APPLICATION OF LINEAR PROGRAMMING TO THE EVALUATION OF AGRICULTURAL FLOOD CONTROL PROJECTS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

DANIEL GLENN PIPER

1972

This is to certify that the

thesis entitled

Application of Linear Programming to the Evaluation of Agricultural Flood Control Projects

presented by

Daniel Glenn Piper

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural Economics

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Date May 18, 1972

O-7639

ABSTRACT

APPLICATION OF LINEAR PROGRAMMING TO THE
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By

Daniel Glenn Piper

This study investigates the feasibility of estimating agricultural flood control benefits using a modified river basin linear programming (LP) projection model. The regional LP basin planning model (RLP-BP) employed in this study was previously used to evaluate the potential for additional drainage, flood control, and irrigation development in the Wabash River Basin. The modification of the Wabash RLP-BP was undertaken in order to evaluate the anticipated effects of six existing and two proposed Corps of Engineers (COE) reservoirs. The resulting LP model, hereafter referred to as the regional linear programming project evaluation model (RLP-PE) was utilized to evaluate the anticipated effects of these projects on the Wabash Basin agricultural economy in 1980.

The RLP-PE model has the capability of evaluating on-farm cost savings and land use changes which are anticipated to be induced by the Corps flood control projects. This model was formulated to provide estimates of the cost of producing a specific output from

the Wabash Basin in 1980 under conditions of present flood hazards and with flood protection afforded by the Corps' reservoirs. 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 Corps' reservoirs. The analysis can be repeated for each target year in the river basin survey (e.g., 1980, 2000, and 2020), to obtain point estimates of the expected future benefits of the projects. By extrapolating the estimated agricultural production cost savings over the project life and discounting them back to a present value, an estimate is derived of the agricultural crop benefit component of the proposed flood control project.

Compared to current Federal Agency procedures for estimating crop flood control project benefits, the RLP-PE model offers three main conceptual benefits. First, this 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 project's efficiency gains represent savings to the nation by meeting its food and fiber at less cost. Second, the RLP-PE provides a means by which the net enhancement of the project can be estimated. Improving project protected flood plain productivity as a result of flood protection will increase production there and, in the long run will be offset by loss of production elsewhere. The RLP-PE calculates these offsets and thus estimates the net enhancement effect. Third, future benefits are projected on the basis of separate estimates of changes in the demand for farm commodities and changes in technology. This contrasts with the Federal Agency practice of simply projecting future benefits on the basis of some assumed growth rate.

An empirical test of the RLP-PE model was conducted. The effect of adding the Big Pine and Lafayette reservoirs to the existing six Corps reservoirs in the Wabash Basin was evaluated. 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 projects.

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A THESIS

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

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1972

ACKNOWLEDGMENTS

The author would like to express sincere appreciation to Dr. A. Allan Schmid who served as chairman of both the guidance and thesis committees. His pertinent questions, suggestions, and constructive criticisms have improved the manuscript significantly. Comments by other committee members were also helpful, that is, by Drs. Larry Connor, Lawrence Libby, and Gail Updegraff.

The author would like to express appreciation to Dr. Roger W. Strohbehn who provided overall guidance to the initial phase of the study while Leader, North Central Resource Group, Economic Research Service (ERS). The special assistance of Robert F. Boxley, Jr., a co-worker during the early period, is also acknowledged. Carmen Sandretto, ERS leader in the Wabash River Basin study, was particularly helpful in modifying the basin planning model data and in interpreting the computer results.

A debt of gratitude is due Dr. Melvin Cotner, Director of the Natural Resource Economics Division (NRED), ERS, and William A. Green, Assistant Director for Water Planning Activities, who provided administrative and technical support as well as financial arrangements for the study.

Within the Corps of Engineers, the suggestions and comments of Nathan Back, formerly Chief, Institute for Water Resources, and his staff are appreciated. Russell Whistler and his staff in the Louisville District Corps office were helpful in providing the flood loss and project data.

The author thanks John Hostetler for diverting the resources of his staff to allow completion of the final phase of the undertaking. Mrs. Priscilla Prophet assisted in all computer programming done at Michigan State University. Waldon Miller aided greatly in providing the author with good background information regarding the basis for the Wabash Basin data used in the study. The author thanks Miss Linda Farrell and Mrs. Joan Roby for their assistance in typing drafts of the manuscript. These people, as well as the author, are on the staff of the NRED, ERS, USDA at East Lansing.

Finally, the encouragement and understanding of my wife, Judith Ann, and children Mark, Mary Esther, and Rosann are deeply appreciated. Without their support and sacrifice, this work would not have been completed.

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CHAPTER I

INTRODUCTION

The Problem

The Flood Control Act of 1936 set forth the criterion for evaluation of proposed public expenditures in water resource investments. In this Act, the specification was made that benefits must exceed costs for a flood control project "to whomsoever they may accrue" in order for a project to have economic feasibility and thus to be eligible for authorization by Congress. The interpretation of this Act by the Army Corps of Engineers and other public agencies responsible for construction of flood control projects has been that a national economic efficiency analysis of each proposed project be conducted. In order to receive favorable consideration by Congress, the present value of the expected benefit stream must exceed the present value of the expected cost stream. If the net present value is positive, the project is considered efficient and it is assumed that national income will increase if the project is undertaken.

Federal investment in flood protection and prevention has amounted to more than $7 billion since the Flood Control Act of 1936.

The current Federal expenditures are approximately $500 million per year and the annual rate of investment is increasing.[1]

Agricultural flood control benefits have been and will continue to be important in the benefit-cost justification analysis by federal agencies. The assumption made for individual project evaluation is that flood protection afforded to the small impact is too small to have any appreciable effect on product prices. Although this assumption may be reasonable for any single project taken separately, it cannot be expected to be valid for the summation of all projects in a region or nation.

Three important characteristics of U.S. agriculture seem to warrant a departure from federal agencies use of completely elastic demand (assumption of no price effect as supply increases because of the project). First, the various agricultural regions of the United States compete with one another in a common market characterized by very inelastic demands. Second, the various regions produce crops in common, however, the regions differ in comparative advantage due to differences in soil, climate, and extent to which man-made productivity investments have been made in altering natural production characteristics. Examples of the latter include drainage, irrigation, and flood control. Third, the U.S. agricultural economy is characterized by excess capacity. Acreage allotments and other restrictions

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[1]U.S., Congress, House, Task Force on Federal Flood Control Policy, A Unified National Program for Managing Flood Losses, H. Doc. 465, 89th Cong., 2nd sess., 1966, p. 3.

are necessary in order to prevent even larger price-depressing surpluses.

Under these conditions, the issue arises as to whether the public investment in flood control can be justified relative to other uses of public funds. Will further development of flood plain lands have a positive benefit to society? One must also evaluate the distributional consequences of flood control investment. Will the creation of more highly productive flood plain land in one region create offsetting income losses in other parts of the region or in other regions? Clearly an empirical procedure for evaluating some of these questions is needed in order to resolve the above issues.

Objectives and Scope of the Study

Objectives

The primary purpose of this investigation 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 Army Corps of Engineers. A secondary objective is to assess the distributional effects of flood control projects, identifying the gainers and losers, if any, from this public investment.

The Corps of Engineers and the other federal agencies responsible for evaluating water resource investments have employed economic analysis for years. This economic analysis, however, has been confined to the single objective of maximizing gross national product. This approach has been faulted by many economists because it fails to consider the distributional effects on other parts of the system, whether the system be the region or the nation as a whole. Bromley, Schmid, and Lord[1] recently pointed out the fallacy of relying exclusively on the project-by-project analysis conducted by the Corps and other water resource agencies:

> The sum total of many small decisions which society makes may produce results which carry great significance for the quality of all of our lives. Often such "system effects" go unrecognized . . . For example, continued reservoir development for hydropower production, flood control, navigation, water supply, and . . . recreation may seem quite justifiable when examined on a piecemeal project-by-project basis.[2]

In their work, Bromley, Schmid, and Lord imply that a more systematic approach to evaluation of flood control investment is a worthwhile undertaking. This view is shared by Knetsch[3] in a 1969 paper:

> Analysis--program planning, budgeting, and benefit-cost-is essentially an aid in determining efficient allocation and investment of public funds. Comparison of alternative means of achieving given ends is an integral part of such analysis. . . . In many cases the principals for determining gains and losses have not been correct nor defined in as meaningful terms as might be possible.[4]

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[1]Daniel W. Bromley, A. Allan Schmid, and William B. Lord, Public Water Resource Project Planning and Evaluation: Impacts, Incidence, and Institutions (Madison, Wisc.: Center for Resource Policy Studies and Programs, 1971).

[2]*Ibid.*, p. 2.

[3]Jack L. Knetsch, "Economic Analysis in Natural Resource Programs," The Analysis and Evaluation of Public Expenditures: The PPB System, Vol. III (Washington, D.C.: U.S. Government Printing Office, Joint Economic Committee, 1969).

[4]*Ibid.*, p. 1096.

The RLP model which will be evaluated in this application will offer the advantage of systematically evaluating the regional impacts of two flood control projects. In this study, the RLP model will not evaluate the effect of alternative public or private water resource investments. Nor will other possible ways of achieving the same regional agricultural output be evaluated. For example, it is possible to evaluate the effect of utilizing additional fertilizer in the Basin to achieve the same level of output at perhaps lower societal costs than in the case of flood control investment.

Thus, the rather limited objective of this application will be to access the RLP as an alternative framework for agricultural flood control benefit estimation. The RLP possesses the advantage of being a systems analysis, with system being defined in the sense that it is

> 1) a portion of the universe around which is drawn an imaginary boundary for purpose of studying what is enclosed with this boundary; and 2) a medium which relates a cause to an effect, or an input to an output.[1]

A further objective of the study is that the theoretical and empirical advantages associated with the application of an RLP model for evaluating consequences of flood control be documented for the benefit of researchers applying other systems models to water resource planning in the future.

Research Background and Area of Study

This research was conducted under contract between the Corps of Engineers, U.S. Department of the Army (COE), and the Natural

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[1]John A. Dracup, "Systems Analysis, A Substitute for Planning," Evaluation Processes in Water Resources Planning (Urbana, Ill.: American Water Resources Association, 1970).

Resource Economic Division (NRED), Economic Research Service (ERS), U.S. Department of Agriculture as a part of a larger study of alternative procedures for the evaluation of agricultural flood control benefits.[1]

The Wabash River Basin was selected for empirical analysis for administrative convenience and because of considerations involved in other parts of the overall study.

The Wabash RLP model was employed in the on-going Wabash River Basin Type II comprehensive study. The model is a relatively large minimum-cost linear programming analytical model, having a matrix that is about 2,000 rows by 10,000 columns. Since the available core storage at the Michigan State University was insufficient at the outset of the Wabash Type II study in 1966, the decision was made by NRED to utilize the McDonnell Corporation IBM 360-75 computer at St. Louis, Missouri.

Three analytical techniques have been utilized by the NRED in conducting river basin studies. The first major study, the Texas River Basins completed in 1961, did not use a formal mathematical model but instead relied on trend analysis and crop budgeting techniques. The dominant analytical technique, the least cost linear programming model (LCLP) has been utilized by NRED in seven of the thirteen Type I

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[1]Robert F. Boxley, Jr., "The Relationship Between Land Values and Flood Risk in the Wabash River Basin" (unpublished Ph.D. dissertation, Michigan State University, 1969). Institute for Water Resources, Corps of Engineers, Department of the Army, "The Relationship Between Land Values and Flood Risk in the Wabash River Basin," IWR Report 69-4, Alexandria, Virginia, December, 1969.

framework studies.[1] Input-output analysis was used in two Type I studies and simple trend analysis was used in the remaining four Type I studies. The use of simulation models in river basin analysis was also explored for NRED by Battelle Memorial Institute of Columbus, Ohio. The use of simulation was rejected by NRED due to the finding of estimated costs of $500,000 to develop a workable river basin model.[2]

Although input-output and trend analysis continue to be used by NRED in river basin projections, the LCLP remains the dominant analytical technique. Six of the sixteen Type II studies[3] conducted by NRED utilized the LCLP. The author made a survey of twenty-nine NRED Type IV studies[4] and found the LCLP being utilized in eighteen of these completed or ongoing efforts.

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[1]According to USDA Soil Conservation Service Memorandum-9 (Rev. 2), Type I studies are defined as "comprehensive framework studies which will furnish a general appraisal of overall water and related land resource development needs and serve as a guide to further detailed planning within the Regions."

[2]John E. Hostetler, "Sensitivity Analysis of Selected Linear Programming Assumptions: A Study of the Agricultural Projections in River Basin Research" (unpublished Ph.D. dissertation, Michigan State University, 1970), pp. 5-6.

[3]According to SCS River Basin Memorandum-9 (Rev. 2), June 13, 1968, Type II surveys "are studies of a river basin or other area in greater detail then Type I studies. They define and evaluate projects in sufficient detail to comprise a basis for authorization or implementation of those Federal and federally assisted projects to be initiated in the next 10 to 15 years."

[4]According to SCS River Basin Memorandum-9 (Rev. 2), Type IV studies "usually are State sponsored surveys of water and related land resources for all or part of a State or a river basin in which one or more Federal agencies cooperate with the State or each other."

The nature of the LCLP utilized in NRED river basin studies has continued to evolve over time from relatively small-sized models with few activities to large scale, highly constrained, multiple activity models. This is due to the advent of improvements in both computer hardware (physical facilities) and software (computer programming techniques). A typical example of an early LCLP model, the Grand River Basin Type II study had a matrix of 212 rows by 554 vectors. This was about the maximum size matrix which could be run on the computer at Michigan State University in the mid-1960's.

Late LCLP models such as the Upper Mississippi, Missouri, and Wabash studies had considerably larger matrices. The large LCLP models enabled the inclusion of more detailed soils information as well as the simultaneous consideration of more resource activities. At the same time, there also appeared two different approaches to basin projections using the more complex LCLP models. The North Central Resource Group in East Lansing continued in the pattern established in the Ohio River Basin Type I study. This approach minimized the number of constraints to economic efficiency in the agricultural economy in future target years. Hence, their projections were based primarily on the assumption that major shifts in water and related land use were possible, depending upon the comparative cost advantages of the various agricultural lands. By contrast, the Great Plains Group in Lincoln, Nebraska, carefully constrained their LCLP to allow only relatively small deviations from the base period situation (1964). They made the assumption that future agricultural production patterns will likely reflect relatively minor deviations from current patterns.

General Characteristics, Wabash River Basin

The Wabash River Basin comprises the southern two-thirds of Indiana, southeastern one-sixth of Illinois, and 319 square miles of two Ohio counties. The Wabash River is the second largest tributary of the Ohio River.

The valley of the Wabash River is flat and wide, and its flood plain is a highly agriculturalized area. The result is that floods are frequent and destructive. The principal cause of floods on the river is excessive rainfall.

The Wabash Basin has been surveyed by the federal government in 1932, 1944, and in the 1960's, the latest comprehensive study drawing to a close in June 1971.

Six federally-financed Corps reservoirs in conjunction with over 145 named public and private levees provide a moderate level of protection against the frequent, fairly small floods. Although ten additional Corps reservoirs have been authorized, to date the Patoka reservoir is the only one currently under construction. (See Appendix A for a more complete discussion of Wabash Basin general characteristics.)

Selection of Study Area

In selecting the Wabash Basin projects to evaluate in the empirical application, four primary criteria were considered: (1) data availability, i.e., existence of recent usable hydrological and flood damage data; (2) project impact area sufficiently large; (3) significant project crop loss reduction; and (4) land conversion possibilities.

After evaluating project evaluation data at the Louisville District Corps office, the author, in conjunction with Dr. Strohbehn and Dr. Boxley, selected the Big Pine and Lafayette reservoirs. These authorized but not yet constructed multiple-purpose reservoirs were found to best satisfy all four selection criteria. (See Appendix B for a more complete discussion of the selection of the study area.)

Wabash River Basin and Economic Sub-areas

Figure 1

CHAPTER II

ATTRIBUTES OF BENEFIT EVALUATION METHODOLOGY

In an earlier report of the ERS to the Corps regarding the flood control benefit evaluation study[1] four principal attributes to consider in an ideal flood control benefit evaluation procedure were presented. The attributes included: (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. A discussion of the relevance of this list of attributes follows.

Flood Plain Resource Productivity

The productivity 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 re-planting costs. Increased productivity of inputs used on flood plain lands may result by reducing or eliminating direct loss of agricultural

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[1] Institute for Water Resources, Department of the Army, Corps of Engineers, IWR Report 71-4, July, 1971.

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.

Viewpoint Taken

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 should be pointed out that distinguishing between these two viewpoints is an important one. This is due to the fact that societal benefits may not necessarily equal the sum of 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 a newly-protected flood plain is inelastic. In the case of most agricultural commodities, 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.

Projection of Future Benefits

In addition to determining estimated benefits under current conditions, an ideal benefit estimation procedure would evaluate whether 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.

Under existing agency procedures, the Corps of Engineers projects the prospective "normal" state of development without the project in order to provide a basis for modifying the basic current average annual damages to determine "prospective average annual damages over the life of the project."[1] This procedure provides an estimate of future growth that is expected to occur in the absence of the project. This is in addition to enhancement benefits which are realized only with the project. In the Wabash Basin Corps Interim Reports, future growth was estimated over a 100-year period.

Adverse Effects of Proposed Projects

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

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[1]U.S. Army, Corps of Engineers, "Survey Investigations and Reports: General Procedures," Engineering Manual EM 1120-2-101 (includes change 16), October 12, 1964, pp. 50-50b. (Mimeographed.)

periods, resulting in impaired drainage to adjoining flood plain land.[1]

Let us now turn to a brief discussion of some of the problems associated with the projection of future benefits and to a consideration of an alternative analytical framework for making projections.

Benefit Projections and Alternative Models

In his 1965 book, Ruttan[1] provides not only a new methodology for making agricultural projections, but also a critique of current projections methodology. Ruttan correctly points out that most projections of resource use, including those of USDA, are made on the basis of the quantity of inputs required to support some projected level of final output. Terming these as "requirements approaches," Ruttan maintained that they are inflexible procedures which fail to consider

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[1] The Patoka Reservoir, a partially-constructed Corps of Engineers multiple-purpose reservoir in southern Indiana will have this type of adverse effects. Due to a large amount of reservoir storage capacity and limited channel capacity because of a narrow and crooked channel downstream, it will take 90 days to deplete the flood waters of a 15-year recurrence interval storm if only bankful conditions are to be observed. The recreation benefits are ten times those from flood protection during the summer season. Since the trade-off in benefits favors recreation, a faster drawdown will be used by the Corps so that the seasonal (recreational) pool can be obtained as quickly as possible. The Corps in this case will buy more easement rights from flood plain land owners so that the scheme of reservoir operation can proceed in the way which will minimize drawdown time. (Based on a May 8, 1968, telephone conversation with Russell Whistler, Basin Planning Branch, Louisville District Corps office.)

[2] Vernon W. Ruttan, The Economic Demand for Irrigated Acreage: New Methodology and Some Preliminary Projections, 1954-80 (Baltimore: Johns Hopkins Press, 1965).

the capacity for resource and product substitution in the U.S. agricultural economy. In making his case, Ruttan states that

> The elasticity with which the regional distribution of farm output and factor input combinations respond to economic forces leads to considerable dissatisfaction with the requirements framework employed in most of the regional resource use projections of the decade and a half . . . the use of the requirements framework, in its simplest form, involves the implicit assumption that resource combinations and consumption patterns are technologically, institutionally or psychologically determined and are inelastic with respect to changes in the prices of resource inputs relative to each other, consumption items relative to each other, or resource inputs relative to consumption items.[1]

Ruttan further states that the impact of altering the distribution of agricultural activity can be modified by public investment in one region but not in another region:

> The effects of expansion or contraction in demand or of changes in comparative advantage in production in one agricultural region are transmitted to other regions.[2]

Since the RLP is based on the "requirements approach" framework, it too is subject to the criticisms of Ruttan. Let us now compare Ruttan's suggested methodological improvements using the Cobb-Douglas formulation with the RLP approach.

In an effort to overcome the limitations of the requirements approach, Ruttan suggests that an ideal model consist of the following: (1) factor supply functions for all resources and other inputs, (2) transportation rates or cost functions for inputs and final products, (3) the geographic location of inputs and markets, (4) production functions relating input levels to output levels for each product, and (5) demand functions for each product.

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[1] _Ibid._, pp. 16-17. [2] _Ibid._, p. 16.

Ruttan concedes that more sophisticated forms of the "requirements" approach (e.g., linear programming) may overcome many of the limitations. On the other hand, he points out that their

> Almost insatiable appetite for data becomes a problem so that such applications have, in the past largely been confined to relatively few activities and to limited geographic areas. Empirical studies which have attempted to deal with a complex set of activities for major geographic areas have typically employed what might be termed "aggregate budgeting" rather than the more sophisticated programming techniques.[1]

Ruttan also admits that his "elasticity" approach is "limited by an opposite deficiency [in that] models currently developed have not been able to absorb as much data as many analysts would like to incorporate into their models." Ruttan refers to the work of Zvi Griliches[2] in saying that for these elasticity models

> Statistical models which include *large numbers of variables* tend to be limited by *lack of significance* of the elasticity coefficient; those which include *few variables*, by *biased* elasticity *coefficients*.[3] (Italics mine.)

Ruttan presented three elasticity models. His *productivity model* "is developed to permit a comparison of current resource productivity and cost levels."[4] His *demand* and *equilibrium* models are "developed to facilitate projection of future farm output growth and factor input levels."[5] In distinguishing between his last two models, Ruttan notes that

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[1] *Ibid.*, pp. 18-19.

[2] Zvi Griliches, "Specification Bias in Estimates of Production Functions," *Journal of Farm Economics*, XXXIX (February, 1957), 8-20.

[3] *Ibid.*, p. 19. [4] *Ibid.* [5] *Ibid.*

> The basic distinction lies in the determination of output growth in each region. In the demand model the regional output levels are determined from outside the system, while in the equilibrium model they are determined simultaneously along with factor input levels.[1]

Regarding usefulness in making projections, only Ruttan's last two models appear to be relevant in comparison with the RLP model.

The Ruttan demand model contains five equations. It is made operational by the inclusion of a hypothetical supply function for irrigated land and of a procedure for determining regional production requirements when given a national production requirement. By deriving a regional output requirement, the demand model can be solved to obtain the number of acres of irrigated land in each region which equates the annual marginal value productivity of irrigated land with a specified annual rate of return which should equal the annual cost of bringing an acre of irrigated land into production and producing a crop on it in each region. When this happens, interregional equilibrium is attained.

The demand model contains some serious deficiencies. It assumes, in common with the "requirements approach," that regional demand in a period is inelastic with respect to price. The second deficiency is that it embodies the concept of a perfectly elastic supply of homogeneous irrigation land. The third shortcoming is that it contains only a historical production function. Fourth, the model traces out a "demand curve" by setting the acreage of irrigated land at alternative levels and solving for the marginal value productivity of irrigated land consistent with this specified output level. This

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[1] Ibid.

"demand curve" is unusual because changes in output in response to changes in the price of irrigated land are not permitted. This is not only unrealistic, but it seems that this is yet another requirement model with a pre-ordained inelastic demand for output.

The equilibrium model differs from Ruttan's previous two in that the implicit assumption that current operating expenses are a costless input is replaced by the explicit inclusion of a supply function for that mix of inputs. In addition, regional output requirements are no longer derived from an exogenously determined national requirement but are generated as an optimum by the model itself. Hence, it is the only Ruttan model not employing the requirements approach. Unfortunately it is also the one in which Ruttan has the least faith as a projection.[1]

Let us now summarize some of the deficiencies of the Ruttan models:

1. None of the models improve on the "requirements" assumption of inelastic regional demand functions. All demand functions, both national and regional, are assumed to be price inelastic.

2. The interregional competition problem is ignored (as does the RLP).

3. The production function is still static and historically based (as in the RLP).[2]

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[1] Ibid., p. 25.

[2] Ibid., pp. 78-79.

4. The supply function for land is both perfectly elastic and unconstrained. Even if the available irrigation land is assumed to be completely homogeneous within a region, there will still be a finite and possibly limiting supply of it.

In conclusion, Ruttan's study provides an excellent critique of previous attempts at projection in the water and land use field. His models represent an effort to overcome many of the objections found in linear programming. In the end, however, the author concludes that Ruttan's models do not compare favorably with mathematical models such as the RLP which have the capability of bringing more information to bear upon the problem of determining the projected need for water resource investment. Given that a new generation of computers and software have evolved since Ruttan's 1965 analysis, his objections to LP seem far less powerful than previously. From the standpoint of the planners a rational LP model, although complex, is probably easier to conceptualize than Ruttan's three models. The LP models have the further advantage of evaluating many resource development alternatives simultaneously, a feature notably lacking in Ruttan's models.

In this regard, the advantages of the RLP model will be discussed in the next chapter in the section entitled "Selection and Features of Linear Programming."

Objectives of Water Resource Development

In ERS's report to the Corps,[1] but not reported in the final Corps report, IWR 69-4,[2] Boxley argues that "benefits derived from providing flood protection to agricultural lands are efficiency gains." gains."[3] Boxley reasons that the Green Book[4] implies that the efficiency criteria is the underlying rationale for water resource investments:

> The objective of economic analysis in planning river basin and watershed programs is to provide a guide for effective use of the required economic resources, such as land, labor, and materials, in producing goods and services to satisfy human wants by determining whether economic resources would be the case without the project.[5]

Boxley asserts that an efficiency gain is realized "if, as the results of water resource development, either more goods or services are obtained with the same resources, or the same goods and services are obtained from fewer resources than would be required in

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[1] U.S., Department of Agriculture, Economic Research Service, Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, Vol. I, edited by R. F. Boxley, Jr. (Washington, D.C.: Government Printing Office, August, 1969), 201 pp.

[2] Institute for Water Resources, IWR Report 69-4, December, 1969.

[3] U.S., Department of Agriculture, Flood Control Benefits, p. 8.

[4] Subcommittee on Evaluation Standards, Report to the Inter-agency Committee on Water Resources, Proposed Practices for Economic Analysis of River Basin Projects (Washington, D.C.: Government Printing Office, May, 1958).

[5] Ibid., p. 5.

the absence of development."[1] To this he added the third case that efficiency gains also result if:

> A greater level of output is obtained with fewer productive resources than would have been required in the absence of protection.[2]

As noted in the previous section on "attributes of benefit evaluation," two viewpoints from which to evaluate are indicated. First, the national viewpoint or the viewpoint of society as a whole. Second, the viewpoint of a specific group directly or indirectly affected by a public water resource investment, for example, flood plain landowners.

Boxley argues that "there seems little doubt that the appropriate viewpoint should first be the national viewpoint [since] . . . this is apparent in the many charges to compute 'benefits to whomsoever they may accrue' that can be found in many government documents, as this passage from the Green Book illustrates"[3]

> A summation of project effects, beneficial or adverse, to whomsoever they may accrue, in terms of market values would approach full coverage from a public viewpoint if allowance could be made in the summation for all transferences, cancellations, and offsets; i.e., values that are realized by one individual or group at the expense of some other individual or group.[4]

Let us now turn to the effect of adopting efficiency gains in conjunction with taking the viewpoint of society as a whole (national viewpoint).

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[1]U.S., Department of Agriculture, Flood Control Benefits, Vol. I, p. 6.

[2]Ibid., p. 8.

[3]Ibid., p. 7.

[4]Subcommittee on Evaluation Standards, River Basin Projects, May, 1958, p. 6.

Output Valuation Issues

The key issue regarding output valuation turns around the question of whether flood control projects will displace other firms' outputs or whether output will increase. If the former, we need not concern ourselves with constructing a demand curve but only satisfy ourselves that the willingness of consumers to pay is at least as large as without project costs.

The appropriate output valuation concept hinges on whether or not nonmarginal change is implied by public investment in the project. As discussed by Schmid, there is a vast difference between marginal changes and nonmarginal changes. Marginal change is concerned only with adjustments at the margin whereas "major large-scale water development projects . . . and whole programs of development . . . involve a number of projects over a period of years of such a magnitude as to have a nonmarginal effect on supply and thus on prices."[1]

The three cases under which efficiency gains are obtained noted in the previous section related to three elasticity of demand conditions for the output changes resulting from flood control or other water resource investment.

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[1] A. Allan Schmid, "Water Resource Development: Public and Private Investment," in Opportunities for Regional Research on Water Resources Problems, ed. by D. T. Massey and G. D. Rose (Iowa City: University of Iowa, Agricultural Law Center, College of Law, 1968), p. 62.

Case	Elasticity of Demand Condition[1]
a. Fewer productive resources required to produce same level of agricultural output.	a. Completely inelastic demand for agricultural products. (vertical demand curve).
b. Same productive resources yield a greater level of output.	b. Completely elastic demand for agricultural products (horizontal demand curve).
c. Greater level of output is obtained with fewer productive resources than would have been required in the absence of protection.	c. Downward sloping demand curve somewhere between slope of cases (a) and (b).

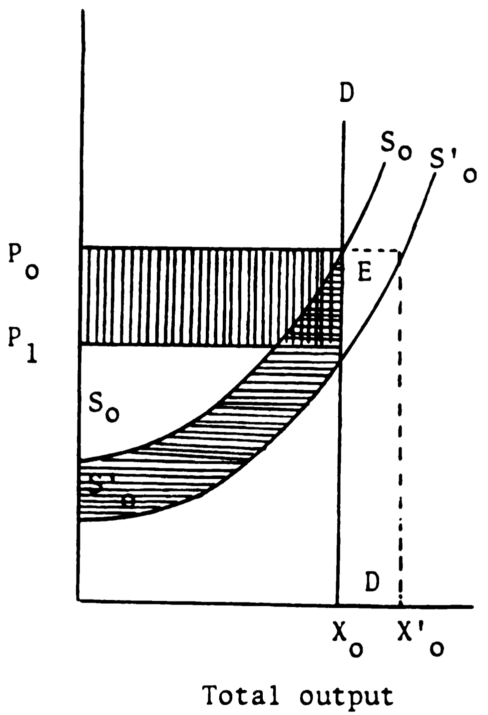
The three cases regarding elasticity of demand conditions for the project output changes are displayed in Figure 2.

Panel I represents the case of a completely inelastic (vertical) demand curve (DD). This case implies that consumers place no value on any production in excess of a given level of output. (S_oS_o) represents the aggregate supply curve for a given output prior to the project. Following the project installation, the supply curve shifts to $(S_o'S_o)$ because of lowered production costs and output price falls to P_1. Economic efficiency gains are measured by the area between the old (S_oS_o) and new $(S_o'S_o')$ supply curves. It should be noted that this analysis would apply in the case of nonmarginal change. The nonmarginal change could either be the result of many

[1]Elasticity of demand refers to the extent to which quantity changes in response to some given price change, or vice versa, a relationship that is generally assumed negative in price analysis. For example, an elasticity of demand of -.5 means that for a 10 percent increase in price there will be a 5 percent decrease in quantity sold; conversely putting 5 percent more of the commodity on the market (increasing supply by 5 percent) will lower the price by 10 percent.

Panel I

Inelastic Demand Conditions Related to Aggregate Regional Supply Function Before and After Flood Control Projects



Panel II

Elastic Demand Conditions Related to Aggregate Regional Supply Function Before and After Flood Control Projects

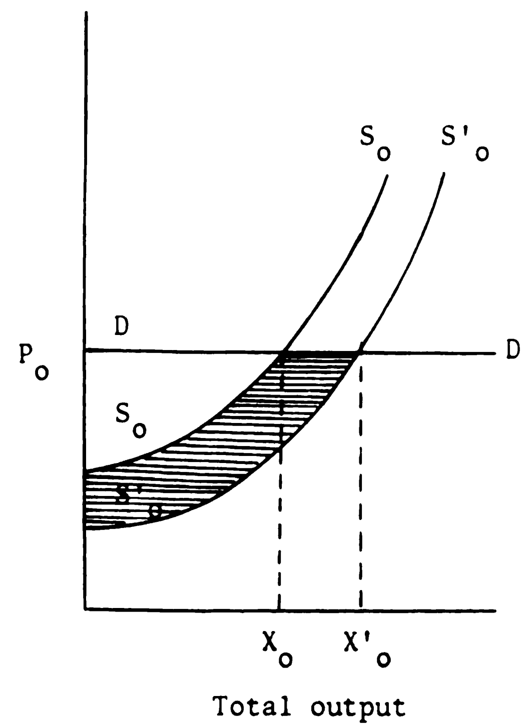


Figure 2. Effects of elasticity conditions on output valuation.

Panel III

Somewhat Inelastic Conditions Related to Aggregate
Regional Supply Function Before and
After Flood Control Projects

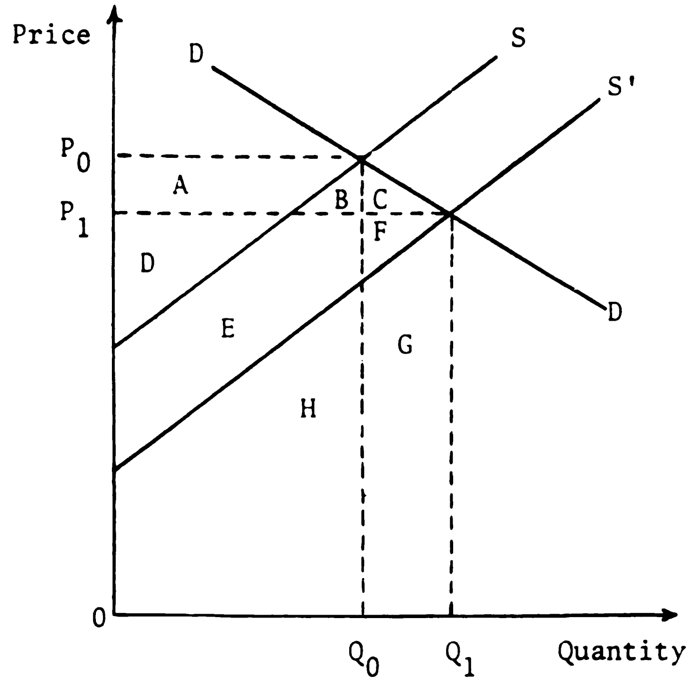


Figure 2. Continued

small projects in the nation or a large, single project as it affects a region of a nation.

Panel II represents the case of a completely elastic demand curve. The demand curve is perfectly elastic, and implies that the market will accept any increase (or decrease) in supply at a constant price. The supply curve (S_oS_o) represents the supply curve prior to the public project. The supply curve ($S_o'S_o'$) represents the supply curve following the project. The supply curve shifts rightward because productivity of some suppliers has been improved by the project. All of the additional output is assumed to marketed without affecting the post project price levels.

The Corps of Engineers, Soil Conservation Service, Bureau of Reclamation and other public agencies have used the assumption of elastic demand as displayed in Panel II. If the elastic demand approach is granted, efficiency gains from the project are represented by the area between the old (S_oS_o) and new output supply curves ($S_o'S_o'$).

Panel III represents the case of a downward-sloping demand. This situation is seen to be intermediate between the completely elastic and completely inelastic cases just discussed. The project effects in this case are represented by the rightward and downward shift of the supply curve from S to S'. Calculation of the net gain to society is a matter of debate in the economic literature since it involves the interpretation of consumer surplus which is area C.[1]

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[1]For a summary of the literature regarding consumer surplus and related issues, see John Martin Currie, John A. Murphy, and Andrew

The increased output generated by the project pushes the output price down affecting all producers. A necessary assumption associated with this approach is that marginal producers are unable to cover variable costs after the price falls and are, as a result, forced to drop out of production.

In the RLP model of benefits, there is no consumer surplus since there is no change in total quantity produced. Thus, the role of the role of consumer surplus in welfare analysis doesn't arise because of the character of the assumptions made.

The project output in the RLP model displaces other firms' output, so there is no change in consumer surplus since output is constant. There can only be resource savings (and some transfers among resource owners of different productivity).

Demand Conditions in U.S. Agriculture

The classical study of demand for U.S. agricultural commodities was made by Brandow in 1961.[1] In his study, Brandow found the price elasticity at retail to be -.34 for all foods. A more recent econometric analysis by Egbert[2] found that price elasticity for consumption

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Schmitz, "The Concept of Economic Surplus and its Use in Economic Analysis," The Economic Journal [the quarterly journal of the Royal Economic Society], LXXXI (December, 1971), 741-99. Also see Bromley, Schmid, and Lord, Public Water Resource Project, p. A-2.

[1]George Brandow, Interrelationships Among Demands for Farm Products and Implications for Control of Market Supply, Bulletin 680 (State College, Pa.: Pennsylvania State University, College of Agriculture, 1961).

[2]Alvin C. Egbert, "An Aggregate Model of Agriculture-Empirical Estimates and Some Policy Implications," American Journal of Agricultural Economics, LI (February, 1969), 71-86.

demand for the period 1964-66 is -.06. The interpretation of this coefficient is that a 1 percent decrease in retail flood prices will cause only a 1/16 percent increase in quantity demanded by consumers.

The U.S. agricultural economy is also characterized by excess capacity. Acreage allotments and other restrictions are necessary in order to prevent even larger price depressing surpluses. In his analysis, Egbert found that

> even though output expansion is bridled by holding available cropland out of production, average prices are projected to decline moderately through 1974 . . . The implication is: Even if current programs are continued, additional land will need to be withdrawn from production in order to keep prices of farm commodities advancing at the same pace as other commodities, at least through the mid-seventies. Looking at it another way, this result indicates that surplus productive capacity in (U.S.) agriculture will continue to grow over the next several years.[1]

From the Brandow and Egbert studies, it can be seen that the demand curve is quite inelastic. Thus, public investment in additional flood control projects will result in project-induced output which will be accepted by the economy, but at lower prices.

The RLP Model Approach

The RLP model is a cost savings model which assumes a fixed requirements assumption regarding output. The RLP assumes that total output is not affected by the project. Graphically, the outcomes anticipated using the RLP model are illustrated in Panel I of Figure 2.

In order to use the RLP model as a benefit measurement model, we must assume that the without-project costs for the fixed output could in fact be covered by consumer willingness to pay. This issue

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[1] *Ibid.*, pp. 80-82.

was discussed by Bromley, Schmid and Lord[1] and involves the case where the alternative cost approach to benefit evaluation is relevant. For this situation, Steiner is relevant:

> Where a viable alternative exists and will be activated in the absence of government action, its costs do substitute for benefits. If the list of services is the same, the benefits will be equal. In this case benefit measurement is totally unnecessary, and comparative costs provide necessary and sufficient conditions for choice.[2]

The RLP model can be used to estimate cost savings when an effective fixed output demand is assumed. The cost saving with the project is estimated. An estimate is made of the resources saved in producing the given output compared with producing the given output under "without" project conditions.

It is granted that the RLP assumptions do not conform to realism with respect to the U.S. agricultural economy. In fact, output has increased as a result of development projects and prices have been depressed as a consequence. The objective chosen here is not to predict future outputs and price, but instead to interpret the value of project effects as a gauge to project investments regardless of the eventual "real world" outcomes.

It is a policy option to regard real gains only as cost savings on a fixed output even though we have no way to manage basin resources as a single firm and hold output constant. Given the demand characteristics of American agriculture, this is a plausible policy

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[1] Bromley, Schmid, and Lord, Public Water Resource Project, p. 17.

[2] Peter O. Steiner, "The Role of Alternative Cost in Project Design and Selection," in Water Research, ed. by A. V. Kneese and Stephen C. Smith (Baltimore, Md.: The Johns Hopkins Press, 1966).

option even if the structure of agriculture is not modified to actually achieve the cost minimization result.

If this policy option is chosen, we can design a model to implement it. The RLP has been tailored to meet the specifications of this policy option.

CHAPTER III

OBJECTIVE OF THE RESEARCH INQUIRY

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.

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 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."[1]

These activities, together with the specified stock of available resources, define the production possibilities of 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.[2]

> (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.[3]

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.[4]

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[1]Earl R. Swanson, "Programming Optimal Farm Plans," Farm Size and Output Research, Southern Cooperative Series, Bulletin No. 56 (June, 1958), 47.

[2]Robert Dorfman, The Application of Linear Programming to the Theory of the Firm (Berkeley: University of California Press, 1951), Chapter IV.

[3]Swanson, "Programming Optimal Farm Plans," p. 47.

[4]Ibid.

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) Assumption of Additivity--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.
> (4) Assumption of Finiteness--means that of all possible processes, only a few are considered as alternatives.[1]

Rationale for Using the Wabash RLP Model

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

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[1] *Ibid.*, p. 49.

shift in the aggregate supply curve."[1] 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 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

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[1]U.S., Department of Agriculture, Economic Research Service, Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, Vol. I (August, 1969), p. 31.

conditions for each respective selected time period. Target years of 1980, 2000, and 2020 have been used in the river basin planning studies.

It should be pointed out to the reader that if the RLP program selects and uses a given soil group then a fixed combination of inputs is assumed used. The only difference is represented by a slight increase in variable inputs associated with the increased output, i.e., increased fertilizer and seed inputs necessary to sustain the post development yield increase, as well as slightly increased harvesting costs.

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 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 least cost output 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 IV

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 determining future agricultural demands on a river basin, 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 30, 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. In order to provide an indication of "national efficiency" benefits from the proposed flood control projects, a major assumption

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[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.

is necessary. The model assumes 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. 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 (higher) marginal unit costs of production then cropland that remains in production elsewhere in the Nation, the national efficiency gains will be under-estimated (over-estimated). If the adjustments occur outside the region, this implies an increae in the relative share of agricultural commodities produced within the region.

Sensitivity of the ERS Model's Assumptions

In 1970, John Hostetler, field group leader for the North Central Resource Group, NRED, ERS, completed his thesis[1] evaluating the sensitivity of the ERS river basin planning model to changes in assumptions. In his study, Hostetler tested five classes of assumptions with respect to sensitivity. They were assumptions relating to: (1) livestock feeding relationships, (2) projected demand levels, (3) soil management practices, (4) minimum acreage constraints, and (5) level of crop producing technology adoption.

[1]Hostetler, "Sensitivity Analysis of Selected Linear Programming Assumptions."

This study found that of the five classes of assumptions tested, both the assumption concerning soil management practices and minimum acreage restricts were relatively insensitive. Hostetler noted that "of the five classes of assumptions tested, the assumption concerning soil management practices should be dropped from future river basin models."[1] Regarding feeding relationships, ration composition was relatively unimportant but feeding efficiency (conversion ratio) was fairly sensitive. The demand level specification differences cause "production costs to be in error in the same direction by approximately the same degree."[2] The crop producing technology assumption was moderately sensitive to changes.

In the Wabash Basin RLP model, the sensitivity of two of the five classes of assumptions are relevant. First, the minimum acreage constraints, which were used by ERS in an effort to better approximate anticipated land use changes. Second, the evaluation of commodity demand will be undertaken.

Sensitivity of Water Construction Agency Models

A recent thesis[3] evaluated the sensitivity of the Soil Conservation Service's project evaluation model. Since the SCS model employs the same conceptual and analytical framework as that employed by the Corps of Engineers, Vondruska's findings are applicable to a comparison of Corps' and the RLP models.

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[1] *Ibid.*, pp. 121-22. [2] *Ibid.*, p. 114.

[3] John Vondruska, "An Economic Analysis of Small Watershed Project Evaluation Procedures" (unpublished Ph.D. dissertation, Michigan State University, 1971).

In his study, Vondruska evaluated the sensitivity of price, yield, and hydrological variables with respect to their effect on net present values (NPV) and benefit-cost (B-C) ratios for selected Michigan SCS projects. The finding that commodity output values used were highly sensitive was fairly comparative to the Hostetler finding of crop producing technology sensitivity. The latter relates to the effect of on-farm production cost coefficients as anticipated under alternative levels of adoption by farmers, i.e., if most farmers adopt cost reducing technology, basinwide production costs fall significantly. By contrast, Vondruska evaluated the effect of varying commodity market price levels and found them to be very sensitive in influencing NPV and B-C ratios.

Although the Vondruska investigation did not include an investigation of SCS project benefits under an alternative analytical framework as does the RLP, his approach is unique in that it provides the first critical in-depth review of the benefit-cost model common to the Corps and SCS. His findings will be kept in mind as we proceed to our empirical investigation. We will return to evaluate similarities and differences between the Vondruska study and this study in the final chapter.

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).[1] 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.

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[1]U.S., Department of Agriculture, Conservation Needs Inventory [for States of Indiana, Illinois, and Ohio], 1958.

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.

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 pertaining to cost, yield and input combinations for the Wabash Basin were based heavily upon the Ohio River Basin study coefficients. The Ohio study coefficients were developed by a retired Ohio State University agronomist under contract to USDA.[1] Except for reviews by SCS and ERS personnel, the Willard data was utilized without major revisions.

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. Costs associated with owning and maintaining fixed investments were not included.

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 net 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.

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[1] C. J. Willard [Technical Consultant, Ohio River Basin Survey], "Estimated Production of Crops in 1980 and 2010 in the Ohio River Basin," Columbus, Ohio, May 20, 1964, 15 p. (Unpublished paper.)

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 optimal 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 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 occurred 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]	Increasing crops[b]
		---Percent---	---Percent---
1959	1980	50	50
1980	2000	50	40
2000	2020	50	30

[a]Oats, wheat, barley, and hay.

[b]Soybeans, corn, corn silage, and pasture.

Source: Wabash River Basin Type II Survey data.

CHAPTER V

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 2 percent random sample of quarter sections (160 acres) from each county in the United States.

A 2 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 5.

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 of flood plain lands were summed, starting with the first county. A record was kept of the

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 three 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.

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.

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

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.

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, fifteen 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 distribution and

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[1] U.S. Army Engineer District, Corps of Engineers, "Wabash River Comprehensive Study," Interim Report No. 3, Louisville, Kentucky, March, 1967.

[2] *Ibid.*, p. C-67.

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.[1] 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

[1]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.

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.

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 damage factors for corn and soybeans under upstream and downstream flooding conditions were evaluated.

The first test by the author 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 6). 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 6.--Comparison of Average Annual Crop Losses Upstream vs. Downstream Areas, Wabash River Basin

Category	Upstream areas	Downstream areas
Number 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 inundated 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, pp. 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 as compiled by the SCS 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 7). 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.

TABLE 7.--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 (average)	84.0 bu.	92.0 bu.
Average annual soybean loss	9.3%	16.1%
Soybean yield (average)	31.6 bu.	34.6 bu.

[a]Includes all upstream flood plain acreage for economic subareas 1-4.

[b]Represents a sample of eighteen 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 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.

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 required 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 2 percent of the flood plain is in pasture and its value is so low, pasture damages can effectively be ignored.[1]

In summary, the examination of crop yields and the crop damage factors employed for downstream soils did not reveal differences that were felt to invalidate the use of basin-wide cost and yield data, as

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[1]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).

compiled for the RLP planning model, in the project evaluation model. The large differences 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.

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.[1] 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 area. Therefore, the level of protection decreases with distance downstream from the reservoir (Table 8).

TABLE 8.--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.

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[1]U.S. Army, Corps of Engineers, "Survey Investigations and Reports," 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.

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 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 Chapter VII). 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 7) appear to bear this out for the downstream flood plain of the Wabash Basin. The estimates derived from the Wabash planning models in Table 7, 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.

Variation 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 9). 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 9, 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 value per

TABLE 9.--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,(Washington, D.C.: Government Printing Office).

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.

CHAPTER VI

MODIFICATION OF WABASH RLP MODEL

Introduction

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[1] 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.

[1]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.

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

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

3. Upstream and downstream cropland acreages were summed.

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

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

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

7. 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.

8. 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" evaluation 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 7, 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 7). A possible explanation for this discrepancy may relate to the Corps' use of the composite acre concept. The conposite 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 10). 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.[1]

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

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[1]The assumption of homogeneity is modified in crop damage calculations to reflect distribution of crops by flood-hazard zones in normal Corps procedures. While soybean damages in Table 16 indicated considerably higher losses in July-September periods, it should be noted that flood probabilities are much lower for this period. River bottom farmers also shift almost entirely to soybeans after May-early June floods, thereby planting soybeans in apparently high-risk flood zones.

TABLE 10.--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 forty-eight hours.

Note: Maximum damage is total value of crop minus labor and expenses not expended at time of flood.

Source: Wabash River Basin Comprehensive Study, Interim Report No. 3, Vol. III (Louisville, Ky.: U.S. Army Engineer District, Corps of Engineers, March, 1967), Table 53, p. c-70.

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.

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 11). The first set of projects, affording the additional flood protection designated as Flood

TABLE 11.--Crop Acreage and Flood Protection Index, by Selected River Reaches, Wabash River Basin

Stream	Reach	Total acreage	Crop acreage	Production 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
Lowel Eel	LE-1	45,000	43,335	.3500	.3500
White River Main Stem	WE-1	24,200	17,593	.1193	.1193
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.

Control 1, includes all currently (1969) operational Corps 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 11). 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 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 on 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.

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

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

3. Multiply the present "flood-prone inadequately drained" yield by the percentage derived in step 2 to obtain the "flood control only" yield increment.

4. Multiply the flood control yield increment from step 3 by the flood protection index for the particular level and stream reach (Table 11).

5. 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.[1]

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

2. Multiply the flood control increment derived in step 1 by the flood protection index for the particular level and stream reach (Table 11).

3. Add the adjusted yield increment derived in step 2 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

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[1]Analysis of the flood control benefit under the "flood control plus drainage" assumption is presented in the Appendix A.

particular crop on the respective LRA/LCU soil groups. The additional per-acre costs associated with the provision of additional flood protection includes 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.) 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.

CHAPTER VII

EMPIRICAL INVESTIGATIONS

Introduction

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.[1] 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 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 C.

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.

Low and High Demand Analysis

The initial Wabash Basin Type II river basin projections were made on the basis of the regional allocation assigned by the joint Office of Business Economics--Economic Research Service Committee (OBE-ERS). However, in mid-1969, after the initial projections were completed, the OBE-ERS unexpectedly revised the regional share allocated to the Wabash Basin. The extent to which the OBE-ERS reallocation affected the land use, production cost and output projections for 1980 are indicated in Table 12. The effect of the reallocation on the other target years is indicated in the USDA final report:

> The projected agricultural economy of the Wabash River basin could meet the specified level of crop and livestock production for 1980, given the constraints imposed upon the model (in the form of costs, yields, acreages of various soils, etc.) without supplementing the current level of water and related land resource development . . . the same condition held for the 2000 and 2020 projection years as well. However, the "new" OBE-ERS regional allocation of national demand requirements resulted in a substantial increase in the share of some agricultural commodities being allocated to the Wabash River basin. These increased demands were significantly larger for milk and eggs in the livestock sector and for corn silage, wheat and soybeans among the field crops.
>
> The increase in demand requirements was sufficiently large to require a minor amount of additional resource development (flood control and on-farm drainage). By 2020, a substantial amount of additional resource development would be needed to

TABLE 12.--Land Use, Production Cost, and Output Comparisons, Low vs. High Demand Levels, Wabash River Basin, 1980 Projected[a]

Crop	Total acres	Total production cost	Output
	Low Demand Level = 100		
Feed Grain			
Corn	91.06	91.37	91.51
Oats	101.96	101.67	101.01
Barley	109.71	103.86	100.00
Total	91.80	92.33	91.73
Roughage			
Hay	85.06	84.89	89.22
Silage	262.68	267.77	257.34
Pasture	99.90	101.43	100.00
Total	105.09	130.43	114.18
Feed Use Total[b]	95.98	97.86	96.04
Wheat	180.14	177.88	172.43
Soybeans	124.89	124.75	124.03
Grand Total	111.32	110.45	------

[a]Projections with six present Corps reservoirs operational.

[b]Feed grain plus roughage.

obtain the level of output specified by the "new" OBE-ERS demand requirements given to the land resource base available for agricultural production.[1]

In 1980, the impact on overall basin land use indicate a 11 percent increase in agricultural lands utilized, with total basin on-farm costs up 10.5 percent (Table 12). The total output of feed grains was reduced. Total roughage output increased with pasture being held constant, hay reduced, and silage output more than doubled. Wheat and soybeans were also increased.

In order to evaluate the effect of the revised demands with Corps reservoirs in place, the Wabash RLP-PE model was rerun under Flood Control 1 and Flood Control 2 conditions. The results are reported in the sections which follow.

Efficiency Gains

The total on-farm variable costs which would be incurred in producing the estimated levels of agricultural commodities under alternative flood control conditions are indicated in Table 13. Under "low demand" conditions, the total on-farm costs for 1980 are reduced about $318,000 by the addition of the Flood Control 1 set of six reservoirs. Distribution of these efficiency gains across the 654,687 cropland acres indicates a gain in annual return of about $0.49 per acre.

Efficiency gains resulting from the Big Pine-Lafayette project are associated with a flood plain impact area of 412,814 crop acres.

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[1]Wabash River Basin Comprehensive Study, Vol. IX, Appendix H, Agriculture, June, 1971, p. 57.

TABLE 13.--Effect of Flood Control Reservoirs on Agricultural Production Costs, Wabash River Basin, 1980 Projected Demand and Cost Conditions

Status of flood protection	Total on-farm costs	Incremental difference	Incremental percent change
Low Demand Conditions			
No development (no projects)	$471,084,363	----	----
Flood Control 1[a]	470,765,824	$318,539	.07
Flood Control 2[b]	470,547,350	218,474	.05
High Demand Conditions			
Flood Control 1[a]	519,953,210	----	----
Flood Control 2[b]	519,583,100	370,110	.07

[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.

An additional basin-wide cost saving of $218,200 would be realized by the addition of Big Pine and Lafayette reservoirs in 1980 to the six reservoirs of Flood Control Set 1. These cost savings represent the net enhancement to the Big Pine-Lafayette flood plain lands after considering offsetting effects elsewhere in the Wabash Basin.

The addition of the Big Pine-Lafayette project would result in the efficiency gains to the entire flood plain of about $0.53 per acre. If the efficiency gains are attributed only to the 400,631 flood plain acres enhanced by this project, the annual return would be about $0.55 per acre.

The "high demand" analysis was made only to evaluate the effect of the addition of the Big Pine-Lafayette project to existing flood control levels. The cost savings from this project were $370,100 under high demand conditions compared with $218,600 under low demand conditions. Thus, the cost savings under high demand conditions would be about 69 percent more than would be realized under the low demand conditions. No additional flood plain land would be utilized on the project flood plain impact area (Table 16). Thus 409,946 of the possible 412,814 acres of Wabash River flood plain would be utilized with or without the Big Pine-Lafayette project. The efficiency gains to the entire flood plain are $0.90 per acre.

The efficiency gains attributable to the Big Pine-Lafayette reservoirs represents the net societal cost savings available to cover project cost 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 costs reduction is offset somewhat by slightly higher input costs, especially to be applied to flood-protected lands in order to sustain the increased yields over time. In addition to estimating efficiency gains accruing to a reservoir, the RLP-PE model can also provide estimates of probable land-use changes.

A breakdown of on-farm costs by crops are indicated in Tables 14 and 15. In both the low and high demand runs, reduction in basin-wide costs of producing soybeans are responsible for the bulk of the efficiency gains.

TABLE 14.--On-Farm Agricultural Production Costs, Low Demand Conditions, Wabash River Basin, 1980 Projected

	No reservoirs ($1,000)	Cost change (0 to 6)	Six reservoirs ($1,000)	Cost change (6 to 8)	Eight reservoirs ($1,000)
	------------------------Dollars----------------------				
Feed grains					
Corn	242,735	- 13,191	242,722	11,132	242,733
Oats	23,949	14,091	23,963	543	23,964
Barley	653	- 1	653	0	653
Total	267,337	899	267,338	11,675	267,350
Roughage					
Hay	15,586	4,521	15,591	- 6,997	15,584
Silage	9,619	-151,361	9,467	- 51,866	9,416
Pasture	20,348	0	20,348	0	20,348
Total	45,553	-146,840	45,406	- 58,463	45,348
Wheat	31,659	- 89,889	31,570	378	31,570
Soybeans	126,535	- 82,709	126,452	-171,664	126,280
Total costs	471,084	-318,539	470,766	-218,474	470,548

TABLE 15.--On-Farm Agricultural Production Costs, High Demand Conditions, Wabash River Basin, 1980 Projected

	Six reservoirs ($1,000)	Cost change (6 to 8)	Eight reservoirs ($1,000)
	--------------------Dollars--------------------		
Feed Grain			
Corn	221,781	96	221,781
Oats	24,364	0	24,364
Barley	678	- 6,584	671
Total	246,823	- 6,488	246,816
Roughage			
Hay	13,235	0	13,235
Silage	25,351	-229,462	25,122
Pasture	20,639	6,964	20,632
Total	59,225	-236,426	58,989
Wheat	56,155	24,792	56,179
Soybeans	157,750	-151,988	157,598
Total costs	519,953	-370,110	519,582

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 under either low or high demand conditions. As indicated in Table 16, approximately 19 percent of the cropland would be idle, assuming no Corps reservoirs would be operational by 1980. The high demand increased both the cropland and pastureland use significantly. Although only 1.5 percent of pastureland would be idle in 1980 under high demand conditions, 5.5 percent or about 764,000 acres of cropland are projected to remain idle.

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 installation of the six reservoirs of Flood Control 1 indicate a 19,149 acre reduction in cropland required to meet anticipated 1980 Wabash River Basin agricultural demand conditions. 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 afforded by Flood Control 1. In addition, 490,909 acres of project area floodplain lands would be used more intensively. This represents 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 application 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

TABLE 16.--Major Land Use, No Development Situation, Wabash River Basin, 1980 Projected

Category	Available land[a]	Land used[b]	Share of land
	-------Acres-------		--Percent--
Low Demand analysis[d]			
Cropland	13,911,727	11,316,200	81.3
Pasture	2,087,500	1,969,400	94.3
Total	15,999,227	13,285,600	83.0
High Demand analysis[d]			
Cropland	13,911,727	13,147,831	94.5
Pasture	2,087,500	2,055,771	98.5
Total	15,999,227	15,203,602	95.0

[a]Based on 1958 CNI data, less land withdrawn for urban expansion.

[b]Based on the 1980 Wabash River Basin "no development" solutions.

[c]Original demands.

[d]Demands as modified by OBE-ERS in 1969.

Sources: (1) Wabash River Basin Type II unpublished data for low demand analysis.
(2) Wabash River Basin Comprehensive Study, Vol. IX, Appendix H, Agriculture, June, 1971, Table H-12, p. 64.

increased economic efficiency associated with producing on the flood protected lands below the six reservoirs. This equivalent to idling four rural townships which are comprised of about 70 percent cropland. The composition of lands idled is indicated in Table 19.

In the low demand analysis, the addition of the Big Pine-Lafayette project resulted in a reduction of 9,186 acres in the basin-wide cropland requirement. On the flood plain below the reservoirs, an additional 8,293 cropland acres would be converted from idle to productive use and 392,338 cropland acres would be cropped somewhat more intensively (Table 17). In the non-impact areas, 9,798 more acres of cropland would be idled.

The land use changes under the high demand conditions were evaluated with respect to the difference between Flood Control 1 and Flood Control 2 only. The basin-wide cropland requirement was reduced by 7,710 acres (Table 17). The lands idled include about 27 percent roughages and 73 percent soybeans (Table 19).

The distribution of crops were fairly stable within low and high demand categories as the Big Pine-Lafayette project was added (Table 18). In comparing the effect of demand levels, the high demand runs used more soybeans relative to corn (Table 20).

TABLE 17.--Adjustments in Basin Land Use Due to Corps Reservoirs, Wabash River Basin, 1980 Projected

Category	Low Demand		High Demand
	Flood Control 1[a]	Flood Control 2[b]	Flood Control 2[b]
	----------------Acres----------------		
Basin-wide			
Reduction in cropland	19,149	9,186[c]	7,710
Non-impact area			
Reduction in cropland	63,285	9,798[c]	7,710
Flood plain impact area			
Total acreage	823,350	823,350	823,350
Cropland available	654,687	654,687	654,687
Percent crop used	82.50	94.92	99.46
Land use change			
1. Idle to cropland	44,189	8,293[d]	0
2. Cropped more intensively	490,909	392,338[e]	409,946

[a]Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mill, Monroe, and Mansfield reservoirs.

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

[c]Lands idled in addition to Flood Control 1.

[d]Idle lands converted to cropland in addition to Flood Control 1 lands converted.

[e]Includes lands affected by Flood Control 2, not including lands converted per note (d) above.

TABLE 17.--Adjustments in Basin Land Use Due to Corps Reservoirs, Wabash River Basin, 1980 Projected

Category	Low Demand		High Demand
	Flood Control 1[a]	Flood Control 2[b]	Flood Control 2[b]
	----------------Acres----------------		
Basin-wide			
Reduction in cropland	19,149	9,186[c]	7,710
Non-impact area			
Reduction in cropland	63,285	9,798[c]	7,710
Flood plain impact area			
Total acreage	823,350	823,350	823,350
Cropland available	654,687	654,687	654,687
Percent crop used	82.50	94.92	99.46
Land use change			
1. Idle to cropland	44,189	8,293[d]	0
2. Cropped more intensively	490,909	392,338[e]	409,946

[a]Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mill, Monroe, and Mansfield reservoirs.

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

[c]Lands idled <u>in addition</u> to Flood Control 1.

[d]Idle lands converted to cropland in addition to Flood Control 1 lands converted.

[e]Includes lands affected by Flood Control 2, not including lands converted per note (d) above.

TABLE 18.--Land Use[a] Under Alternative Flood Control Conditions, Low Versus High Demand Levels, Wabash River Basin, 1980 Projected

	Low demand levels			High demand levels	
	No reservoirs	Six reservoirs	Eight reservoirs	Six reservoirs	Eight reservoirs
	Acres				
Feed grains					
Corn	5,083,679	5,079,672	5,079,313	4,625,691	4,627,938
Oats	335,113	335,167	335,160	341,747	341,747
Barley	18,600	18,600	18,600	20,406	20,093
Total	5,437,392	5,433,439	5,433,073	4,987,744	4,989,778
Percent land use	41.99	42.02	42.04	34.65	34.68
Roughage					
Hay	394,491	394,671	394,404	335,701	335,701
Silage	117,949	115,381	114,451	303,085	299,777
Pasture	1,982,054	1,982,054	1,982,054	1,980,078	1,980,407
Total	2,494,494	2,492,106	2,490,909	2,618,864	2,615,885
Percent land use	19.26	19.27	19.28	18.19	18.18
Wheat	973,683	970,625	970,611	1,748,453	1,749,851
Percent land use	7.52	7.51	7.51	12.15	12.16
Soybeans	4,044,937	4,035,187	4,027,578	5,039,568	5,031,406
Percent land use	31.23	31.20	31.17	35.01	34.98
Total land use	12,950,506	12,931,357	12,922,171	14,394,629	14,386,919

[a]Harvested acres.

TABLE 19.--Agricultural Lands Idled by Introduction of Corps Reservoirs, Wabash River Basin, 1980 Projected

Situation	Acres used	Composition of lands idled			
		Feed grain	Roughage	Wheat	Soybeans
		Percent			
Low demand					
1. No Corps reservoirs[a]	12,950,506				
6 reservoirs[b]	12,931,357				
Lands idled	19,149	20.64	12.47	15.97	50.92
2. 6 reservoirs[b]	12,931,357				
8 reservoirs[c]	12,922,171				
Lands idled	9,186	4.00	13.03	.15	82.83
Incremental total lands idled	28,335				
High demand					
1. 6 reservoirs	14,394,629				
8 reservoirs	14,386,919				
Land idled	7,710		26.74		73.26

[a]Without project. [b]With Flood Control 1. [c]With Flood Control 2.

TABLE 20.--Flood Plain Land Use, Corps Reservoir Impact Area, Wabash River Basin, 1980 Projected

Category	Share by category			
	Low demand		High demand	
	6 reservoirs	8 reservoirs	6 reservoirs	8 reservoirs
	Percent			
Corn grain	23.5	24.0	19.4	12.6
Corn silage	7.6	8.3	7.3	14.2
All corn	31.1	32.3	26.7	26.8
Soybeans	68.9	67.7	73.3	73.2
Total	100.0	100.0	100.0	100.0

Source: RLP-PE computer solutions.

Subregional Analysis

The discussion to date has been concerned with the impact of the Corps' flood control projects upon the Wabash Basin as a whole. Let us now turn to an evaluation of the extent to which the basin's subareas would be affected, as evaluated by the RLP-PE for the 1980 situation.

Changes in Land Use

As reported in Table 17, the RLP-PE estimated that the introduction of the first six Corps' reservoirs would result in 19,149 cropland acres being idled in the Wabash Basin. This single figure fails to indicate that the agricultural acreage used in Subarea 1 would increase by 45,460 acres whereas crop acreages in all other subareas would decline (Table 21). It is noteworthy that Subarea 1 is the greatest distance from the bulk of the reservoirs, having only the Monroe Reservoir physically located within its borders. The addition of the Big Pine-Lafayette project under low demand conditions would result in acreage reductions in all subareas except Subarea 2 which remains unchanged. Under high demand conditions, the total basin-wide acreage reduction is less than under low demand conditions for the addition of the Big Pine-Lafayette project. Only Subarea 6 would gain acreage utilized under high demand conditions.

The finding of land use reductions following installation of flood control projects has several policy implications. First, the subarea located closest to the reservoirs generally experiences net reductions in cropland use. This is the finding under the RLP-PE for both low and high demand conditions. This is attributed to the presence of marginal lands within that subarea which would be idled under conditions of inelastic demand. Second, as additional flood protection is provided, agricultural lands continue to be idled throughout the basin. From the RLP-PE evaluation of Corps' projects under low and high demand conditions, there appears to be no definite pattern regarding location of idled lands. Knowledge of this fact could perhaps reduce local support for agricultural flood control projects because the lands idled apparently can be in the immediate vicinity of the project. It is unlikely that idled lands would be project flood plain lands, rather it would be non-impact area lands.

TABLE 21.--Changes in Land Use Due to Flood Control Projects, Wabash River Basin, 1980

Subarea	No projects to FC-1[a]	FC-1 to FC-2[b]	Net change
	----------------Acres----------------		
Low demand conditions			
1	+45,460	-3,739	+41,721
2	-13,303	-----	-13,303
3	-19,348	- 385	-19,733
4	-16,328	-2,699	-19,027
5	-11,662	-1,794	-13,456
6	- 3,968	- 569	- 4,537
Total	-19,149	-9,186	-28,235
High demand conditions			
1	not evaluated	-1,246	
2	"	- 16	
3	"	-2,059	
4	"	-4,309	
5	"	- 247	
6	"	+ 135	
Total		-7,742	

[a]Net acreage change induced by the addition of Flood Control 1 reservoirs including Salamonie, Mississinewa, Huntington, Cagles Mill, Monroe, and Manofield.

[b]Additional acreage shifts induced by addition of Big Pine and Lafayette reservoirs to Flood Control 1 reservoirs.

Changes in Total Value of Production

The shifts in total value of production is another area which the author evaluated with respect to regional changes induced by flood control projects. An evaluation of shifts induced by the Big Pine-Lafayette project under high demand conditions is indicated in Table 22. From this table, it is difficult for the author to see a one-to-one relationship between idled acreage and total value of production changes. Under high demand conditions, Subarea 4 would lose about 4,300 acres and lost $250,000 in production value. This compares with Subarea 6 which gained 135 acres and also gained $95,000 in value of production. By contrast, Subarea 1 would lose 1,246 acres yet gain over $375,000 in total value of production. Since the RLP-PE is designed to produce the estimated basin-wide demand for food and fiber at minimum costs, this total value of production analysis by subarea again indicates the difficulty of predicting the geographical location of gainers and losers.

TABLE 22.--Regional Shifts in Total Value of Crop Production[a] Induced by Corps Flood Projects, High Demand Conditions, Wabash River Basin, 1980

Subarea	Flood Control Set 1[b]	Flood Control Set 2[c]	Difference
	Dollars		
1	140,196,720	140,573,700	+376,980
2	255,952,710	255,870,830	- 81,880
3	111,019,230	110,977,490	- 41,740
4	285,980,210	285,729,530	-250,680
5	120,314,340	120,206,380	-107,960
6	339,045,530	339,140,400	- 94,870
Total	1,252,508,730	1,252,498,340	- 10,232

[a]"Interim Price Standards for Planning and Evaluating Water and Land Resources," Interdepartmental Staff Committee of the Water Resources Council, April, 1966, was the source of the current normalized prices used in deriving the value of agricultural production.

[b]Flood Control 1 includes Salamonie, Mississinewa, Huntington, Cagles Mill, Monroe, and Mansfield reservoirs.

[c]Flood Control 2 includes Flood Control 1 plus Big Pine and Lafayette reservoirs.

Source: Examination of ERS budget data by the author.

Effects on Resource Owners

The author utilized data from a recent ERS sample of Wabash Basin flood plain farmers in an effort to display the impacts upon individual farmers within a subarea of the Wabash Basin.

In an unpublished ERS study, a random sample was drawn of the flood plain farms which were surveyed in conjunction with the 1958 Conservation Needs Inventory. As discussed previously, the CNI represents a 2 percent sample of all 160-acre sections in the states of Illinois, Indiana, and other states as well.

The purpose of the 1965 study was to obtain information pertaining to farmer adjustment to flood risks. Regarding the Wabash River flood plain farms, 27 farms were drawn in the sample. Detailed information was obtained regarding crop practices on a 40-acre flood plain tract. Unfortunately the 27 tract survey was too small for such area as the 578,900 acres on the Wabash River flood plain. According to statistical criteria developed by Howard Taylor,[1] at least 1 percent of the 40-acre tracts in the Wabash River flood plain should have been surveyed. This would have been 103 sections, about four times those actually acquired.

Despite this particular shortcoming, the Wabash Flood Plain Survey does provide us with some information on average farm size. The other farm sample data is apparently statistically reliable using

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[1]Howard L. Taylor, Statistical Sampling for Soil Mapping Surveys, Statistical Laboratory Mimeo-Multilith Series No. 5 (Ames, Iowa: Iowa State University, June, 1962), Table 35--"Sampling Rates (percent) Which Provide Standard Relative Precision for 10 Size-Classes and 3 Sizes of Unit."

Taylor's criteria. The average size of the 27 sample farms was 830 acres. Let us assume that 50 percent of these farms were comprised of lands lying in the Wabash River flood plain. If we make this assumption of 415 acres per farm, 26 observations (2% sample) would be required for the 1,300 farms assumed to be in the Wabash River flood plain.

One of the most useful pieces of information, the size of flood plain farm operations, was obtained in the course of the study (Table 23). If this sample is a representative one, it indicates that larger farmers in the Wabash Basin gain the most from public projects providing additional flood protection.

The author chose to evaluate the project impacts upon Subarea 5 farmers since the Middle Wabash area (Subarea 5) had the largest number of observations (12) in the flood plain sample. The sample farms averaged 994 acres in size in 1964 and ranged from 413 to 3,000 acres. The average crop acreage was 818 acres, of which the author estimates about 83 percent would be located in the 25-year recurrence interval flood zone.[1] In this reference, Struyk reports 82.5 percent of Lower Wabash flood plain farm land was located in the 25-year flood zone.

The flood plain cropland use obtained in the 1964 flood plain survey indicated that in 1964, 69 percent was in corn, 8 percent in soybeans, and 13 percent in wheat and 10 percent was idle. The author assumed that the wheat was located in the low-risk flood plain area.

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[1] Institute for Water Resources, Corps of Engineers, Department of the Army, Agricultural Flood Control Benefits and Land Values, IWR Report 71-3, ed. by Raymond J. Struyk, Alexandria, Virginia, June, 1971, p. 87.

TABLE 23.--Comparative Farm Size, Wabash Flood Plain Survey with Comparisons

Category	Survey farms		Size in acres	
	No.	Ave. size	Comparison ave. size	Size index (comparison=100)
<u>All sampled farms</u>	309	391	184[a]	212
1. Illinois samples	110	404	226[b]	179
2. Indiana samples	199	384	166[c]	231
3. Non-Wabash R. farms	282	349	184[a]	190
4. Wabash R. farms	27	830	226[d]	367
a. Upper Wabash	5	452	200[d]	226
b. Middle Wabash	12	994	211[d]	471
c. Lower Wabash	10	823	256[d]	321

[a]Average size Wabash River Basin farm in 1964.

[b]State of Illinois average farm size in 1964.

[c]State of Indiana average farm size in 1964.

[d]Weighted average county farm size for sampled counties.

Sources: (1) ERS Wabash River Basin Flood Plain Survey, Spring, 1965.
(2) 1964 Census of Agriculture for Illinois and Indiana.
(3) Wabash River Basin Coordinating Committee, "Wabash River Basin Comprehensive Study," Vol. IX, Appendix -H, Agriculture, June, 1971.

In Subarea 5, there are two primary flood plain soils, naturally well drained (73%) and imperfectly drained (27%). Let us assume that the distribution of these lands is the same in the Wabash River flood plain as in the remainder of the Subarea 5 flood plain lands. If this assumption is made, we can proceed to evaluate the effects of the flood control projects under low demand conditions.

Using the cost and yield coefficients employed in the RLP-PE, the author added a land charge of $25 per acre based on $400 land at 5 percent interest and $5 per crop acre annual taxes. Fixed costs associated with machinery and equipment were assumed to account for $10 per acre. The sum of the variable costs, land charges, and other fixed costs were assumed to be representative of typical situation faced by cash grain farmers in Subarea 5. Using the 1966 current normalized prices for Indiana as the measure of output values, per acre and per farm costs and returns were computed for Wabash River flood plain farms under low demand conditions (Tables 24 and 25).

The author made the estimates for costs and returns for Wabash River flood plain farms on both a per acre and per farm basis for 1980 (Table 25). The returns above costs are increased as the additional flood protection is provided.

There are 106,742 acres of Wabash River flood plain in Subarea 5. Assuming the average size to be 818 crop acres per farm as found in the sample the author estimates that there are 130 flood plain farmers located on the Wabash River flood plain.

According to the June, 1971 Wabash Basin Comprehensive Survey, there were 8,500 farmers in Subarea 5 in 1964, of which 130 are

TABLE 24.--Cost and Return Coefficients, Flood Plain Soil Groups, Wabash River Flood Plain, Per Acre Basis, Subarea 5, 1980

Flood plain soil type	Crop	Flood control state[a]	Yield (bu.)[b]	Variable costs[b]	Land charges[c]	Other fixed costs[d]	Total costs	Total returns	Return above costs
Well drained	Corn	ND	98.3	$46.26	$25.00	$10.00	$81.46	$103.22	$21.76
	"	FC-1	101.7	"	"	"	82.67	106.79	24.12
	"	FC-2	103.0	"	"	"	83.11	108.20	25.09
	Soybeans	ND	40.0	31.23	"	"	66.23	98.80	32.57
	"	FC-1	41.2	"	"	"	66.67	101.76	35.09
	"	FC-2	41.7	"	"	"	66.83	103.00	36.17
Poorly drained	Corn	ND	91.3	45.09	"	"	80.09	95.87	15.87
	"	FC-1	94.9	"	"	"	81.35	99.65	18.30
	"	FC-2	96.2	"	"	"	81.84	101.00	19.16
	Soybeans	ND	38.0	30.96	"	"	65.96	93.86	27.90
	"	FC-1	39.2	"	"	"	66.39	96.82	30.43
	"	FC-2	39.7	"	"	"	66.56	97.81	31.25

[a]ND=no development; FC-1=Flood Control 1 projects; FC-2=Flood Control 2 projects.

[b]Based on 1980 RLP-PE coefficients.

[c]Based on $20 interest on land ($400 @ 5%) plus $5 annual taxes per acre.

[d]Fixed investments in machinery and equipment.

TABLE 25.--Cost and Return Analysis, Flood Plain Soil Groups, Wabash River Flood Plain, Subarea 5, 1980

Soil type and crop	Per farm acres	Profit per acre			Profit per farm		
		No. Dev.	FC-1	FC-2	No. Dev.	FC-1	FC-2
Well drained							
Corn	468	$21.76	$24.12	$25.09	$10,184	$11,288	$11,742
Soybeans	52	32.57	35.09	36.17	1,694	1,825	1,881
Poorly drained							
Corn	173	15.78	18.30	19.16	2,730	3,166	3,315
Soybeans	19	27.90	30.43	31.25	530	578	594
Total	818				$15,138	$16,857	$17,535
Profit per acre					$21.26	$23.68	$24.62

located on the Wabash River flood plain. The remaining 8,370 farmers had on the average about 155 crop acres in 1964. In the Wabash Basin Type II study, the ERS estimated that there will only be 7,297 farmers in Subarea 5 in 1980. From the Type II projections, there are 1,323,590 crop acres in production in Subarea 5 in 1980. Even assuming that flood plain farm sizes remain constant, there will be about 169 crop acres for each Subarea 5 farmer not located on the Wabash River flood plain.

The impact of flood control projects upon Subarea 5 farmers was estimated by the author. From the 1980 RLP-PE projected land use patterns for Subarea 5, 11,662 acres would be idled in this subarea. Assuming that profits per acre for non-impact crop lands are the same as those for flood plain lands under no project conditions, estimates for the loss in returns were made. Since the author estimates there are 7,167 non-project farms in Subarea 5 in 1980, the non-project per farm loss in net revenue is $34.59 under Flood Control Set 1 conditions. If the Big Pine-Lafayette were to be added to the Set 1 projects, an additional $5.32 in net revenue would be lost by Subarea 5 farmers. Translated into crop acre terms, the loss per acre increased from 20 cents to 24 cents under Set 1 and Set 2 project conditions respectively (Table 26).

The author hastens to point out that this empirical example is perhaps not statistically accurate, given the small sample of flood plain farmers represented. Although this is granted, the policy implications still hold if inelastic demand conditions for agricultural commodities is assumed. This display provides further evidence that

TABLE 26.--Impact of Flood Control Projects on Non-Project Farmers, Subarea 5, 1980

Flood control projects	Acreage idled	Average returns per acre	Total returns lost	No. non-project farmers	Loss per farm	Loss per crop acre[c]
FC-1[a]	11,662	$21.26	$247,934	7167	$34.59	$ .20
FC-2[b]	1,794	21.26	38,140	7167	5.32	.04
Total loss	13,456	$21.26	$286,074	7167	$39.91	$ .24

[a]Flood Control Set 1, six present Corps reservoirs.

[b]Flood Control Set 2, six present Corps reservoirs plus Big Pine and Lafayette reservoirs.

[c]Based on 169 crop acres per farm in 1980.

there will be losers in the case of flood control projects and they may even be adjacent to the project impact area.

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.[1] 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.

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 about 2.4 times larger than the RLP-PE method under low demands and 1.4 times larger under high demands (Table 27). 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 $218,500 after first six reservoirs are installed provides a measure of the gain to society

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[1]U.S. Army Engineer District, Corps of Engineers, "Review of Wabash River Basin Covering Reservoir Sites on Wildcat, Big Pine and Sugar Creeks, Indiana," Interim Report No. 1, Louisville, Kentucky, March, 1963.

TABLE 27.--Estimation of Annual Flood Control Benefits Under Alternative Benefit Evaluation Procedures, Big Pine-Lafayette Project, 1980

Evaluation procedure	Dollar Benefits
RLP-PE Model--Low demand	$218,500
RLP-PE Model--High demand	370,100
Corps procedure[a]	510,900

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

from decreased costs of producing agricultural commodities in the Wabash Basin made possible by the addition of the Big Pine-Lafayette project (Table 13). 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 $218,500 national efficiency gain; hence, $292,400 difference may be interpreted as a flood plain regional income transfer accruing to the flood-plain occupants. This is true only if market prices remained as the Corps assumes. If prices actually decline as indicated by the RLP-PE results, the flood plain owners would get less than the Corps assumes. It represents an income transfer from the basin farmers whose land loses its relative comparative advantage for the production of corn and soybeans.

Under conditions of high demand in the Wabash Basin, the RLP-PE estimate of $370,110 is much closer to the Corps figure. All else equal, the Corps estimate of $510,900 could be decomposed into national efficiency gains of $370,110 and regional income gains of only $140,790. The latter figure is less than one-half of the income transfers from other basin farmers. This implies that as land resources become more limiting in agriculture, flood control projects such as the Big Pine-Lafayette will assist to a greater extent to keep food costs lower to consumers without income redistribution within the farm economy in the basin.

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.[1]

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

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[1]U.S. Army, Corps of Engineers, "Survey Investigations and Reports," p. 59.

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 benefitted 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,[1] 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.[2]

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.[3]

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

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[1]Based on 1955 data adjusted to 1960 prices.

[2]U.S. Army Engineer District, Huntington Reservoir Design Memorandum (revised January 25, 1962), Louisville, Kentucky, p. 82.

[3]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.

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

In the empirical analysis reported in Table 17, the net enhancement feature of the RLP-PE model is indicated. The provision of the eight reservoirs by 1980 would cause a net reduction in basin-wide cropland required of 28,235 acres relative to the no development situation under low demand condition. Although 52,482 flood-plain project impact acres would be converted from idle to cropland use, 73,083 upland acres would be idled. Approximately three-fourths of the project-protected flood plain lands, or 490,909 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. 1 to estimate expected growth for the Big-Pine-Lafayette project were:

> Growth factor used in benefit analysis. A growth of 300 percent over a 100-year period is believed to be reasonably representative of development in the flood plain considering population, land capability, and the changing pattern of economic activity. To develop this factor, the following steps were taken:
>
> 1. Damages were classified into four sectors: agricultural crop, agricultural non-crop, urban, and transportation; indicators used were, respectively, average production of major crops, per capita personal income, total personal income, and population.
> 2. It first was assumed that each economic sector in the flood plain would develop as the historical development of that sector in the particular state. (Transportation was assumed to follow population change).
> 3. The resulting change in each economic sector was then modified to take into consideration change in relationships due to increase or decrease in industrial activity compared to agricultural activity.

4. The composite growth factor resulting from three different assumptions on changing pattern of economic activity in the flood plain was 300 percent in a 100-year period.[1]

In the benefit-estimating process the individual stage-damage curves and growth factors are consolidated into a single future damage multiplier. For the stream reaches below the Big Pine and Lafayette reservoirs, the damage multiplier used was 3.0. Average annual damages at the time of reservoir completion were estimated and were projected to increase 200 percent at the end of 100 years. 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 corresponding one-for-one growth in damages). A three-fold growth over 100 years implies that physical growth (residences, transportation, 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 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.

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[1]U.S. Army Engineer District, _Interim Report No. 1_, p. B-19.

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 28). 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 3.0 used in the Big Pine-Lafayette project.

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 28 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.[1]

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[1]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 28.--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 (Washington, D.C.: Government Printing Office, January, 1969), pp. 237, 238, 245, 254, 268, 318.

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.

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 5 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. Under low demand conditions, 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 13).[1] If the estimated rate of growth in benefits from 2000 to 2020 is extrapolated to 2069, the anticipated annual flood control efficiency gains from Flood Control 2 would be $337,000 for 2069.

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 at interest rate of 3-1/4 percent 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 29. Present-value average annual benefits of $241,300 were estimated (Table 30). 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. Present-value average annual costs were $655,700 (Table 32).

Under high demand conditions, the benefit estimate for 1980 was considerably higher than for low demand conditions (Table 31). The simplifying assumption was made that the 1980 production cost

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[1]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 29.--Projection of 1980 Agricultural Crop Benefit Proportion to 2069, Big Pine-Lafayette Project, Wabash River Basin

Target year	Efficiency gains from project[a]	
	Low demand	High demand
1969	$201,000	$201,000
1980	218,000	370,000
2000	249,000	429,000
2020	273,000	444,000
2069	337,000	481,000

[a]Efficiency gains represented by reduced basin-wide on-farm costs for producing specified demand levels.

TABLE 30.--Computation of Average Annual Benefits for Big Pine-Lafayette Project, Low Demand Conditions, RLP-PE Data, 1969-2069 (3-1/4% Rate of Interest)

1. Present value (P.V.) of increasing annuity for first eleven years of project life (1969-1980). Benefits increase from $201,241 to $218,132 to 11 years or $1,536 per year:

   $1,536 x 51.84216 = $79,630

2. P.V. of an annuity of 1 per year for 11 years (initial increase of $16,891 will then be a constant annuity for next 89 years):

   $16,891 x 28.98315 = $489,554

3. P.V. of 1 delayed 11 years:

   $489,554 x .70341 = $344,357

4. P.V. of an increasing annuity for 20 years (1980-2000). Note: The increasing annuity of $1,520/year will be delayed by 11 years.

   $1,520 x 137.30608 = $208,705

5. The P.V. of increasing annuity of $1,520/year will be delayed 11 years:

   $208,705 x .70341 = $146,805

6. P.V. of an annuity of 1 per year for 31 years (1980-2000 increase of $30,400 will then be a constant annuity for next 69 years):

   $30,400 x 27.38311 = $832,447

7. P.V. of 1 delayed 31 years:

   $832,447 x .37103 = $308,862

8. P.V. of an increasing annuity for 20 years (2000-2020):

   $1,225 x 137.30608 = $168,200

9. P.V. of (8) delayed 31 years:

   $168,200 x .37103 = $62,407

10. P.V. of an increasing annuity for 49 years (2020-2069):

    $1,306 x 459.001168 = $599,469

11. P.V. of (10) delayed 51 years:

    $599,469 x .20863 = $125,067

12. P.V. of an annuity of 1 per year for 51 years (2000-2020 increase of $24,490 will then be a constant annuity for next 49 years):

    $24,490 x 24.34969 = $596,324

13. P.V. of 1 delayed 51 years:

    $596,324 x .19571 = $116,707

14. Present capital value of benefits:

	$ 79,630	from (1)
	344,357	from (3)
	146,805	from (5)
	308,862	from (7)
	62,407	from (9)
	125,067	from (11)
	116,707	from (13)
Total	$1,183,835	

15. Amortization: Converting present capital value benefits to annual benefits:

    $1,183,835 x .03388 (Amort. factor for 100 years @ 3-1/4%) = $40,108
    Discounted future increment in benefits.

16. Average annual benefits--discounted to present (1969) at 3-1/4 percent interest:

$ 40,108	from (15)
201,241	present benefits (Table 29)
$241,349	

TABLE 31.--Computation of Average Benefits for Big Pine-Lafayette Project, High Demand Conditions, 1969-2069

1. Present value (P.V.) of increasing annuity for first 11 years of project life (1969-1980). Benefits increase from $201,241 to $370,110 in 11 years or $15,352 per year:

   $15,352 x 51.84216 = $795,881

2. P.V. of an annuity of 1 for 11 years (initial increase of $ will then be a constant annuity for next 89 years):

   $168,869 x 28.98315 = $4,894,356

3. P.V. of 1 delayed 11 years:

   $4,894,356 x .70341 = $3,442,739

4. P.V. of an increasing annuity for 20 years (1980-2000). Note: The increasing annuity of $2,954/year will be delayed by 11 years.

   $2,954 x 137.30608 = $405,602

5. The P.V. of an increasing annuity of $2,954/year delayed 11 years:

   $405,602 x .70341 = $285,304

6. P.V. of an annuity of 1 per year for 31 years (1980-2000) increase of $59,078 will then be a constant annuity for next 69 years):

   $59,078 x 27.38311 = $1,617,739

7. P.V. of 1 delayed 31 years:

   $1,617,739 x .37103 = $600,230

8. The P.V. of an increasing annuity for 20 years (2000-2020):

   $740 x 137.30608 = $101,606

9. The P.V. of (8) delayed 31 years:

   $101,606 x .37103 = $37,699

10. The P.V. of an increasing annuity for 49 years (2020-2069):

    $764 x 459.01168 = $350,685

11. The P.V. of (10) delayed 51 years:

    $350,685 x .20863 = $73,163

12. P.V. of an annuity of 1 per year for 51 years (2000-2020 increase of $14,794 will then be a constant annuity for next 49 years):

    $14,794 x 24.34969 = $360,229

13. P.V. of 1 delayed 51 years:

    $360,229 x .19571 = $70,500

14. Present capital value of benefits:

	$ 795,881	from (1)
	3,442,739	from (3)
	285,304	from (5)
	600,230	from (7)
	37,699	from (9)
	73,163	from (11)
	70,500	from (13)
Total	$5,305,516	

15. Amortization: Converting present capital value benefits to annual benefits:

    $5,305,516 x .03388 (Amort. factor for 100 years @ 3-1/4%) = $179,751
    Discounted value of future increment in benefits.

16. Average annual benefits--discounted to present (1969):

	$179,751	from (15)
	201,241	present benefits (Table 29).
Total	$380,992	

TABLE 32.--Benefit Cost Evaluation of Agricultural Crop Benefits Under Alternative Benefit Formulations, Big Pine-Lafayette Project (3-1/4% Interest Rate)

Formulation	Annual growth rate	Annual benefits	Allocated annual costs[g]	Benefit-cost ratio
	-Percent-	----Dollars----		
Wabash RLP-PE, low demand	.68[a]	241,349[c]	655,700	.37
Wabash RLP-PE, high demand	1.39[a]	380,992[d]	655,700	.58
Corps conventional model	.68[a]	609,500[e]	655,700	.93
Corps conventional model	3.00[b]	1,079,975[f]	655,700	1.65

[a]Growth rate over 100 project life, based on Table 28.

[b]Growth rate over 100 life based on Corps project justification documents.

[c]Based on Table 30. [d]Based on Table 31.

[e]Based on projecting 1969 damage levels per Corps Interim Report No. 1, Vol. II, March, 1963, at RLP-PE low demand growth rates. Share of benefits attributable to agricultural crop losses avoided based on unpublished Corps project justification data furnished to ERS by Louisville District Corps office.

[f]Same as (e) except that 3 percent annual growth in benefits (same rate as used by Corps in Interim Report No. 1).

[g]Project costs assigned in proportion to benefits with 48.5 percent crop benefits portion of total benefits applying likewise to cost portion, 1963 cost values. One-hundred-year project life, 3-1/4 percent interest rate.

savings share would apply to future target years as well.[1] The 2000 - 2020 rate of benefit increase was assumed to apply for the 2020 - 2069 period as well.

In contrast, the conventional Corps method of estimating benefits resulted in damages at a much higher rate than found in the RLP-PE evaluation. The Big Pine-Lafayette project was evaluated at two growth in benefit rates. The 0.68 percent per year rate was the average growth in damages found using the RLP-PE under low demand conditions. The 3 percent annual growth rate was the rate actually used by the Corps in the final Big Pine-Lafayette project justification statements.

A comparison of benefits under alternative formulations and under varying growth rates is presented in Table 32. The B-C ratio is shown to be less than unity for all growth rates displayed, except the 3 percent rate used by the Corps. A discussion of the reasons for the variation in benefit levels under the RLP-PE as opposed to Corps conventional analysis is undertaken in the next section. As mentioned previously, the major reason for these differences is that the RLP-PE model is based on a net enhancement concept whereas the conventional Corps method is based on a gross enhancement concept.

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[1]Based upon cost of agricultural production without resource development as reported in Wabash River Basin Comprehensive Study, Table H-85, p. 248.

Resolution of Corps and RLP-PE Benefit Differences

As reported in Table 32, there are large absolute differences between the Corps and the RLP-PE crop benefit estimates for the Big Pine-Lafayette project. This is true not only for target year 1980 but for the project life as well. There appear to be five sources which have contributed to this large difference in the Big Pine-Lafayette project:

1. Difference in Corps and RLP estimated land use pattern.
2. Differences in agricultural crop yields.
3. Difference in valuation of flood plain output.
4. Difference in expected damage factors.
5. Conceptual differences.

The comparisons which follow are based on an analysis of the low demand situation with the Corps projective techniques for the Big Pine-Lafayette project.

Land Use Differences

One possible source of difference between Corps and RLP-PE crop damage estimates is that there is a significant difference in intensity of land use between the two approaches. The Corps approach is to survey pre-project flood plain land use and project this pattern to continue after the project is completed. The Corps modifies this approach only to the extent that land enhancement benefits are anticipated to be induced as a result of providing flood protection. Since no enhancement was projected by the Corps for the Big Pine-Lafayette, this was not an issue in this application.

The RLP-PE approach is that available cropland can either be used in production or be idle in any given target year, depending on the comparative advantage of flood plain lands relative to other lands in the river basin. The pattern is also true of available pastureland. The RLP-PE program has the capability of converting pastureland to cropland at a fixed per acre cost of conversion. This conversion was not utilized in this application, apparently because of the excess of cropland under both low and high demand conditions. Conversion from cropland to permanent pasture was not possible under the RLP-PE program used in this application.

In the twelve downstream reaches reported in Table 9, corn and soybeans combined to comprise 87.5 percent of the average annual damages, based on Corps estimates. It follows that the greater the proportion of these two crops on the project projected flood plain, the higher the damages, all else equal.

A comparison between Corps and RLP-PE land use projections (under low demand conditions) is presented in Table 33. It should be noted that the Corps assumed that all available cropland at the time of their surveys in the late 1950's and early 1960's would continue to be used. By contrast, the RLP-PE allows cropland to remain idle, some of which did occur under both Flood Control 1 and Flood Control 2 conditions. The Corps projections indicate a lower proportion of the two high-valued, high damageable crops, corn and soybeans than are indicated in RLP-PE projections. The Corps projections indicate about 65 percent of the project flood plain lands will be used for these two crops compared with about 71 percent in the RLP-PE analysis.

TABLE 33.--Percentage Share of Corn and Soybeans, Corps and RLP Projections, Big Pine-Lafayette Flood Plain, 1980

Projection	Corn and soybeans	Share of flood plain
	-----Acres-----	-----Percent-----
Corps of Engineers	349,525	64.7
Flood Control 2	383,498	71.0

Sources: (1) Corps of Engineers unpublished project justification data.
(2) RLP-PE low demand computer analysis.

This finding implies that the RLP dollar crop benefits would be higher than the Corps, if a common denominator of output valuation were employed.

Crop Yield Differences

The agricultural crop yields used by the Corps are assumed to grow at a rate of 3 percent per year over the life of the project. The bulk of the crop yields for the Big Pine-Lafayette flood plain impact area were collected prior to 1960 and then revised to a 1960 base yield. The weighted average yields used by the Corps with 3 percent annual increases during the 1960-1980 period are reported in Table 34.

The RLP-PE yields for the flood plain area were projected as indicated in previous discussion. Weighted average yields of commodities which will be grown according to the solution for Flood Control 2 are also reported in Table 34. The RLP yields are higher than Corps yields for all crops grown on the flood plain.

TABLE 34.--Yield Comparisons, Corps and RLP-PE Yields, Big Pine-Lafayette Reservoirs, 1980 Projected

Crop	Unit	Corps of Engineers	Flood Control 2	Yield index (Corps=100)
Corn	bushel	79.0	98.4	124
Soybeans	"	31.4	39.4	125
Wheat	"	32.5	a	---
Oats	"	56.8	a	---
Hay	ton	3.1	a	---

[a]RLP-PE assumed only economical crops following flood control were corn and soybeans.

The implication of the approximately 25 percent higher RLP-PE projected yields is that RLP benefits would be higher than the Corps, all else equal.

Differences in Value of Flood Plain Output

The Corps benefit estimation procedure used in the Big Pine-Lafayette project was to estimate dollar damages, and consequently benefits, on the basis of total market value of the crop minus labor and expenses non-expended at the time of the flood. By contrast, the RLP-PE evaluates benefits on the basis of basin-wide production costs savings associated with reductions in flood risk.

At the time of the Big Pine-Lafayette project justification study, the Louisville Corps office valued the additional output produced on project protected flood plain lands on the basis of state-wide average commodity price levels. Since 1967, Water Resource Council normalized prices have been used.[1]

By contrast, the on-farm costs of production differences provide the basis for the RLP-PE valuation in output. On-farm costs can be expected to be lower than the total market value of output increase computed by the Corps. This is true to the extent that land charges, property taxes, and profit are not included in the RLP-PE valuation.

The net effect of the difference between Corps and RLP-PE in this case indicates that Corps output valuation will be somewhat higher than RLP-PE, all else equal.

Difference in Expected Damage Factors

Two different approaches were used in the Corps and RLP-PE studies. The Corps estimated the average flood plain yield by crop which would be obtained in a flood-free year. This yield was then damaged by successive floods and an estimate of the average dollar damage per acre by crop was obtained. This information is incorporated into the stage-damage curve and when combined with the stage-discharge and frequency-discharge curves, the frequency-damage curve is then constructed for pre- and post-project conditions. The area between the curves comprises the estimate of reduction in flood damages attributed to the flood control project.

By contrast, the RLP-PE borrowed flood plain crop yields for affected soil groups from the Wabash Basin Planning model (RLP-BP).

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[1] Water Resource Council, Interim Price Standards for Planning and Evaluating Water and Land Resources, April, 1966.

First, the soil groups which were affected by the project were identified. Second, the current flood-prone yield and the flood-free yield estimates were obtained for these soil groups. There was a wide range in absolute yield increases associated with affording flood protection to the various soil groups. The flood-control increment for corn had a range from 3.2 percent to 23.1 percent. The yield increases associated with protecting soybeans on the soil groups varied from 1.4 percent to 13 percent.

As discussed previously, the percentage reduction in Corps reach dollar damages attributed to the project was used as the factor for determining the flood control yield. In other words, if average annual crop damages were reduced by 10 percent, the flood control yield (with project) would be 10 percent of the distance between the flood-prone and flood-free yields. This procedure departs from Corps frequency-damage analysis which is based on the composite acre approach in which the various crops are assumed to be uniformly distributed across the flood plain.

Estimating the Net Effect of Differences

A comparison was made in an effort to evaluate the combined effect of alternative land use, crop yield, and product price assumptions as used by the Corps and RLP-PE. The total value of output anticipated to be produced on the Wabash River flood plain lands below the Big Pine-Lafayette project was evaluated under the alternative procedures. Five alternative combinations of land use, crop yield and output valuation were estimated (Table 35). Based on the

TABLE 35.--Effect of Alternative Land Use, Yield, and Product Value Assumptions on Total Value of Flood Plain Output for 1980, Wabash River Below Big Pine-Lafayette Reservoirs

Alternative	Land use	Crop yields	Product yield	Total value of output
1	C	P	N	$31,748,098
2	FC-2	FC-2	FC-2	15,561,103
3	FC-2	P	N	31,815,399
4	C	FC-2	N	39,811,654
5	C	P	FC-2	14,377,953

Note:

C = Corps of Engineers project justification studies, 1960 base.

P = Corps 1960 yields projected to increase 3 percent annually to 1980.

N = Water Resource Council normalized prices. Source: WRC, Interim Price Standards for Planning and Evaluating Water and Land Resources, April, 1966.

FC-2 = Flood Control 2 under "flood control only" conditions with low demand levels.

alternatives displayed in Table 35, through a process of elimination, the differences due to land use and crop yields were derived (Table 36). The RLP-PE procedure indicates that both more intensive land use and higher yield levels were projected under Flood Control 2 conditions than was true in the Corps analysis. Thus, the comparisons undertaken reduce the initial $16,186,995 difference between the Corps and RLP-PE agricultural crop benefit estimates for the Big Pine-Lafayette project to $6,947,707 (Table 37).

A summary of benefit comparisons is provided in Table 38. Under low demand conditions and with 1969-1980 growth in Corps benefits at the rate of .68 percent per year, the Corps estimate is decomposed into two areas. The national efficiency gains portion ($218,200) is based on the RLP-PE benefit estimate and the regional efficiency gains portion ($292,700) is assumed to be the remainder. At the high demand level, the national efficiency gain level for 1980 is $370,100 or 72 percent of the Corps estimate for 1980. This compares with a national efficiency gains portion of 43 percent under low demand conditions.

If the Corps 3 percent growth rate[1] over the 1969-1980 period is used, regional income gains are significantly higher at comparable demand levels (Table 38). The regional income share at low demand rises from 57 percent to 65 percent and from 28 percent to 41 percent at high demand levels. Thus the higher Corps growth rate of 3 percent per annum is shown to emphasize the regional income gain component relative to the national efficiency gain component.

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[1]The 3 percent rate used in the Big Pine-Lafayette applied to 1969 benefits results in 1980 benefits of $630,089.

TABLE 36.--Derivation of Differences Between Corps and RLP-PE Total Value of Flood Plain Output for 1980, Wabash River Below Big Pine-Lafayette Reservoirs

Alternative	Land use	Yields	Output value	Value	Comment
1. Overall Difference					
1	C	P	N	$31,748,098	Difference of $16,186,995 reflects the net effect of differences between the two procedures regarding land use, crop yield, output value, and conceptual framework.
2	FC-2	FC-2	FC-2	15,561,103	
a. Difference				$16,186,995	
2. Partitioning of Differences Between Procedures					
3	FC-2	P	N	$31,815,399	Difference of $67,301 indicates that FC-2 contains a slightly higher proportion of high valued crops.
1	C	P	N	31,748,098	
a. Difference				$ 67,301	
4	C	FC-2	N	$39,811,654	Difference of $8,063,556 reflects higher FC-2 yields relative to the Corps crop yields.
1	C	P	N	31,748,098	
b. Difference				$ 8,063,556	
1	C	P	N	$31,748,098	Difference of $17,370,145 reflects significantly higher Corps output values relative to FC-2 values.
5	C	P	FC-2	14,377,953	
c. Difference				$17,370,145	

Note: C = Corps of Engineers project justification studies, 1960 base.

P = Corps 1960 yields projected to increase 3 percent annually to 1980.

N = Water Resource Council normalized prices.

FC-2 = Flood Control 2 under "flood control only" conditions with low demand levels.

Source: Table 35.

TABLE 37.--Summary of Differences Between Corps and RLP-PE Total Value of Flood Plain Output for 1980, Wabash River Below Big Pine-Lafayette Reservoirs

Difference	Description
$17,370,145	Reflects higher Corps output values
- 67,301	Shows FC-2 land use more intensive than Corps
- 8,063,556	Indicates FC-2 crop yields higher than Corps
$ 9,239,288	Explained difference
- 16,186,995	Extent to which FC-2 less than Corps (Row 3, Table 35)
-$ 6,947,707	Unexplained difference attributed to conceptual variations between the two procedures

Source: Table 36.

TABLE 38.--Summary of Differences Between RLP-PE and Corps Benefit Estimates for 1980, Big Pine-Lafayette Project

Procedure	Benefit value	Share (percent)	Description
Low demand conditions			
Corps	$510,900[a]	--	Gross income changes under perfectly elastic demand
RLP-PE	218,200	43	National efficiency gains under perfectly inelastic demand
Difference	$292,700	57	Regional income gains
High demand conditions			
Corps	$510,900[a]	--	Gross income changes
RLP-PE	370,100	72	National efficiency gains
Difference	$140,800	28	Regional income gains
Low demand conditions			
Corps	$630,100[b]	--	Gross income changes
RLP-PE	218,200	35	National efficiency gains
Difference	$411,900	65	Regional income gains
High demand conditions			
Corps	$630,100[b]	--	Gross income changes
RLP-PE	370,100	59	National efficiency gains
Difference	$260,000	41	Regional income gains

[a]Based on growth rate in benefits of .68 percent per year from 1969-1980.

[b]Based on growth rate in benefits of 3 percent per year from 1969-1980.

Sources: (1) Table 27. (2) Corps of Engineers unpublished project justification materials. (3) RLP-PE computer analysis.

Study Costs

The author provided an estimate of both the costs of the RLP-PE application under Corps' contract (Table 39) and a judgment estimate of the anticipated cost of performing another empirical application (Table 40).

The costs of the Wabash Basin application were considerably higher than would be expected if the same methodology were to be used by ERS in another investigation. First, a great deal of the investigation was centered about conceptualizing the Corps and RLP-PE framework, a cost which would be much lower in another application. Second, much of the clerical effort was used to collect and code data which have since been computerized. Third, computer costs were excessively high due to having to re-run the no development (no projects) analysis, a cost which should be avoided. Fourth, the secretarial costs were primarily devoted to preparation of two interim reports and a complete final report with several retypings required. The clerical effort could be reduced significantly without adversely affecting the quality of future RLP-PE investigations.

In the event that the application of the RLP-PE were undertaken in a river basin study without adequate flood plain cost, yield, and land use data, estimated study costs would be substantially higher than estimated in Table 40.

TABLE 39.--Breakdown of Costs Associated with Estimating Project Benefits Using RLP Model, September, 1967 - December, 1969

Category	Expenditure	Proportion (percent)
Economist salary	$17,830	51.6
Secretarial salaries	4,579	13.2
Clerical[a]	7,747	22.4
Computer related[b]	3,534	10.2
Travel[c]	904	2.6

[a]Based on 3,521 hours at $2.20/hour.

[b]Includes $377 for NCRG programmer, $770 for MSU computer center, and $2,387 for McDonnell Corp. Does not include $630 for unsuccessful analysis at Control Data Corp., Minneapolis.

[c]Includes two trips to Louisville, Kentucky; two trips to Washington, D.C. (4/69 and 12/69); one trip to St. Louis, Missouri; one trip to Wabash Basin; one trip to Indianapolis, Indiana.

Source: Examination of ERS budget data by the author.

TABLE 40.--Breakdown of Costs Associated with a Future RLP Application over One Year Period

Category	Rate per hour	Hours	Expenditures	Proportion (percent)
Economist salary[a]	$6.40	200	$1,280	32
Secretarial[b]	3.15	40	126	3
Clerical[c]	2.48	200	496	12
Computer related[d]	----	---	2,000	49
Travel[e]	----	---	150	4
Total			$4,052	100

[a]GS-11, step 1. [b]GS-4, step 1. [c]GS-2, step 1.

[d]Based on McDonnell Corp., St. Louis, Missouri rate for four revisions.

[e]Based on one trip to and from St. Louis, Missouri.

Source: Examination of ERS budget data by the author.

CHAPTER VIII

SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

Summary

Regional linear programming basin planning (RLP-BP) models have been designed and applied in river basin planning surveys to identify the potential 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 present value of 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. Assuming inelastic demand for farm commodities, the efficiency gains resulting from the proposed project represent savings to the nation by meeting a given food and fiber output 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 relative to other regions, the model will underestimate the national efficiency gain and vice versa.

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 Corps reservoirs in the 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 flood and fiber in the Wabash Basin with and without the proposed Big Pine-Lafayette project were evaluated under two levels of commodity demands. Under low demands, an annual saving of $218,200 would be realized as a national benefit in

1980. With regional demands at approximately 10 percent higher levels, national benefits attributed to the project by the RLP-PE rose 69 percent to $370,110. This indicates that as land becomes the scarce factor in a river basin, project benefits under conditions of inelastic demand will increase at an increasing rate.

A comparison with Corps of Engineers benefit estimates for the Big Pine-Lafayette project for 1980 revealed several things. First, under low demand conditions where the growth in benefits is the same as implied by the RLP-PE evaluation during the 1969-1980 period (.68% per year), the national efficiency gains amount to about 43 percent of the Corps estimates. About 57 percent of the benefits can be attributed to transfers of income to the region's impact area flood plain resource owners at the expense of other producers in the Wabash Basin. Under conditions where commodity demands are increased by about 10 percent, national efficiency gains dominate (72%) versus the transfer income gain component (28%).

The growth rate in benefits over the life of the project was shown to be an important variable. If agricultural benefits are assumed to grow at the same rate as general economic growth (about 3% per annum), an over-estimate of national efficiency gains occur, other assumptions equal.

The analysis revealed that flood control projects are a mixed blessing to a region under conditions of completely inelastic demand. The implicit assumption that a flood control project is always good for regional growth is subject to question. This is revealed in the finding that under either low or high demand conditions the improved productivity of benefiting flood plain lands will necessarily idle lands elsewhere in the river basin. The RLP-PE analysis of the Big Pine-Lafayette revealed that affording additional flood protection to 412,814 acres would result in the idling of between 8-10,000 acres elsewhere in the basin. The RLP-PE estimating procedure thus evaluates the net enhancement effects on land resources within the basin as farmers if the basin were efficiently managed as a unit 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 annual benefits from the project could be calculated. A constant annual benefit of $241,300 was obtained for the Big Pine-Lafayette project, which represents 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 $241,150 (40%) and a transfer income component of $368,150 (60%). Under conditions of high demand the national efficiency gain component is $381,000 (63%) and transfer component is $228,500 (37%).

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 <u>productivity change of land</u> 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 <u>national efficiency point of view</u>. And it provides an explicit method for <u>projecting future benefits</u> based on separate projections of future commodity demand and future resource capability (supply conditions). The model does not include any provision for estimating <u>adverse effects</u> of a proposed project.

Flood control benefits that arise from reduction in damage to real or personal property are not estimated by this RLP-PE model. Thus, the present version 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.

Limitations

Introduction

Although many of the basic objectives of the empirical investigation were evaluated in the course of the analysis, there remain ways in which this study could have been improved. Some of the suggested changes were potentially realizable given somewhat more time and money. Other suggested revisions would either require a major restructuring of input data, change in model specification or disproportionately large time and budgetary costs. Although some of the latter type of revisions were recognized in the course of the study, the author and his supervisors felt that the only relevant alternative to acknowledge and document the limitations. Therefore, an attempt was made to make a crude estimate of the possible bias which these limitations introduced into the findings.

Data Problems

One of the first problems encountered in the study was that of determining a methodology for specifying the characteristics of project protected flood plain lands. In this regard, there were three factors which should have been considered in the analysis. First, the distribution of present flood plain land use by category (cropland, pastureland, woods and wasteland) at each recurrence interval. Second, the productivity of the currently cropped flood plain lands as reflected by average yields under present flooding conditions. Third, the distribution and costs of converting present pasture, woods and wasteland to higher level uses and the productivity associated with these lands following their conversion.

The first factor, distribution of flood plain lands by category, was confounded due to the fact that the Corps data available utilized the composite acre concept. This use of this concept assumes that all categories of land are evenly distributed across the flood plain without regard to flood frequency. This was found to be false in the land value study conducted by Boxley in that he discovered that:

> In the Upper Wabash, 51 percent of the land in the one-year flood zone was in unproductive use (nearly all the land bordering the Wabash has been left uncleared, probably for bank stabilization). The wood and waste percentage drops to about 6 percent between the one-year and 50-year flood zones.[1]
>
> In the Lower Wabash, 30 percent of the unprotected land in the one-year flood zone on the tracts sold was unproductive.

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[1]Robert F. Boxley, Jr., Analysis of Alternative Procedures for Evaluation of Agricultural Flood Control Benefits, Vol. I, p. 132.

Unproductive land dropped to about 12 percent over the remainder of the flood plain.[1]

The net effect of employing the composite-acre concept, particularly in the Upper Wabash area, is that there are actually fewer crop acres in high risk zones than predicted using this concept. This will lead to over-estimation of benefits to project protected cropland areas. In short, the RLP-PE shares the same conceptual weakness as does the Corps analysis from which the initial flood plain input data was obtained.

There appear to be two ways to overcome this problem. First, utilize county soil survey reports to furnish flood plain land use information. As discussed in Chapter V, an insufficient number of up-to-date soil survey reports were available for the study area. The second alternative is to conduct an inventory of affected flood plain lands as part of the study. This was rejected as too costly and time-consuming relative to the marginal benefit of the more refined information obtained.

Related to the problem of determining composition of flood plain lands is that of determining their present productivity. Earlier discussion revealed that there are average annual crop loss differences for soybeans depending on stream reach location (Table 7). A more detailed inventory of project protected flood plain lands appeared to be the only approach to overcome this problem. This was rejected as too costly and time-consuming relative to the marginal gains which would be derived.

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[1]Boxley, unpublished land value study materials.

A detailed flood plain inventory would also have assisted in better establishing the distribution of pasture, woods and wasteland in the project affected lands. These lands comprise about one-quarter of the lands downstream from the Big Pine-Lafayette project. A cost function for converting these lands to higher level uses would have been necessary. In addition, estimated post-conversion yields would also be necessary inputs. If some of these pasture, woods, and waste lands were converted to cropland due to affording higher levels of flood protection, net enhancement cost reduction benefits and land use changes would have been more dramatic. In order for these lands to be converted, extensive land clearing and drainage investments would be necessary. Public projects would be required in order for many of these lands to be converted by farmers. The feasibility of converting these lands should therefore be evaluated in another study.

Basic Decision-Making Unit

The RLP-PE may be faulted because it uses the soil group as the basic decision-making unit, i.e., each soil group is assumed to be a homogeneous unit for decision-making. Thus, the simplifying assumption is made that farm firm decisions are made in relation to each soil group as a distinct entity. In the aggregate, this assumption may not be too unrealistic. The alternative is to go to other levels of decision-making, such as the county or by type of manager (upland farmers, flood plain farmers, etc.). Conceptually, the RLP-PE outcome would be the same irregardless of the assumption regarding the decision-making unit.

Inability to Identify Beneficiaries

Closely tied to the previous problem of appropriate decision-making unit is that of identifying the gainers and losers from public investment. Since the soil group is the RLP-PE decision-making unit, this methodology does not lend itself to ready analysis regarding the individuals or groups benefiting or harmed as a result of a flood control project.

It is probably too much to ask that any single methodological procedure be able to answer all questions pertaining to the effects of public investment. Perhaps a more efficient way to utilize the RLP-PE is for it to measure efficiency gains and utilize other methods to discover potential income redistribution effects.

The type of information reported in the 1964 Wabash Basin flood plain survey used in conjunction with the RLP-PE should provide the policy maker with more power in evaluating redistributional effects. This type of cross-check is not generally obtainable in conventional Corps or agency analysis. Bonnen[1] discovered this when he attempted to document the distribution of benefits of certain subsidy programs. When he attempted to evaluate the Bureau of Reclamation's irrigation water development, he was stymied. He observed that:

> There is a wealth of data, but readily available only in forms that tend to defeat any comprehensive analysis of the programs distributional impacts.[2]

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[1]James T. Bonnen, "The Absence of Knowledge of Distributional Impacts: An Obstacle to Effective Public Program Analysis and Decisions," in Joint Economic Committee, The Analysis and Evaluation of Public Expenditures: The PPB System, Vol. I (Washington, D.C.: U.S. Government Printing Office, 1969).

[2]*Ibid.*, p. 424.

Relevant Uninvestigated Areas

The Vondruska[1] study suggests a number of other pertinent areas which could have been investigated in the RLP-PE study. These include: (1) the effects of employing the composite acre concept by the Corps of Engineers, (2) the effect of project life, and (3) the rate at which crop yields and production costs are anticipated to change over the life of the flood control project.

The Hostetler[2] study suggested that both the crop producing technology and feeding relationships were moderately sensitive to small changes. Neither were evaluated in this RLP study but they ideally should have been examined. Even though two alternative demand levels were evaluated in the RLP-PE study, this represents an inadequate evaluation of the range of possible demand levels which ideally should have been evaluated in this application.

Application of Results

Introduction

There appear to be two levels at which the RLP-PE model can be used. First, it can be used as a substitute for Corps analysis. Second, it can serve as a "check" on the Corps analysis. In this role, it would most likely be used by one of four major groups: (1) river basin planners; (2) citizen groups; (3) state agencies; or (4) other

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[1]Vondruska, "An Economic Analysis of Small Watershed Project Evaluation Procedures."

[2]Hostetler, "Sensitivity Analysis of Selected Linear Programming Assumptions."

federal agencies. Let us now turn to an evaluation of the alternative ways in which the output of the RLP-PE model could be utilized.

Substitute for Corps Analysis

The RLP-PE, as currently constructed, appears to be inadequate as a replacement for the conventional Corps analysis. First, the Corps' conventional flood hydrograph-flood damage model will be needed to estimate flood control benefits to the non-agricultural sectors. The RLP-PE model evaluated in this study does not have this capability independent of the Corps. Second, the conventional Corps model has the advantage of being an operational model familiar to both Corps personnel and reviewers of project justification studies. Third, the RLP-PE model depends heavily for its inputs on Corps' data generated in its conventional Corps analysis. Unless a separate data gathering capability was added to the RLP-PE, there would be insufficient data on which to base the analysis. Since the data gathering responsibilities of the ERS do not include flood hydrograph information and related stream data, this aspect will continue to be carried out by the Corps. For these reasons, it is inappropriate to anticipate that the RLP-PE would replace the Corps' model in the foreseeable future. Let us now turn to other ways in which the RLP-PE might be used.

Use of RLP as a Check on Corps Analysis

The more realistic way in which the RLP-PE would be useful to the public would appear to be as an alternative estimating procedure. As discussed previously, the RLP-PE has the advantage of measuring the net effects of a flood control project, an advantage not found in the Corps conventional model.

River basin planners could use the RLP-PE model in several ways. First, as a means of evaluating the impacts of alternative projects or sets of projects on a river basin region. Several criteris could be used. One possibility is in using the project or set of projects which provides the greatest net societal saving in food cost. A second possibility is in ranking projects affecting agricultural flood plains in terms of the greatest net benefit per dollar of flood control cost. A third possibility is to evaluate those projects which would least disrupt the current income distribution in the river basin. A fourth use is in the area of sequential analysis where alternative projects or sets of projects are evaluated with respect to the effect of the timing of construction with respect to the disruption of on-going patterns of agricultural activity in a river basin.

Citizen groups could likewise utilize the RLP-PE results in several ways. First, upstream groups could use the model to gain an estimate of the impact of alternative flood control projects on their area of concern. Second, downstream groups could gain a general sense of the way in which the most economic management of affected flood plain lands could be undertaken. They could grasp the difference between the Corps and RLP-PE analysis in terms of what to reasonably expect in the way of land use changes which would be induced by the project.

Regional interest groups, such as the Wabash Valley Association, implicitly assume that flood control projects are necessarily beneficial to all of their clientele. The RLP-PE could serve to show some of the intra-basin offsets which are associated with public projects such as the Big Pine-Lafayette reservoirs.

The whole problem with allowing citizen groups to gain access to the information provided by the RLP-PE seems to be that unless the interpretation is provided by the ERS, misunderstandings concerning the impacts would likely occur. The citizen groups would then be faced with a credibility problem with respect to which analysis is given the most weight. Given that the Corps has a well-established clientele at the local, regional, and national level and ERS does not, the Corps would have the advantage of being the most widely respected agency. There would also be the problem of resolving conflicts between the Corps and ERS if they were to occur. Given that the Corps has more to lose in the event any of their projects appear to be cast in an unfavorable light, Corps personnel would be reluctant to provide data which would be the subject of controversy.

The use of the RLP-PE model results by state agencies would essentially be like that of river basin planners. The use would differ to the extent that there would be more concern over state-wide effects relative to local impacts than in the case of the river basin planners.

The use of the RLP-PE by other federal agencies is hard to anticipate. The use of the Wabash RLP-BP model by the Soil Conservation Service is the subject of an on-going ERS project with Carmen

Sandretto as researcher. This project is attempting to evaluate the impact which different sets of SCS projects will have on the river basin under varying levels of water resource development and commodity demand conditions. This project will perhaps serve to enlist the interest and support of other federal agencies to the point where they are willing to assess potentials of the RLP model. The RLP-PE application to the Big Pine-Lafayette project could potentially be of concern to the Bureau of Reclamation as well as the SCS.

BIBLIOGRAPHY

BIBLIOGRAPHY

Bonnen, James T. "The Absence of Knowledge of Distributional Impacts: An Obstacle to Effective Public Program Analysis and Decisions." Joint Economic Committee. The Analysis and Evaluation of Public Expenditures: The PPB System. Joint Committee Print, Vol. I. Washington, D.C.: Government Printing Office, 1969.

Boxley, Robert F., Jr. "The Relationship between Land Values and Flood Risk in the Wabash River Basin." Unpublished Ph.D. dissertation, Michigan State University, 1969.

Brandow, George. Interrelationships Among Demands for Farm Products and Implications for Control of Market Supply. Bulletin 680. State College, Pa.: Pennsylvania State University, College of Agriculture, 1961.

Bromley, Daniel; Schmid, A. Allan; and Lord, William B. Public Water Resource Project Planning and Evaluation: Impacts, Incidence, and Institutions. Madison, Wisc.: Center for Policy Studies and Programs.

Council of Economic Advisors. Economic Report of the President. Washington, D.C.: Government Printing Office, January, 1969.

Currie, John Martin; Murphy, John A.; and Schmitz, Andrew. "The Concept of Economic Surplus and Its Use in Economic Analysis." The Economic Journal [The Quarterly Journal of the Royal Economic Society], LXXXI (December, 1971), 741-99.

Dorfman, Robert. The Application of Linear Programming to the Theory of the Firm. Berkeley: University of California Press, 1951.

Dracup, John A. "Systems Analysis, A Substitute for Planning." American Water Resources Association. Evaluation Processes in Water Resources Planning. Urbana, Illinois, 1970.

Egbert, Alvin C. "An Aggregate Model of Agriculture--Empirical Estimates and Some Policy Implications." American Journal of Agricultural Economics, LI (February, 1969), 71-86.

Griliches, Zvi. "Specification Bias in Estimates of Production Functions." Journal of Farm Economics, XXXIX (February, 1957), 8-20.

Halter, Albert N., and Miller, Stanley F. River Basin Planning: A Simulation Approach. Special Report 224. Oregon Agricultural Experiment Station, November, 1966.

Hostetler, John E. "Sensitivity Analysis of Selected Linear Programming Assumptions: A Study of the Agricultural Projections in River Basin Research." Unpublished Ph.D. dissertation, Michigan State University, 1970.

Institute for Water Resources. Corps of Engineers. Department of the Army. The Relationship between Land Values and Flood Risk in the Wabash River Basin, by Robert F. Boxley, Jr. IWR Report 69-4. Alexandria, Virginia, December, 1969.

________. Corps of Engineers. Department of the Army. Agricultural Flood Control Benefits and Land Values, edited by Raymond J. Struyk. IWR Report 71-3. Alexandria, Virginia, June, 1971.

________. Corps of Engineers. Department of the Army. Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, by Daniel Piper, Roger Strohbehn, and Robert Boxley. IWR Report 71-4. Alexandria, Virginia, July, 1971.

Kates, Robert. "Seasonality." Papers on Flood Problems. Edited by Gilbert F. White. Research Paper No. 70. Chicago: University of Chicago, Department of Geography, 1961.

Knetsch, Jack L. "Economic Analysis in Natural Resource Programs." Joint Economic Committee. The Analysis and Evaluation of Public Expenditures: The PPB System. Joint Committee Print, Vol. III. Washington, D.C.: Government Printing Office.

Little, I. M. D. A Critique of Welfare Economics. Oxford, 1960.

Ruttan, Vernon W. The Economic Demand for Irrigated Acreage: New Methodology and Some Preliminary Projections, 1954-80. Baltimore: Johns Hopkins Press, 1965.

Schmid, A. Allan. "Water Resource Development: Public and Private Investment." Opportunities for Regional Research on Water Resources Problems. Edited by D. T. Massey and G. D. Rose. Iowa City, Iowa: University of Iowa, College of Law, Agricultural Law Center, 1968.

Steiner, Peter O. "The Role of Alternative Cost in Project Design and Selection." Water Research. Edited by A. V. Kneese and Stephen C. Smith. Baltimore, Md.: The John Hopkins Press, 1966.

Subcommittee on Evaluation Standards. Report to the Interagency Committee on Water Resources. Proposed Practices for Economic Analysis of River Basin Projects. Washington, D.C.: Government Printing Office, May, 1958.

Swanson, Earl R. "Programming Optimal Farm Plans." Farm Size and Output Research. Bulletin 56. Southern Cooperative Series, June, 1958.

Taylor, Howard L. Statistical Sampling for Soil Mapping Surveys. Statistical Laboratory Mimeo-Multilith Series No. 5. Ames Iowa: Iowa State University, June, 1962.

U.S. Army Corps of Engineers. "Survey Investigations and Reports: General Procedures." Engineering Manual EM 1120-2-101 (includes change 16). October 12, 1964. (Mimeographed.)

U.S. Army Engineer District. Corps of Engineers. Existing Levees. Map #1, Wabash River Basin Emergency Flood Control Activities. Louisville, Kentucky, January, 1966.

________. Corps of Engineers. "Huntington Reservoir Design Memorandum." Revised January 25, 1962. Louisville, Kentucky. (Mimeographed.)

________. Corps of Engineers. "Wabash River Basin Comprehensive Study." Vol. I, Interim Report No. 1 (March, 1963); Vol. II, Interim Report No. 2 (January, 1964); Vol. III, Interim Report No. 3 (March, 1967). Louisville, Kentucky. (Mimeographed.)

U.S. Army Engineer Division. Corps of Engineers. Ohio River Basin Comprehensive Survey. Appendix M, "Flood Control." Cincinnati, Ohio, December, 1967.

U.S. Congress. Lincoln, Clifty Creek, and Patoka Reservoirs, Wabash River Basin, Indiana and Illinois. H.R. 202, 89th Cong., 1st sess., 1965.

U.S. Congress. House. Task Force on Federal Flood Control Policy. A Unified National Program for Managing Flood Losses. H.R. 465, 89th Cong., 2nd sess., 1966.

________. Congress. House. Wabash River and Tributaries, Indiana and Illinois. H.R. 197, 80th Cong., 1st sess., 1944.

________. Congress. House. Wabash River, Ohio, Indiana, and Illinois. H.R. 100, 73rd Cong., 1st sess., 1932.

________. Congress. Joint Economic Committee. The Analysis and Evaluation of Public Expenditures: The PPB System. "The Absence of Knowledge of Distributional Impacts: An Obstacle to Effective Public Program Analysis and Decisions," by James T. Bonnen. Joint Committee Print, Vol. I. Washington, D.C.: Government Printing Office, 1969.

________. Congress. Senate. Lafayette and Big Pine Reservoirs, Wabash River Basin, Indiana. S. Doc. 29, 89th Cong., 1st sess., 1965.

U.S. Department of Agriculture. Economic Research Service. Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits. Edited by Robert F. Boxley, Jr. Vol. I. Washington, D.C., August, 1969. (Mimeographed.)

________. Economic Research Service. An Analysis of Alternative Procedures for the Evaluation of Agricultural Flood Control Benefits, by Daniel Piper, Roger Strohbehn, and Robert Boxley. Vol. II. Washington, D.C., May, 1971. (Mimeographed.)

________. Farm Real Estate Market Developments. CD-67, August, 1965.

________. Farm Real Estate Market Developments. CD-71, December, 1968.

________. Statistical Reporting Service. Crop Production Annual Summaries for the years 1960-69.

U.S. Water Resources Council. Interdepartmental Staff Committee. "Interim Price Standards for Planning and Evaluating Water and Land Resources." Washington, D.C., April, 1966.

Vondruska, John. "An Economic Analysis of Small Watershed Project Evaluation Procedures." Unpublished Ph.D. dissertation, Michigan State University, 1971.

Wabash River Coordinating Committee. Wabash River Basin Comprehensive Study. Vols. V, VI, IX, XIII, Appendices D, E, H, and L. June, 1971.

Willard, C. J. "Estimated Production of Crops in 1980 and 2010 in the Ohio River Basin." Unpublished paper. Columbus, Ohio, May 20, 1964.

APPENDICES

APPENDIX A

GENERAL CHARACTERISTICS, WABASH RIVER BASIN

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GENERAL CHARACTERISTICS, WABASH RIVER BASIN

The Wabash River Basin is comprised of 33,100 square miles including about the southern two-thirds of Indiana and southeastern one-sixth of Illinois and 319 square miles of two Ohio counties. The northern portion comprising 27,500 square miles has been glaciated. The unglaciated section is located in the south-central part of the Basin and comprises only 5,575 square miles.[1]

The Wabash River, the second largest tributary of the Ohio River, originates in Mercer County, Ohio, about fifteen miles east of the Indiana-Ohio State line. It flows in a northwesterly direction to the vicinity of Huntington, Indiana, and then in a westerly and southerly direction until it joins the Ohio River about halfway between Mt. Vernon, Indiana and Shawneetown, Illinois. The principal tributaries entering the Wabash along its 475 miles of length are the Salamonie, Mississinewa, Eel, Tippecanoe, Vermilion, Embarras, and White Rivers. The largest tributary of the Wabash River is the White

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[1]Wabash River Coordinating Committee, Wabash River Basin Comprehensive Study, Vol. XIII, Appendix-L, Project Engineering Studies section on "Physiography" (June, 1971), pp. 9-11.

River which, with its two forks, drains approximately 34 percent of the total drainage basin, or 11,349 square miles.[1]

The climate of the basin is classed as humid continental. Rainfall is fairly well distributed throughout the year. Average annual precipitation during the growing season (April through November) is 26 inches. The average growing season varies between 145 to 200 days over the basin, length decreasing from south to north.

The farming industry is the second most important economic activity in the Wabash Basin. The annual income from farming since 1959 has exceeded one billion dollars. Although, the manufacturing industry is the major economic activity in terms of employment, farming still employs about 100,000 workers. In 1964, about one-third of all cropland in the basin was in corn. Soybean acreage has increased during the 1954-64 period, as has wheat acreage. The acreage of other small grains (oats, barley, rye) has declined sharply. The acreage of hay crops declined significantly between 1959 and 1964 (Table A-1).

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[1]Wabash River Coordinating Committee, Wabash River Basin Comprehensive Study, Vol. VI, Appendix-E, Hydrology (June, 1971), pp. 3-5.

TABLE A-1.--Acreage of Principal Basin Crops Grown

Crop	Basin acreage			Percent of total basin cropland		
	1954	1959	1964	1954	1959	1964
	-----------1,000 acres-----------			-----------Percent-----------		
Corn	5,065	5,319	4,838	42.8	45.3	42.9
Soybeans	2,535	2,918	3,421	21.4	24.9	30.4
Wheat	1,297	1,303	1,555	10.9	11.1	13.8
Oats	1,160	799	308	9.8	6.8	2.7
Barley	52	52	11	0.4	0.4	0.1
Rye	123	60	26	1.0	0.5	0.2
Hay	1,445	1,171	973	12.2	10.0	8.6
Vegetables	76	72	43	0.6	0.6	0.4
Potatoes	2	2	2	0.0	0.0	0.0
Fruit Orchards	18	13	10	0.2	0.1	0.1
Other	81	33	85	0.7	0.3	0.8
Total	11,854	11,742	11,272	100.0	100.0	100.0

Source: Wabash River Basin Comprehensive Study, Vol. IX, Appendix-H, Agriculture (June, 1971), Table H-4.

Flood Problems

The Wabash River from its mouth to Mt. Carmel, Illinois, a distance of 96 miles, occupies a valley averaging about six miles in width and has an average slope of 0.6 foot per mile. The average depth of flow from mean low water to bank line is 18 feet and from low water to maximum high water, 38 feet. The channel width in this reach averages 1,200 feet. Backwater from Ohio River floods affects the lower reaches of the river.

In the meandering reach from Mt. Carmel to Terre Haute, Indiana, the average slope of the river is 0.7 foot per mile. The depth of flow from mean high water to bank line averages 17 feet, and from low water to maximum high water, 29 feet. The average width of channel is 800 feet, and the total width at elevation of maximum high water, four miles.

From Terre Haute to Lafayette, Indiana, the average slope of the river is 0.6 foot per mile. Between Terre Haute and the mouth of the Vermilion River, the slope is only 0.5 foot per mile, the flattest gradient on the river for so long a reach. The average depth of flow from mean low flow to bank line is 16 feet and from low water to maximum high water is 32 feet. The average channel width is 600 feet and the total width at maximum high water elevation, about one mile.

From Lafayette to Bluffton, Indiana, the Wabash River and its tributaries have narrow valleys and steep slopes. The average low water slope in this reach is about 2.5 feet per mile. From the mouth of the Mississinewa River to the mouth of the Salamonie River, the average gradient of 1.8 feet per mile is somewhat less than the reach average. The average depth of flow of mean low water to maximum high water, 24 feet. The average channel width between banks is 500 feet and the total width at maximum high water elevation is about 0.7 of a mile. Table A-2 summarizes the characteristics of the Wabash River flood plain.[1]

As noted in previous discussion, the valley of the Wabash River is flat and wide. The flood plain is a highly agriculturalized area. The result is that floods are frequent and destructive. Stream flows are subject to great variation with small discharges during prolonged dry periods and large crest flows after heavy rainfall. The principal cause of floods on the river is excessive rainfall. Snow melt, the release of ground water by thawing, or the saturated condition of the ground at the time rainfall occurs, aggravates flood conditions by increasing runoff. Floods have occurred in every month of the year but those of the summer and fall seasons ordinarily have less areal coverage than those of winter and spring. The maximum flood of record for both the Wabash River and Wabash Basin as a whole occurred during March and April of 1913, inundating about 900,000 acres of land along the Wabash and White Rivers and East and West forks of the White River, not including tributaries.[2] A summary of average annual Wabash River flood plain losses is provided (Table A-3).

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[1]Wabash River Coordinating Committee, <u>Wabash River Basin</u>, Appendix-E, pp. 3-5.

[2]<u>Ibid</u>., pp. 33-101.

TABLE A-2.--Wabash River Flood Plain Characteristics

Reach	Stream miles			Acres	
	From	To	Miles	Total flood plain	Per stream mile
W- 1	0.0	40.0	40.0	108,000	2700.0
W- 2	40.0	94.5	54.5	114,000	2091.7
W- 3	94.5	124.2	29.7	99,700	3356.9
W- 4	124.2	214.8	90.6	154,500	1705.3
W- 5A	214.8	238.0	23.2	19,700	849.1
W- 5B	238.0	257.5	19.5	13,700	702.6
W- 6	275.5	287.8	12.3	16,200	1317.1
W- 7	287.8	317.0	29.2	14,600	500.0
W- 8	317.0	332.8	15.8	3,800	240.5
W- 9	332.8	374.8	42.0	19,500	464.3
W-10	374.8	393.3	18.5	11,600	627.0
W-11	393.3	411.4	18.1	3,600	198.9
Total				578,900	

Source: Corps of Engineers project justification data.

TABLE A-3.--Average Annual Flood Losses, Wabash River, 1960 and 1963 Values

Reach	Year value	Average annual losses[a]		Composition of losses (percent)				
		Total	Per acre	Crop	Non-crop	Transportation	Level	Urban
W- 1	1960	$ 700,005	$ 6.48	66.0	33.9	----	---	.1
W- 2	1963	711,802	6.24	34.0	60.1	3.0	2.8	.1
W- 3	1960	395,276	3.96	30.5	48.8	18.5	2.2	----
W- 4	1960	1,068,219	6.91	43.1	48.6	1.4	2.1	4.8
W- 5A	1960	170,794	8.67	54.9	31.7	2.7	6.0	4.7
W- 5B	1960	175,154	12.78	60.6	24.0	8.6	6.4	.4
W- 6	1960	358,330	22.12	77.0	20.8	.9	1.3	----
W- 7	1960	173,374	11.87	64.7	30.2	3.4	---	1.7
W- 8	1960	38,082	7.39	46.9	39.0	3.1	8.8	2.2
W- 9	1960	54,818	2.81	14.7	12.5	1.1	---	71.7
W-10	1960	68,160	5.88	31.2	33.8	4.0	---	30.9
W-11	1960	11,620	3.23	45.0	7.8	47.2	---	----
Total		$3,915,634	$ 6.76					

[a]With six operational Corps reservoirs in place: Cagles Mills, Mansfield, Monroe, Salamonie, Mississinewa, Huntington.

Source: Louisville District Corps office project justification materials reviewed by author in July, 1968.

According to Boxley[1]

> Kates, in his study of seasonality of flooding on the Ohio River Basin,[2] found that flooding in the Wabash and White Watersheds was less seasonal (less concentrated) than in the other major watersheds of the Ohio Basin. The cumulative concentration of flood events by months did not exceed 70 percent until the month of May, and the mode of occurrence was March-April. Thus, flooding in the basin encroaches on the crop-planting and early growing season to a much greater extent than in other watersheds of the Ohio Basin.

Flood Control in the Wabash Basin

Private levees have been used for many years as a means of providing some means of flood protection. In the March-April 1913 flood, "every existing levee in the Wabash River basin was breached."[3] Private levees continue to be used to afford protection to areas lacking publicly constructed levees.[4]

The earliest comprehensive report of flooding problems and other water resource problems was the survey completed in 1932.[5]

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[1]Boxley, Institute for Water Resources, Wabash River Basin, IWR Report 69-4, p. 62.

[2]Robert W. Kates, "Seasonality," Papers on Flood Problems, ed. by Gilbert F. White, Research Paper No. 70 (Chicago, Ill.: University of Chicago, Department of Geography, 1961).

[3]Wabash River Coordinating Committee, Wabash River Basin, Appendix-E, p. 35.

[4]There are 145 named levees in the Wabash Basin, with the majority constructed by private interests. In addition, there are other small unenumerated levees. Source: Existing Levees, Map #1, Wabash River Basin Emergency Flood Control Activities, January, 1966. Obtained from Louisville District, U.S. Army Corps of Engineers.

[5]U.S., Congress, House, Wabash River and Tributaries, Indiana and Illinois, H. Doc. 197, 80th Cong., 1st sess., 1932.

This survey according to Boxley "found that improvements of the Wabash River by the Federal Government were not advisable at that time."[1] The 1944 survey report recommended flood control by levees as the most feasible method.[2]

Since the 1944 report, which led to the construction of several levee projects, emphasis switched to multi-purpose reservoirs as the primary flood device. Since single-purpose flood control reservoirs were found to be marginally above unity in benefit-cost analysis, project authorization was more likely with multiple uses. The Corps reservoirs authorized in the 1950's and 1960's were generally multiple purpose reservoirs capable of providing flood control plus low-flow augmentation and water-based recreational activities.

At the present time, six Federally-financed Corps reservoirs are operational in the Wabash Basin: Cagles Mill, Mansfield, Monroe, Mississinewa, Salamonie, and Huntington. The Cagles Mill was the first one having been completed in 1953, the Huntington is the most recent with its 1969 completion date.

Construction of five additional Corps reservoirs was authorized in 1965,[3] but to date the Patoka is the only one under construction.

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[1] Boxley, Institute for Water Resources, Wabash River Basin, IWR Report 69-4, p. 62.

[2] U.S., Congress, House, Wabash River and Tributaries, Indiana and Illinois, H. Doc. 197, 80th Cong., 1st sess., 1944.

[3] U.S., Congress, Senate, Lafayette and Big Pine Reservoirs, Wabash River Basin, Indiana, S. Doc. 29, 89th Cong., 1st sess., 1965. U.S., Congress, House, Lincoln, Clifty Creek, and Patoka Reservoirs, Wabash River Basin, Indiana and Illinois, H. Doc. 202, 89th Cong., 1st sess., 1965.

In addition, a Corps report published in 1967 found favorable consideration for five more reservoirs.[1]

The last in the series of Corps reports dealing with a comprehensive survey of water resources in the Wabash Basin is the final report.[2] The findings of the Corps were that:

> One hundred and eighty seven potential major multipurpose reservoir sites were screened in the Wabash Basin as a part of the general appraisal and preliminary screening studies. This resulted in fifty potential reservoir sites being selected for Phase I study as potential alternatives for meeting defined water resource needs. Sixty possible levee units were considered in the general appraisal and preliminary screening studies. Engineering and economic analysis of the levee projects not displaced by recommended reservoir projects indicated that only ten levee units were economically justified in second position to the recommended system of major reservoirs and watershed projects.[3]

The June 1971 report was also significant in that consideration of non-structural alternatives, in particular flood proofing, were seriously evaluated for the first time. Detailed analysis of the feasibility of flood proofing two communities was undertaken. In the Villa Grove, Illinois study the Corps evaluated the costs of raising houses to the 30-year flood level, the maximum of record at Villa Grove. At Anderson, Indiana, flood proofing to the 100-year level was analyzed.[4]

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[1]U.S. Army Engineer District, Interim Report No. 3, Vol. III.

[2]Wabash River Coordinating Committee, Wabash River Basin Comprehensive Study, Vol. XIII, Appendix L, Project Engineering Studies (June, 1971), pp. 1-43.

[3]Ibid., p. 4.

[4]Ibid., p. 13. See Wabash River Basin Comprehensive Study, Appendix D, June, 1971, for additional details on the flood proofing evaluation.

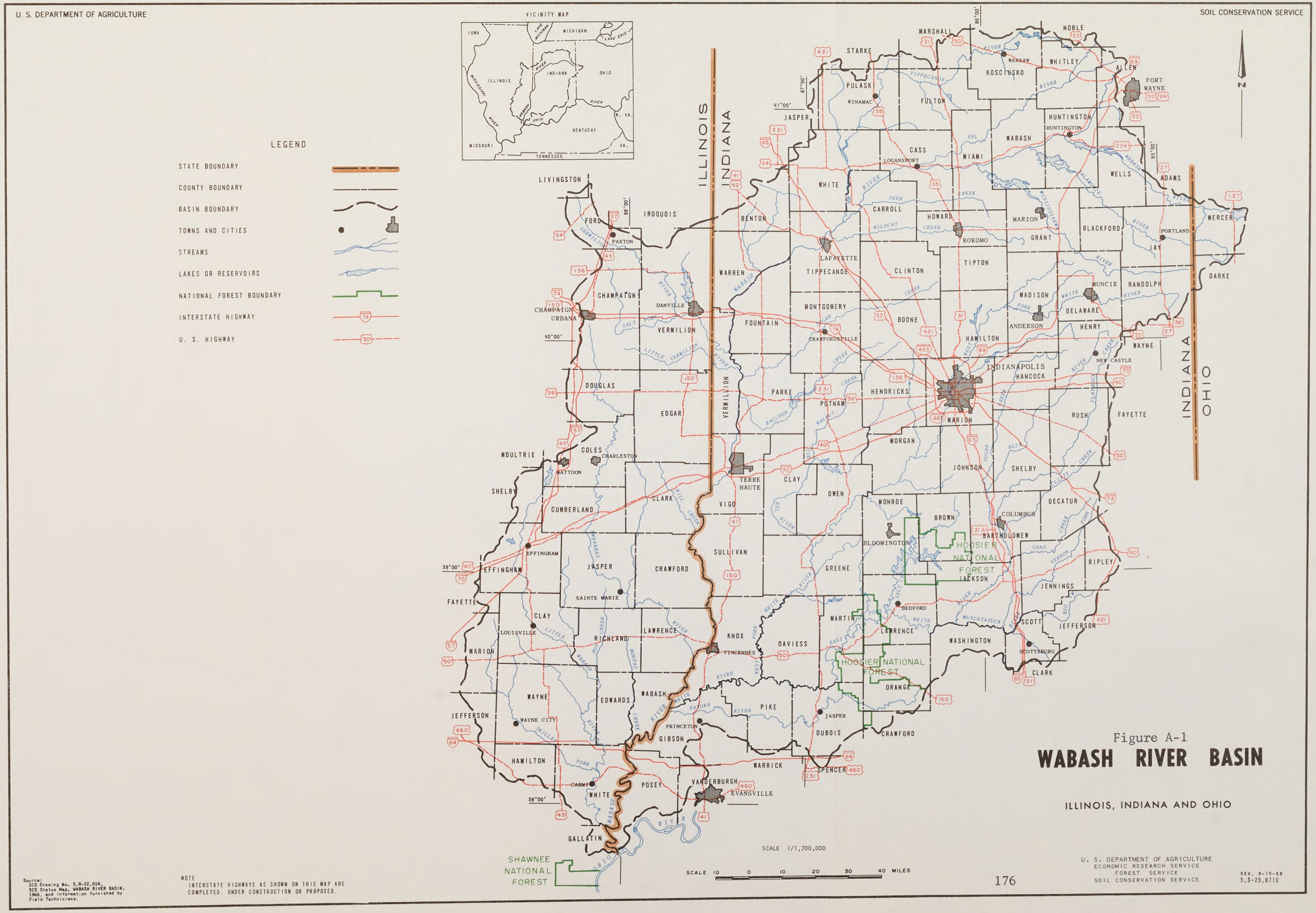


Figure A-1
WABASH RIVER BASIN
ILLINOIS, INDIANA AND OHIO

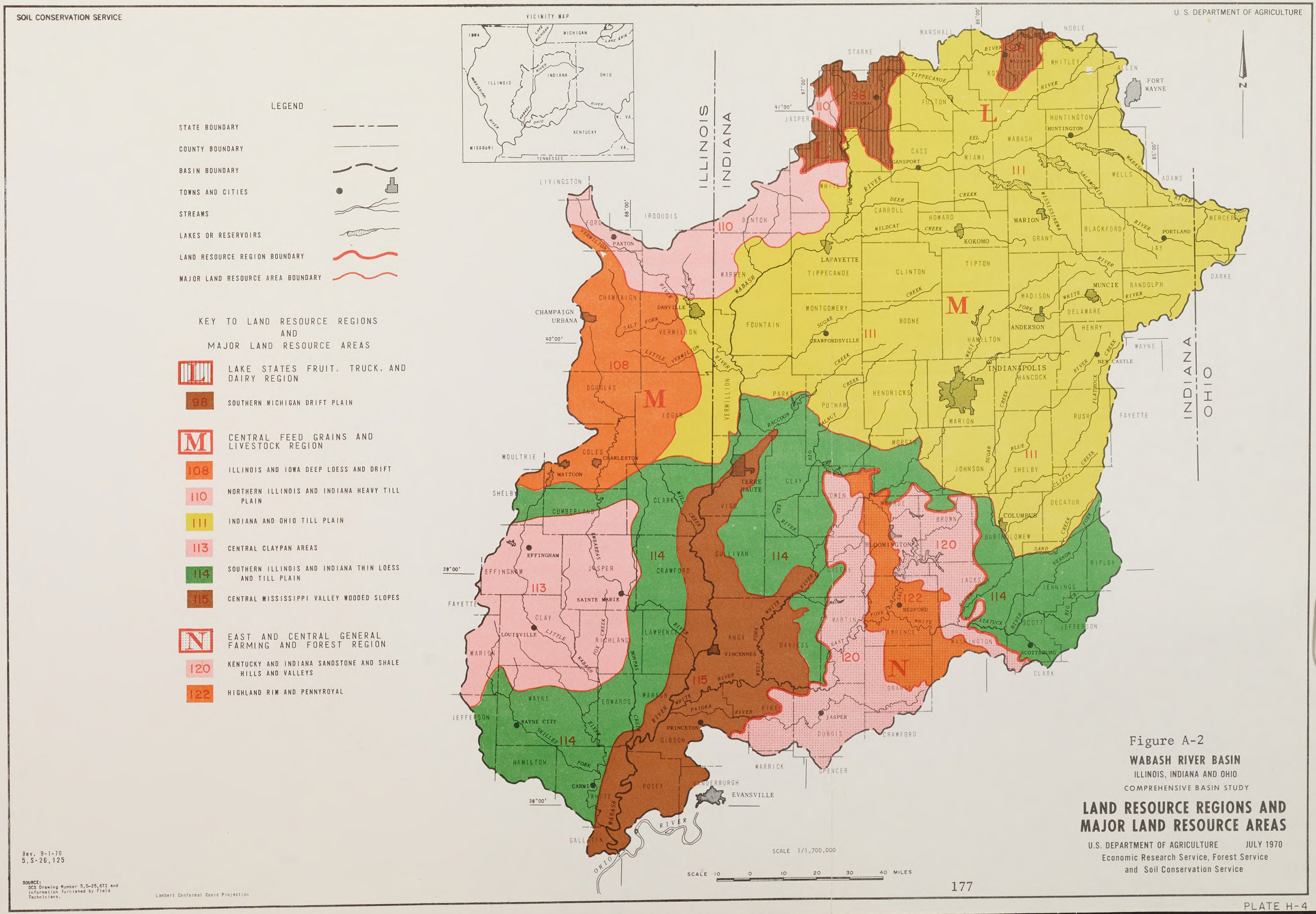


Figure A-2
WABASH RIVER BASIN
ILLINOIS, INDIANA AND OHIO
COMPREHENSIVE BASIN STUDY
LAND RESOURCE REGIONS AND MAJOR LAND RESOURCE AREAS
U.S. DEPARTMENT OF AGRICULTURE JULY 1970
Economic Research Service, Forest Service and Soil Conservation Service

USDA-SCS-LINCOLN, NEBR. 1970

DESCRIPTION OF THE PHYSIOGRAPHIC AREAS

TIPTON TILL PLAIN - Nearly flat to gently rolling glacial plain traversed by several low terminal moraines. Mainly ground-moraine deposits with some end-moraine, valley-train and outwash-plain deposits.

BLOOMINGTON RIDGED PLAIN - Low, broad, morainic ridges with intervening wide stretches of relatively flat to gently rolling ground-moraine.

SPRINGFIELD PLAIN - Flat to gently rolling upland characterized by relatively well-developed, shallow entrenchment of drainage into Illinoian drift overlying Pennsylvanian sandstones, shales, coal, and limestones.

MOUNT VERNON HILL COUNTRY - Rolling topography on thin Illinoian drift over Pennsylvanian sandstones, shales, coal, and limestones. Valleys extensively aggraded with Illinoian till, glacio-lacustrine, and glacio-fluvial deposits.

KANKAKEE OUTWASH PLAIN - A nearly flat area of ground-moraine, outwash-plain, glacio-lacustrine, glacio-fluvial and sandy eolian deposits.

STEUBEN MORAINAL LAKE AREA - Uneven, morainic topography with numerous lakes of kettle origin within moraines or outwash-plains.

MUSCATATUCK REGIONAL SLOPE - Broad and flat to gently rolling, dissected upland on glacial drift over middle Paleozoic limestones and dolomites.

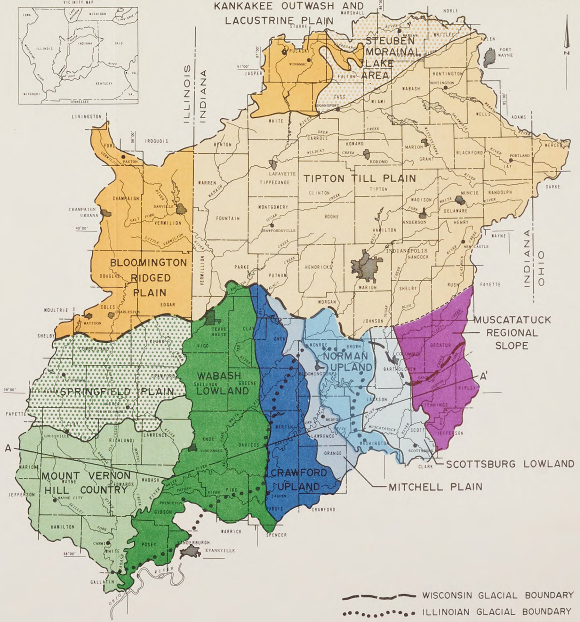
SCOTTSBURG LOWLAND - Nearly level to gently rolling topography on glacial drift over late Devonian and early Mississippian nonresistant shales.

NORMAN UPLAND - Dissected plateau of strong relief characterized by flat-topped narrow divides, steep slopes, and V-shaped valleys developed on relatively resistant siltstones and interbedded softer shales of the Borden Group of early to middle Mississippian age.

MITCHELL PLAIN - Essentially a rolling plain developed on middle Mississippian limestones. Sinkholes, caves, and disappearing streams are common.

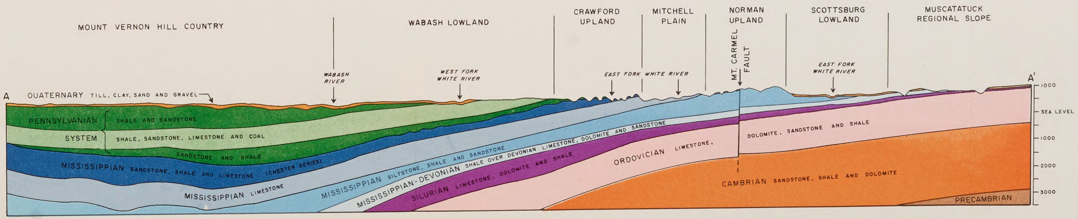
CRAWFORD UPLAND - Rugged, angular topography of strong relief developed on interlayered sandstones, shales, and limestones of the Chester Series of late Mississippian age and sandstones and shales of early Pennsylvanian age. Areas of karst features including caves are common.

WABASH LOWLAND - Rounded land forms of comparatively little relief developed on thin glacial drift over Pennsylvanian shales and coals. Valleys are extensively aggraded by deposition of Illinoian till, glacio-lacustrine and glacio-fluvial deposits.



MAP MODIFIED FROM:
Leighton, M. M., Ekblaw, G. E., and Horberg, L., 1948, Physiographic divisions of Illinois: Jour. Geology, V. 56, No. 1, p. 16-33.
Wayne, W. J., 1956, Thickness of drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary: Rept. of Progress No. 7, Indiana Geological Survey.

SECTION MODIFIED FROM:
Patton, J. B. and others, 1956, Geologic Map of Indiana, Indiana Geological Survey.
Weller, J. M. and others, 1945, Geologic Map of Illinois, Illinois Geological Survey.



SCHEMATIC SECTION SHOWING RELATIONSHIPS OF BEDROCK TO PHYSIOGRAPHY

Figure A-3

WABASH RIVER BASIN
PHYSIOGRAPHIC MAP
ILLINOIS, INDIANA AND OHIO

U. S. DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE
SOIL CONSERVATION SERVICE

SOURCE:
SCS Drawing Number 5,S-25,671 and information furnished by Field Technicians.

REV. 8-15-68
5,S-26,132

USDA-SCS-LINCOLN, NEBR. 1968

APPENDIX B

SELECTION OF STUDY AREA

APPENDIX B

SELECTION OF STUDY AREA

Four primary criteria were considered in selecting the downstream flood area to be evaluated in the empirical investigation. First, the agricultural flood plain lands in the downstream project benefited flood plain must have been evaluated recently with respect to both hydrological characteristics and damage estimates due to flooding. Second, the acreage of the impact area must be sufficiently large so that 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% 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.

Louisville District Corps office 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. Indiana Corps projects considered included twelve authorized or proposed reservoir projects located on major tributaries of the Wabash River. These included the Big Pine, Lafayette, Patoka, Downeyville, Big Blue, Big Walnut, Annapolis, Eel River, Danville, Tippecanoe, Clifty Creek, and Shouls reservoirs.

As single reservoirs were considered, it became readily apparent that none of the single reservoir Corps projects was able to exert a statistically significant effect over a sufficiently large impact area to meet both the CNI minimum acre requirement of 200,000 acres and the significant flood loss reduction requirement (see criteria two in this section).

The authorized Big Pine and Lafayette reservoirs, located on major tributaries of 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.[1] Second, the downstream flood plain contains over 400,000 cropland areas (affects all reaches below W-6). Third, the hydrologic effect of the combined 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--see Table B-1).

Fourth, there is a reasonable expectation that enhancement benefits will be realized if the Big Pine-Lafayette project is

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[1]U.S. Army Engineer District, "Review of Wabash River Basin Covering Reservoir Sites on Wildcat, Big Pine and Sugar Creeks, Indiana for Flood Control and Allied Purposes" [Survey], Interim Report No. 1 (Louisville, Ky., March, 1963). U.S., Congress, Senate, Lafayette and Big Pine Reservoirs, Wabash River Basin, Indiana, S. Doc. 29, 89th Cong., 1st sess., 1965.

TABLE B-1.--Crop Acreage and Flood Protection Index, by Selected River Reaches, Wabash River Basin

Stream	Reach	Total acreage	Crop acreage	Production 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

[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.

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 only cultivated one or two times every five years.[1]

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[1]U.S., Congress, Senate, Lafayette and Big Pine Reservoirs, p. 30.

APPENDIX C

FLOOD CONTROL PLUS OPTIMAL DRAINAGE ALTERNATIVE

APPENDIX C

FLOOD CONTROL PLUS OPTIMAL DRAINAGE ALTERNATIVE

In a previous section 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 C-1). 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

TABLE C-1.--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----------		--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.

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 C-2). 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 C-2.--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------	
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 D

WABASH BASIN LINEAR PROGRAMMING MODEL

APPENDIX D

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. "Low demand" analysis levels are shown in the equations below.

(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]

$$a_{11} X_1 + a_{12} X_2 + \ldots + a_{1n} X_n \geq d_1 = 290{,}912{,}416 \text{ feed units}^2$$

(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: $a_{41} X_1 + a_{42} X_2 + \ldots a_4n X_n \geq d_4 = 150{,}764{,}000$ 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]

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

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

---

[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.

[5] One ton of alfalfa hay provides 11.0 feed units.

[6] One bushel of oats provides .29 feed unit.

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

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

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

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

Land availability restraint:

(3) $b_{11} X_1 + b_{12} X_2 + \ldots + b_{1n} X_n \geq r_1,$

$b_{21} X_1 + b_{22} X_2 + \ldots + b_{2n} X_n \geq r_2$

$\vdots \qquad\qquad\qquad \vdots$

$b_{s1} X_1 + b_{s2} X_2 + \ldots + b_{sn} X_n \geq r_s$

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

$r_1, r_2, \ldots, r_s$ = 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.

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[7]One ton of other hay provides 8.0 feed units.

[8]One animal unit day provides .15 feed unit.

Subarea minimum restraint:

$$(4) \quad e_{11} X_1 + 3_{12} X_2 + \ldots + e_{1n} X_n \geq w_1$$

$$\vdots \qquad\qquad\qquad \vdots$$

$$e_{61} X_1 + e_{62} X_2 + \ldots + e_{6n} X_n \geq w_v$$

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

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

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 10 minutes of computer time or an average of 2.5 minutes per revision.