems of converting a regional linear programming basin planning model (RLP-BP) to a project evaluation model (RLP-PE); (3) to apply the RLP-PE model to a specific flood control project(s); and (4) to indicate how a RLP-PE model can supplement current agency procedures.

Regional linear programming basin planning (RLP-BP) models have been designed and applied in river basin planning surveys to identify the economic need for water resource development as it relates to the production of agricultural commodities. With appropriate modification, these models present a potential for utilizing their analytical framework and data base to evaluate the agricultural benefits of proposed flood control projects. A project evaluation model (RLP-PE) can be formulated to provide estimates of the cost of producing a specified output from an area under present flood hazard conditions and also with flood protection afforded by the proposed reservoir. The difference between these two estimates provides a single measure of the efficiency gain which reflects both the direct damage reduction and the <u>net</u> enhancement effect to agricultural lands protected by the reservoir. The analysis can be repeated for each year in which data were assembled for the river basin survey (e.g., 1980, 2000, and 2020), to obtain point estimates of expected future benefits of the flood control project. By extrapolating the estimated agricultural production cost savings over the life of the project and discounting them back to a present value, an estimate is derived of the agricultural crop benefit component of the proposed flood control project.

This method of estimating agricultural crop benefits offers three main conceptual advantages as a method for determining the national benefit of providing flood protection to an area. First, the RLP-PE model provides information about the effects of a proposed project from a national efficiency point of view. Inelastic demand for farm commodities is assumed; thus, the efficiency gains resulting from the proposed project represent savings to the nation by meeting specified food and fiber needs at less cost. Second, this approach provides a means by which the net enhancement of the project can be estimated. The RLP-PE model operates on the basis of utilizing land for the production of various crops for which the land has a comparative cost advantage. Improvement of the productive capacity of flood plain lands as a result of flood protection will increase production on the flood plain and, in the long run, will be offset by loss of production elsewhere. The RLP-PE model calculates these offsets and thus estimates the net enhancement effect. To the extent that the relative comparative advantage of lands that shift out of production within the study area are similar to the comparative advantage of land elsewhere in the nation that would actually shift out of production, the estimated efficiency gains represent an unbiased estimate of the national gains. If the marginal lands within the basin have a comparative advantage, the model will underestimate the national efficiency gain. The third conceptual advantage of the RLP-PE model is the manner and detail in which future benefits are estimated. Instead of projecting future benefits on some assumed growth rate, they are calculated on the basis of separate estimates of changes in the demand for farm commodities and changes in technology which affect the yield and cost information in the model.

Three major issues or obstacles exist in converting the RLP-BP model to a RLP-PE model: (1) Adequacy of sample data of the land base to provide reliable estimates of flood control impacts on relatively small areas; (2) derivation of accurate estimates of crop yields on flood plain land under with and without flood protection conditions; and (3) determination of partial-protection crop yield increments to use in place of flood-free yield increments used in the planning model.

Sample data of the land base on which the planning model is based were found to be adequate for evaluating the effects of a single project if the flood plain to be protected includes at least 200,000 acres. The RLP-PE model can evaluate flood protection effects on smaller areas; however, supplemental information describing the land characteristics of the flood plain impact area must be obtained. The problem of deriving accurate yield estimates for downstream flood plain soils as compared to all flood plain soils in the basin, upon examination, turned out to be an insignificant problem. Comparisons between crop yields and damage factors employed for upstream and downstream areas were not sufficiently different to invalidate the use of RLP-BP basin-wide yield and cost data in conducting tests of the RLP-PE model. Even if there were unique crop yield and damage factors associated with a proposed project flood plain, this would not preclude the application of the RLP-PE model. Additional information specific to the flood plain would have to be derived from outside sources and introduced into the model as yield and cost revisions. The third conceptual difficulty was to devise appropriate means of adjusting flood-free yield estimates of the RLP-BP model to reflect the actual partial protection expected from the project. This was accomplished by applying the Corps' estimate of percent reduction in flood damages to the RLP-BP model "flood-free yield increment" and adding this "partial increment" to the existing flood-prone yield to derive the partial protection yield. This operation was completed on a reach-by-reach basis since the level of protection varies by reach.

An empirical test of the RLP-PE model was conducted, utilizing information from the RLP-BP model that was constructed for the Wabash Comprehensive River Basin Survey and data supplied by the Louisville District Office of the Corps of Engineers. The effect of adding the Big Pine-Lafayette reservoir complex to the existing six reservoirs in the Upper Wabash Basin was evaluated. This was not a feasibility study of the Big Pine-Lafayette project, but rather a test of the application of the RLP-PE model in a real situation. Only one year (1980) was selected to test the procedures for converting the RLP-BP model to a RLP-PE model. Estimates were obtained of the efficiency gains and changes in land use patterns that would be expected to result from the project.

Comparisons of the estimated production cost of achieving estimated demands for food and fiber in the Wabash Basin with and without the proposed Big Pine-Lafayette project revealed an annual saving of $218,100 as a national benefit. Associated with this efficiency gain was a land enhancement on the flood plain of 8,300 acres of land conversion and 60,200 acres cropped more intensively. In other parts of the basin, however, 9,800 acres were idled.

The significance of estimating national agricultural flood control benefits by this approach is readily seen in a comparison of estimated benefits for the year 1980 derived from the RLP-PE model, and the benefits calculated by the Corps using conventional methods. The RLP-PE model and the conventional methods provided estimated benefits of $218,100 and $510,900, respectively. Similar yield and damage reduction factors were used in both analyses. Therefore, the difference can be largely attributed to the different underlying concepts between the two approachs. The RLP estimate represents a net enhancement of land within the whole basin as farmers in the basin efficiently manage their resources to meet an inelastic demand for farm commodities. On the other hand, the Corps procedure represents a gross enhancement on the flood plain without offsetting reductions elsewhere, and an expansion of output in response to a perfectly elastic demand for farm commodities.

Calculations of production costs with and without the Big Pine-Lafayette project could be completed for 2000 and 2020, as was done for 1980, to derive point estimates of the expected efficiency gains for these years. This array of estimates could then be extrapolated over the life of the project to derive an estimate of total anticipated benefits of the project. The RLP-PE model was not applied to the 2000 and 2020 data for the Wabash River Basin to obtain separate estimates of flood control benefits for these years. However, simulated values of the 2000 and 2020 benefits were made by calculating the percentage reduction in production cost for the Big Pine-Lafayette project in 1980 and applying this percentage to the "no development" production costs of the 2000 and 2020 RLP-BP models. The set of flood control benefits, as estimated for 1980 and simulated for 2000 and 2020, were then extrapolated over the life of the project and discounted back to the present to indicate how the average annual benefits from the project could be calculated. An average annual benefit of $241,300 was obtained for the Big Pine-Lafayette project, which represent an estimate of national efficiency gains based on the RLP-PE model and the above procedures. The comparable estimate of average annual benefit by conventional methods used by the Corps is $609,500. This figure can be divided into a national efficiency gain component of $241,300 and a regional income gain component of $368,200.

Conclusions

A RLP-PE model adequately meets three of the four principal items that should be considered in an ideal flood control benefit evaluation procedure. First, it provides an estimate of the productivity change of land due to flood protection by directly estimating the damage reduction and enhancement components of the benefits. Second, the analytical framework of the model enables the benefits to be estimated from a national efficiency point of view. And, it provides an explicit method for projecting future benefits based on separate projections of future commodity demand and future resource capability (supply conditions). The model does not include any provision for estimating adverse effects of a proposed project.

Flood control benefits that arise from reduction in damage to real or personal property are not estimated by the RLP-PE model. Thus, the model does not represent a sufficient single method of estimating the total agricultural benefits that may result from a flood control measure.

As additional comprehensive river basin planning surveys are completed across the country, an expanding data base and basic RLP-BP models will be established that could be used to assist flood control project planners in formulating plans. The application of RLP-PE models to this process would provide a continuity link between the comprehensive basin plans and the subsequent proposed flood control projects. In addition, the model could be used to provide a broader display of information about the consequence of a proposed project than can be obtained from conventional agency methods.

A Composite System of Analysis

As has been noted throughout this study, both the land value and the RLP-PE models have particular strengths and weaknesses, as do the conventional flood hydrograph-flood damage estimation models. First, neither the land value or the RLP-PE model is a complete model in the sense that either could be used to estimate expected flood control benefits from all sources--particularly nonagricultural benefits. Secondly, the basin-planning type regional linear programming models (RLP-BP) are not operational for all river basins of the United States and, for the operational ones, time will be required to convert them to project evaluation models (RLP-PE). Additionally, further applications and experimentation with the land value model in other regions appears desirable. Finally, the land value and RLP-PE models have different conceptual bases and therefore yield estimates of expected benefits of different dollar magnitude that must be reconciled within an evaluation framework.

For these reasons, neither the land value or the RLP-PE model in their present state of development are viewed as capable of supplanting conventional techniques. As an alternative, a logical system of development would be to integrate both the land value and RLP-PE into a composite estimating system built around existing techniques. In this development the conventional procedures would continue to be used, largely in their present form. However, the conventionally derived estimates of the dollar magnitude of expected direct crop and non-crop agricultural damages (which provide the basis for estimating expected benefits from damage reduction), as well as gross flood plain land enhancement benefits, would be evaluated in relation to prevailing or expected land value relationships in the flood plain area to be benefited. The evaluation team should seek consistency between the land market's evaluation of flood risk and expected benefits and the estimates derived from conventional techniques (taking into account, if necessary, any market aberrations that may exist) as assurance that the resulting estimate of expected benefits can be supported by capitalization theory.

The RLP-PE model would supplement the conventional and land value analyses at several points, beginning with surveys to evaluate sites for project feasibility studies. The RLP-PE model could also be used to evaluate expected <u>net</u> land enhancement benefits and to project future flood plain growth rates. Primarily, however, the RLP-PE would provide estimates of expected national efficiency gains from the project. The combination of RLP-PE estimated national efficiency gains and the conventionally estimated agricultural crop flood control benefits would provide a basis for distinguishing the efficiency component and the regional income component of the conventionally estimated benefit.

This synthesized model, at the present level of development, is presented as a goal for eventual development. None of the suggested modifications require extensive changes in currently used techniques, and the modifications could be adopted sequentially as they are further tested and developed.

APPENDIX A

Flood Control Plus Optimal Drainage Alternative

In a previous section (p. 50-55), the effects of the "flood control only" alternative were evaluated. A second alternative was evaluated, based on the assumption that drainage would be required on inadequately drained flood plain lands to realize increased crop yields and land conversion that is anticipated as a result of flood protection. On-farm drainage costs were included to represent the additional costs that would be borne by farmers if they are to realize higher yields on the protected land in the flood plain.

Efficiency Gains

Treating flood control and drainage as a joint development on project affected lands resulted in an efficiency gain in 1980 of $201,200 from Flood Control 1 (Table A1). An additional efficiency gain of $109,300 would be realized with the increased flood protection afforded by the Big Pine and Lafayette reservoirs. The efficiency gain under the flood control plus drainage assumption was only half as large as was estimated under the flood control only assumption. This was due to the fact that additional on-farm drainage costs are incurred which tends to increase unit costs. In some cases, unit costs for some "flood control plus drainage" soil groups were actually higher than unit costs for the "no development" alternative on the same soil groups. This implies that the provision of flood protection to some inadequately drained land does not automatically result in increased crop yields and/or land conversion. Including the cost of draining the land reduces the relative comparative advantage of this land. Other soil groups in the Basin can be used to meet the projected output level at less cost than if drainage costs are incurred in order to realize the higher potential crop yields from flood protection.

Changes in Land Use

The "flood control plus drainage" alternative would reduce the amount of cropland required to meet the anticipated 1980 agricultural demands (Table A2). The addition of the Big Pine-Lafayette project to the Flood Control 1 reservoirs under "flood control plus drainage" conditions would reduce cropland requirements by 2,572 acres. No additional lands would be converted to higher value uses, and only 4,872 acres would be cropped more intensively. In addition 2,575 cropland acres would be idled throughout the Basin. These changes in land use were less than the changes under the "flood control only" assumption, because of the higher unit costs on flood plain lands under the joint development assumption. The corresponding land use changes under the "flood control only" assumption were as follows: (1) Reduction in basin-wide cropland--1,505 acres; (2) idle flood plain to cropland--8,293 acres; (3) flood plain cropped more intensively--60,201 acres; and (4) basin-wide cropland idled--9,798 acres.

Table A1.--Effect of Flood Control plus Optimal Drainage Alternatives on Agricultural Production Costs, Wabash River Basin, 1980

Status of flood protection	Total on-farm costs	Incremental difference	Incremental change
	Dollars	Dollars	Percent
No development	$471,136,200	--	--
Flood Control 1 a/	470,935,000	$201,200	.043
Flood Control 2 b/	470,825,700	109,300	.023

a/ Flood control plus optimal drainage of project area flood plain lands with six reservoirs - Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe and Mansfield.

b/ Flood control plus optimal drainage of project area flood plain lands, with eight reservoirs - Flood Control 1 plus Big Pine and Lafayette.

Table A2.--Adjustments in Land Use due to Big Pine-Lafayette Reservoirs under Flood Control plus Drainage Assumption, Wabash River Basin, 1980

Category	Flood Control 1 a/	Flood Control 2 b/
	Acres	Acres
Flood Plain:		
Total acreage	823,350	540,400
Cropland	654,687	412,814
Land Use Adjustments		
Flood Plain:		
Idle to cropland	11,978	0
Cropped more intensively	180,339	4,872
Basin-wide		
Cropland reduction	7,929	2,572
Cropland to idle	9,469	2,575

a/ Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mills, Monroe, and Mansfield reservoirs.

b/ Flood Control 2 includes Flood Control 1 plus Big Pine and Lafayette reservoirs.

APPENDIX B

Wabash Basin Linear Programming Model

The basic analytical tool is a regional cost minimization LP model. It was utilized to determine total on-farm costs of production and associated land uses in 1980, as required to meet specified Wabash River Basin demands for the major agricultural commodities. These demands are expressed in terms of bushels for wheat and soybeans and feed units for the other major field crops.

(1) Minimize $Z = C_1 X_1 + C_2 X_2 + \ldots + C_n X_n$

where Z = total on-farm production cost excluding any payments to land and management.

Subject to: $X_1, X_2, \ldots, X_n$

$C_1, C_2, \ldots, C_m$ = costs of production per acre for various potential $X_1, X_2, \ldots, X_n$ land uses.

$X_1, X_2 \ldots, X_n$ = acres of various land uses: by crops, land capability unit groups (LCU's), land resource areas (LRA's), economic subareas, and water development activities. (level of various activities)

The commodity demands for each of the nine specified commodity groups was specified in the following form:

(2a) Feed grains (corn, oats, and barley) 1/ : $a_{11} X_1 + a_{12} X_2 + \ldots + a_{1n} X_n \geq d_1$ = 290,912,416 feed units 2/

(2b) Barley: $a_{21} X_1 + a_{22} X_2 + \ldots + a_{2n} X_n \geq d_2$ = 460,080 feed units 3/

(2c) Wheat: $a_{31} X_1 + a_{32} X_2 + \ldots + a_{3n} X_n \geq d_3$ = 37,986,000 bushels

(2d) Soybeans: $a_{41} X_1 + a_{42} X_2 + \ldots + a_{4}n X_n \geq d_4$ = 150,764,000 bushels

(2e) Silage: $a_{51} X_1 + a_{52} X_2 + \ldots + a_{5n} X_n \geq d_5$ = 7,772,000 feed units 4/

1/ Corn, oats, and barley were permitted to compete for meeting the total feed grain demand.
2/ One bushel of corn provides .56 feed unit.
3/ One bushel of barley provides .43 feed unit.
4/ One ton of silage provides 4.0 feed units.

(2f) Alfalfa hay: $a_{61} X_1 + a_{62} X_2 + \dots + a_{6n} X_n \geq d_6$ = 22,417,274 feed units 5/

(2g) Oats: $a_{71} X_1 + a_{72} X_2 + \dots + a_{7n} X_n \geq d_7$ = 6,336,000 feed units 6/

(2h) Other hay: $a_{81} X_1 + a_{82} X_2 + \dots + a_{8n} X_n \geq d_8$ = 760,000 feed units 7/

(2i) Pasture: $a_{91} X_1 + a_{92} X_2 + \dots + a_{9n} X_n \geq d_9$ = 39,000,000 feed units 8/

Where: $a_{11}, a_{21}, \dots, agn$ = amount of product (feed units or bushels) supplied from a unit of activity (harvested acre).

$d_1, d_2, \dots, d_9$ = commodity demand for each of the 9 specified commodity groups.

Land availability restraint:

(3)
$$
\begin{aligned}
b_{11} X_1 + b_{12} X_2 + \dots + b_{1n} X_n &\geq r_1, \\
b_{21} X_1 + b_{22} X_2 + \dots + b_{2n} X_n &\geq r_2 \\
&\vdots \\
b_{s1} X_1 + b_{s2} X_2 + \dots + b_{sn} Xn &\geq r_s
\end{aligned}
$$

Where: $b_{11}, b_{21}, \dots, b_{sn}$ = acreage of land required to supply one harvested acre for the activity.

$r_1, r_2, \dots, r_s$ = amount of land available for each set of activities utilizing the same land. Combinations of (1) no additional water and related land development and (2) flood protection were permitted to compete for specified land availability in the solution.

Subarea minimum restraint:

(4)
$$
\begin{aligned}
e_{11} X_1 + e_{12} X_2 + \dots + e_{1n} X_n &\geq w_1 \\
&\vdots \\
e_{61} X_1 + e_{62} X_2 + \dots + e_{6n} X_n &\geq w_v
\end{aligned}
$$

Where: $e_{11}, \dots e_{vn}$ = yield of activity from one acre toward minimum production requirement for each economic subarea for crops.

$w_1, w_2, \dots w_v$ = minimum production requirements for each subarea.

5/ One ton of alfalfa hay provides 11.0 feed units.
6/ One bushel of oats provides .29 feed unit.
7/ One ton of other hay provides 8.0 feed units.
8/ One animal unit day provides .15 feed unit.

Computer Analysis

The "no development" problem was comprised of a matrix containing 1,069 rows and 4,893 columns. The LP problem was run using the IBM System 360, Model 65/75 computer, and other facilities at McDonnell Automation Company in St. Louis, Missouri. The least cost solution for the basic or "no development" solution was obtained in approximately 40 minutes. The revised land and resource coefficients for the four flood control alternatives were entered as additional rows and columns to the existing matrix. This included 43 rows and 645 columns as well as 43 right-hand-side revisions to incorporate flood plain lands affected by the eight reservoirs. Using the IBM revise procedure, the four solutions were obtained in a total of ten minutes of computer time or an average of 2.5 minutes per revision.

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13. ABSTRACT

This report is devoted to evaluating alternative methodologies to the frequency-damage procedure for estimating agricultural crop flood control benefits. An extension of the Economic Research Service Regional Linear Programming model to the case of project analysis has been made. The RLP model operates in the same way as a basin wide firm and estimates the change in production costs (out of pocket cost) as flood protection (and drainage) measures are provided. Efficiency benefits are equal to decreases in production costs, since output is held constant. Critical assumptions and several major empirical problems encountered during the study are discussed.

Finally, a synopsis of the utility of the land value approach, the regional linear programming approach and the frequency-damage approach is made in Part IV.

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