INCOME REDISTRIBUTION AS A FUNCTION OF FLOOD-CONTROL BENEFITS OF HULAH RESERVOIR, OKLAHOMA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Flood Control Act of 1936 set forth a broad criterion for evaluation of public water resources investments. This criterion proposed that economic analysis of water resources development be a measure of project efficiency in terms of input and output. The criterion has been implemented by procedures which have determined if the expected benefit stream exceeds the expected cost stream. Results of these evaluations, stated as benefit-cost ratios, have provided a test for excluding projects not meeting the efficiency criterion. After thirty-five years, the benefit-cost analysis has evolved into a standard procedure in the economic analysis of public water resources investments.

Various analytical procedures have been suggested for evaluation of benefits and costs. Among these are "Proposed Practices for Economic Analysis of River Basin Projects," May 1950; Budget Bureau Circular No. A-47, December 1952; and Senate Document No. 97, May 1962. A special task force report to the Water Resources Council entitled "Procedures for Evaluation of Water and Related Land Resource Projects," June 1969, (30) contains the latest suggested guidelines for project evaluation. The task force recommends that national income, regional development, environmental enhancement, and well-being of people be the objectives through which water and related land projects are analyzed. Other than environmental enhancement, these objectives are related

in some degree to personal income.

The procedures for evaluation of public water resources projects suggested by the task force involve multidimensional social welfare objectives. The quantification of personal income distribution is one facet of this social welfare. Society's goals and objectives deem this to be very relevant in Federal planning. Area redevelopment programs in economically depressed regions, such as the program authorized by the Appalachian Regional Development Act of 1965, are visual evidence of how income redistribution is obtained.

Planning agencies measure the desirability of projects through the benefit-cost analysis. Only those projects showing a B/C ratio greater than one are submitted to Congress for authorization. Since the portion of the Federal budget for water resources development is limited, not all justified projects can be authorized. Congress is placed in the position of having to decide which of several "good" projects are in the best interest of the nation. It is therefore essential that the information provided the authorizing bodies reflects all facets of the multidimensional social welfare objectives.

Decisions about resource investments affect diverse interests. The planning procedures must provide the information which will ensure decisions acceptable to these varying interests. The analytical system must show who is affected by a particular proposal, i.e., who receives what benefits and pays what costs.

Benefit-cost procedures currently used are not geared to measure personal utility or social welfare. This limited procedure cannot provide decision makers the information needed to effectively implement the four social objectives previously mentioned. This is evident from the

disagreement over how various projects meet requirements of technical or scale efficiency. Economic principles on which the efficiency criterion is founded are incapable of answering questions of the incidence of benefits and costs.

Achieving multidimensional welfare objectives will require evaluation of individual marginal utility. Such evaluations may produce results inconsistent with the efficiency analysis of conventional benefit-cost procedures. However, the evaluations will provide information needed by the decision makers in fulfilling objectives such as income redistribution.

This study represents an effort to measure the redistribution of income that has resulted from Hulah Reservoir, a Corps of Engineers project located in Osage County, Oklahoma. The scope of the study is limited to the measurement of income redistribution applicable to the people in Osage and Washington Counties immediately below Hulah Reservoir. It is hoped that this study will provide useful empirical knowledge of the welfare impacts of water resources development and that some improvement in present techniques of economic evaluation might result.

The objectives of the study are to determine the people to whom the flood-control benefits have flowed, the relative income status of those people, the actual flood-control benefits received, and a welfare value for the benefit flow. Welfare equivalent weights showing the welfare value of various incomes in regard to a base income are calculated from marginal tax rates. Flood-control benefits are assumed to flow to a cross section of the county populations with the size of the flow to each individual being related to the individual's income.

Actual flood losses prevented within specified stream reaches are available from the Tulsa District, Corps of Engineers. These recorded benefits are reallocated to apply specifically to the two-county area being studied.

Knowing the relative direction and size of the benefit flow and the welfare equivalent weights with which to evaluate this flow, income redistribution factors are then calculated. These factors are social welfare functions for weighing the flow of benefits throughout the income structure of each county by use of the marginal utility concept. The factors indicate the desirability of an income shift during any year of project operation. Multiplication of the reallocated annual flood-control benefits by the redistribution factor for the year results in the net income redistribution benefit.

CHAPTER II

REVIEW OF LITERATURE

Benefit-Cost Analysis

The heretofore meager Federal involvement in multiple purpose water resources development was significantly expanded by the Flood Control Act of 1936. This act brought increasing pressures for new projects from a limited Federal budget. Credit must go to Congress for providing within the act tools through which it could meet these pressures.

The Flood Control Act of 1936 established a procedure for measuring the desirability of a water project. This procedure is used to reduce projects to a common denominator, thus providing a control on the economic arguments of proposed projects. Basis for the procedure evolved from the statement that a project is economically justified if "benefits to whomsoever they may accrue are in excess of the estimated costs, and if lives and social security of people are otherwise adversely affected."[1] The justification procedure so established involved the collection and evaluation of data to determine the relative preferredness of alternatives.

The relative preferredness of projects through benefit-cost

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[1]United States Code, Washington, D. C.: U. S. Government Printing Office, 1940, p. 2964.

analysis is usually weighed in terms of efficiency, or the relationship between input and output. Stated in other terms, benefit-cost analysis has been used to rank projects according to their contribution to the national product with little concern over the direction of the benefit and cost streams. The guidelines established by the Flood Control Act of 1936 present benefits as non-utilitarian quantities. "Benefits to whomsoever they may accure" denotes that the gains of one person are equivalent in value to gains for any other person.

There exists a dichotomy between this method of analysis and one of the underlying causes for Federal intervention in public water resources development. Federal control was recognized as a means to encourage efficient and equitable allocation of resources, an allocation not provided by the private market. This is not to imply that the mere presence of the Federal government in water resources development will assure the desired efficiency. But it will assure needed development although no market demand for the development exists and it will promote public rather than individual gains from national resources.

Haveman (5) attempts to measure the misallocation of national resources because of economically inefficient projects developed by the Corps of Engineers. He states that "one can hardly doubt that a great number of projects have been constructed which, if economic efficiency had been the sole objective, would not have been constructed."[2] With but few exceptions the projects analyzed in his works had a computed benefit-cost ratio greater than one. He doubts not the accuracy of the

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[2]Haveman, Robert H. Water resource Investment and the Public Interest, Nashville, 1965, pp. 116-117.

benefit-cost ratio computed by the Corps of Engineers but questions the weight placed upon project recommendation based entirely on this ratio.

Objective functions of government projects in water resources development have been shown to include more than maximization of efficiency. Low-income areas receive a greater portion of the Federal appropriations for water resources projects than would be expected based on efficiency criteria alone (5).

This fact demonstrates that Congress gives some weight to the implicit goal of income redistribution, even though current benefit-cost analysis makes no attempt to evaluate such a goal. With the noticeable concern of Congress to improve the social well-being of low-income families, it appears that benefit-cost analysis should be expanded so as to be relevant to new micro-economic implications of Federal water resources development.

Present-day benefit-cost analysis must veer from its well beaten path leading to maximization of national product. The developing social objectives of Federal water resources investments will be achieved only if the evaluation procedures complement these objectives. Evaluations to determine the price relation between project inputs and outputs is no longer a complete analysis. Social objectives suggest the inclusion of marginal utilities as factors influencing the size of project benefits.

Economic Efficiency

Economic efficiency has been widely written and discussed but a consistent definition of this concept is still lacking. Haveman (5) and Maass (12) define economic efficiency as the measure of, or the size

of, the increase of national income or product with no restriction on its distribution. The distribution or redistribution of income is a separate variable or welfare determinant.

Krutilla and Eckstein define economic efficiency as a "situation in which productive resources are so allocated among alternative uses that any reshuffling from the pattern cannot improve any individual's position and still leave all other individuals as well off as before".[3] Such a concept leads to the maximization of aggregate output of those goods and services preferred by the members of the society per unit of input. Reorganization of the resource employment to improve the conditions of some people at the expense of others, if solely on ethical grounds, results only in redistribution of income. The reshuffling can be regarded as more efficient only when those who benefit gain more than enough to compensate the losers. A measure of individual utilities therefore cannot be divorced from the economic efficiency concept.

Maass also states that a major limitation in the application of benefit-cost analysis is that it ranks projects only in terms of economic efficiency. However, benefit-cost analysis accurately measures economic efficiency only when there is no deviation, such as income redistribution, from the efficiency concept. There are no provisions within the analysis to equate individual gains and losses; consequently, it cannot be inferred that benefit-cost analysis fully measures economic efficiency. If benefit-cost analysis is to assure the suggested objectives for water resources projects, it must be reoriented so that the welfare status of project participants is reflected in the economic efficiency

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[3] Krutilla, John V., and Otto Eckstein. Multiple Purpose River Development, Baltimore, 1958, p. 16.

ratio. That is, the economic efficiency test should include the measure of individual marginal utilities.

Project evaluation by the Corps of Engineers leads to technical or scale efficiency. The Corps of Engineers evaluates proposed projects through the benefit-cost analysis to determine both maximum output per invested dollar, stated in terms of the B/C ratio, and maximum excess benefits over costs. The benefit-cost analysis has assured the most advantageous project scale and has determined justified purposes in multiple purpose water resources development projects. Little regard for welfare appears in the analysis.

Project evaluation in terms of economic efficiency so defined exemplifies the lack of quantifiable parameters regarding general welfare. The most rigorous measure of economic efficiency is perhaps the Pareto optimum theory previously stated. However, this proposition provides little help in evaluating gains to general welfare.

An ideal measure or welfare function would express all human goals in such a manner that the larger the function the happier and more contented society will be. Would maximization of national income maximize national or general welfare? No, because income is not a guarantee for happiness. Society desires distribution of national income but cannot agree in what proportions. Other undefinable values of society lead to the conclusion that an ideal measure of economic efficiency is not attainable.

Several noted welfare economists have suggested theoretical approaches for measuring changes in economic efficiency. Hicks (6) proposed that economic efficiency has increased if the individuals who experience a gain from an economic change would be willing to

compensate those individuals who experience a net loss rather than forego the impact of the change. This proposal is of little additional help over the Pareto optimum. The determination of the people who benefit and lose and in what amounts would be an insurmountable problem. This proposal assumes that the losses and gains of individuals are of equal utility and can be measured in terms of market prices.

Professor Little (11) recognized that ethical considerations cannot be excluded from measurement of economic efficiency or welfare. His proposed welfare criterion was that "an economic change increases welfare if it causes a good redistribution of wealth, and if the potential losers could not profitably bribe the potential gainers to oppose it, always assuming that no still better change is therefore prejudice."[4] This criterion minimizes the social inequality of Hicks' proposal but it requires the responsible planner to weigh certain distributions of income as better or worse.

Although all of these proposals are relevant welfare yardsticks, they offer little practical assistance in the quantification of economic efficiency. Eckstein, (1) realizing that ethical considerations are beyond numerical analysis, suggested that the welfare impact of any economic change be measured based on the marginal utility of income. In some respect this approach is supported by the government's policy for graduated tax rates on personal income. However, if the government supported the principal of marginal utility as sole basis for the tax structure, it would tax away all incomes above some level determined by society.

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[4]Little, Ian Malcolm David, A Critique of Welfare Economics, Oxford, 1950, p. 57.

The approach appears feasible nonetheless in that numerical weights can be determined for relative utilities of income for any selected base. Haveman (5) used the marginal utility of income function to show that income redistribution effects, when applied to a project not exhibiting technical efficiency, can many times qualify the project under the economic efficiency criterion. This can result from the high utility value of those influenced by the project. The welfare value of the benefits in such cases is larger than the value of those same benefits stated in terms of market prices.

Income Redistribution

Federal expenditures in water resources development have resulted in redistribution of income. Congressional appropriations for water related projects tend to favor the poor states over the rich ones, as shown in Table I. Studies have shown that as a state's rank in per capita appropriation among the fifty states becomes higher, that state's rank in per capita income tends to be lower.

Three functions of a governmental budget are service, stabilization of economy, and the distribution of income. It has been assumed in past efficiency analysis of water resources development that the marginal utility of money is constant for all income groups and that income distributions are fixed and good.

If recent recommendations concerning Federal procedures in water resources development are adopted (30), new criteria for implementing these procedures must be developed. These criteria will be the framework for evaluating four objectives - national economic efficiency, regional economic growth, environmental quality, and personal income

distribution. In regard to the last objective, additional efforts should be placed on quantifying the redistributional aspects of proposed projects. Personal income distribution appears to be a vital aspect of society's goals.

TABLE I[5]

COMPARISON OF MEDIAN RANK IN PER CAPITA APPROPRIATION AND PER CAPITA INCOME

Groups of Ten States From Highest to Lowest Per Capita Appropriation	Median Rank by Per Capita Appropriation	Median Rank Per Capita Income
Top 10 states	5.5	38.5
Next 10 states	15.5	30.5
Next 10 states	25.5	30.5
Next 10 states	35.5	17
Bottom 10 states	45.5	15

Regional income distribution has been the objective of past specialized programs such as Ozarkia and Appalachia. Procedures utilized in these projects could be excellent guidelines for income redistribution studies of proposed water resources projects. Techniques for evaluation of redistribution benefits should be applied on an individual project basis and not as a standard procedure for project justification. The incidence of water resources development in low income

[5] Haveman, p. 56.

areas substantiates the necessity for analysis of redistribution benefits when that clearly is a project intent.

Marglin (13) develops design criteria for water resources systems which incorporate the somewhat implied objective of income redistribution. He states that to achieve a measurable amount of income redistribution, a lesser degree of efficiency must be accepted. If this be true, resulting conflicts between efficiency and economic efficiency, as defined in this thesis, should not impede evaluation of redistributional effects. The past records of Congress indicate a willingness to sacrifice some efficiency for the sake of improving welfare, or economic efficiency. Most people would rather see general welfare improved through useful projects rather than through direct income payments.

Marglin goes on to indicate that measuring the benefits from income redistribution is not a major difficulty. But that defining the constraints or the efficiency values that society as a whole agrees upon makes this procedure difficult to implement. However, this is to be expected when the objective deviates from the neutral position of simple efficiency. He suggests that objectives other than efficiency be used to measure the marginal opportunity cost of income redistribution in terms of efficiency.

Freeman (4) points out, as others have, that today's benefit-cost procedures maximize national income and can maximize social welfare only if one of two conditions are met. Either equal income increments have the same welfare equivalent or there exists a means for achieving a proper distribution of income. He assumes that income distribution does matter and also that there is no effective system of achieving the

proper income distribution. He further assumes that there is a value judgment held by society concerning the distribution of income. A study of a model project is made by him to determine the problems that arise when income distribution is considered.

Planning and selecting projects on the basis of their impact on the distribution of income implies that there is a social welfare function capable of evaluating alternative distributions. Freeman investigates the form for such a function by assuming that total social welfare or utility is the summation of individual contributions to society when those contributions are a sole function of individual income. He concludes that social welfare is at a maximum for a given aggregate income when all incomes are equal. However, since incomes are not equal, it is apparent that studies to determine income variations are prerequisites to utility analyses.

CHAPTER III

HULAH RESERVOIR AND PROJECT AREA

Description of Project

Hulah Dam and Reservoir Project was authorized by Congress in the Flood Control Bill of 1936 as one unit in the comprehensive plan of development for the Verdigris and Arkansas River Basins (19). The project was designed and built by the Tulsa District, Corps of Engineers, to fulfill purposes of flood control, water supply, and pollution abatement. Construction began in May 1946 and the project was completed in 1951.

The project is located in northeastern Oklahoma on the Caney River, the largest tributary of the Verdigris River. The dam is two miles west of Hulah, Oklahoma, five miles south of the Kansas State line, and about 15 miles northwest of Bartlesville, Oklahoma. The reservoir lies northwestward from the dam in the upper reaches of the high, rounded Osage hills, an area much of which is within the Osage Indian Reservation. These and other physical features of the project area are shown in Figure 1.

Hulah Dam is a rolled earthfill structure 4,728 feet long, rising to a height of 94 feet above the Caney River. Flows from the structure are controlled by a concrete spillway 472 feet long having 10 tainter gates. State Highway 10 crosses the dam, linking State Highway 99 and U. S. Highway 75. By controlling the flows from 732 square miles of

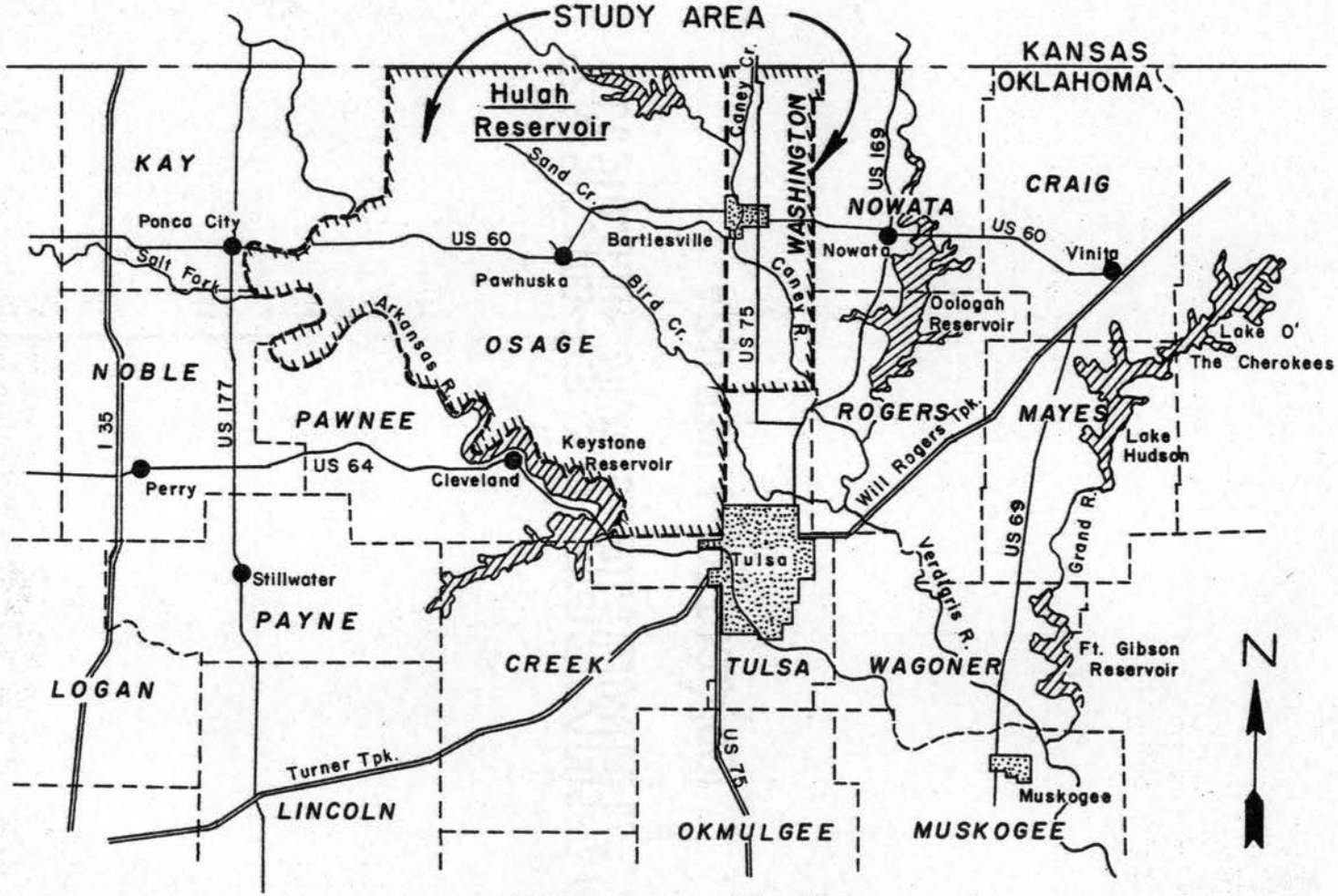

Figure 1. Location Map for Hulah Reservoir

the 2,111 square miles of drainage area of the Caney River Basin, Hulah Reservoir provides flood protection for about 57,000 acres downstream from the dam (20).

When operated in conjunction with other projects in the Arkansas River Basin, Hulah Reservoir aids in water control along the Arkansas River. Since 1951 Hulah Reservoir has been credited with preventing about $18,700,000 flood damages.[1] The reservoir has 257,900 acre-feet of storage for flood control and 33,400 acre-feet of conservation storage for water supply to the city of Bartlesville. Low flow augmentation and recreation are other beneficial purposes of this reservoir (20).

The project area is favorable to ranching and related agricultural activities and to the production of petroleum products. Major flood losses in the area were sustained by crops and agricultural improvements prior to construction of Hulah Reservoir. The larger floods caused extensive damage to residential and commercial property in the city of Bartlesville. Crop losses generally accounted for about 60 percent of the total flood losses in the Caney River valley. Because of high frequency flooding prior to project construction, production of high value crops such as alfalfa was reduced.

Economic Conditions Within the Study Area

The economies of the two counties to be studied in this thesis have contrasting features. This is illustrated by comparisons of population growths, relevant indicators of economic growths. The

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[1] This data was obtained from Corps of Engineers, Tulsa, Oklahoma, May, 1970.

population in Osage County has decreased continuously from about 47,000 in 1930 to about 32,000 in 1960, a reduction of 32 percent. Conversely, the population in Washington County has increased uniformly from about 28,000 in 1930 to a little over 42,000 in 1960, an increase of 50 percent (3).

Distributional aspects of the population during the 1950-60 period in the two counties are shown in Figure 2 (24) (25). Not only has the total population declined in Osage County but there has also been a decrease in the number of persons below age fifty, the sector most influential on economic growth. Increases are noted in all segments of the population in Washington County, being significantly larger, however, in the younger half of the population.

Employment within the two counties has been predominantly agriculture, mining (petroleum), construction, manufacturing, and retail trade. The distribution of employed persons by work sectors and the changes in this distribution between 1950 and 1960 are shown in Table II (24) (25).

The data on distributions of employment clearly show a sharp decline in agricultural employment. Since this trend is noted throughout the United States, the effects of this decline on the economies of the two counties are not apparent. The principal crops produced include corn, sorghums, wheat, alfalfa, and cotton. Information depicting the size and trend of agriculture in these two counties from 1945 to 1959 is shown in Table III (21) (22) (23). This information is indicative of the economic influences of agriculture in the study area.

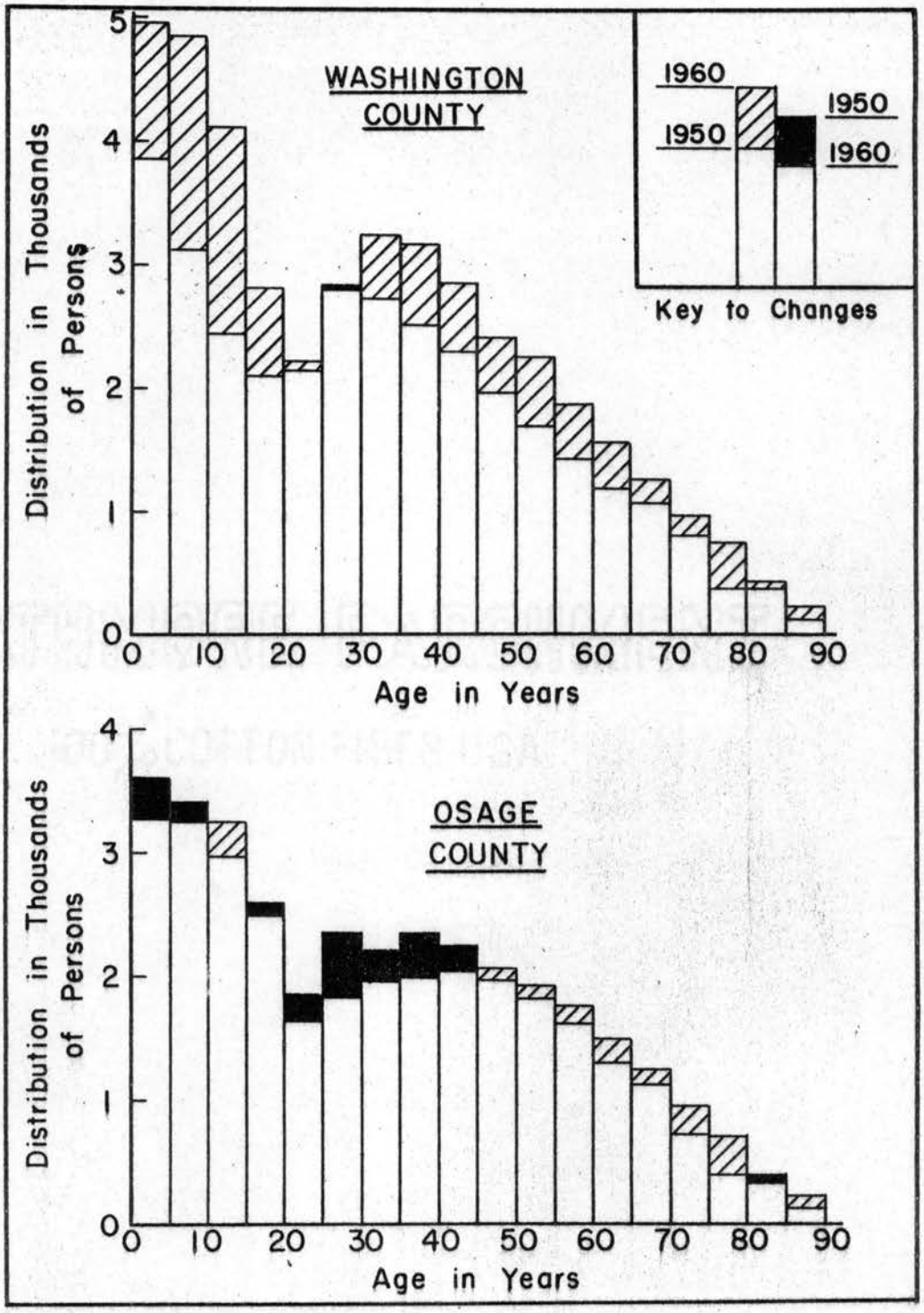

Figure 2. Changes in Age Distributions

TABLE II

DISTRIBUTION OF EMPLOYED PERSONS

Employment	Osage County 1950	Osage County 1960	Washington County 1950	Washington County 1960
Agriculture	2,247	1,158	915	454
Mining	1,526	1,761	3,687	3,797
Construction	811	754	1,217	810
Manufacturing	1,128	1,212	1,636	2,626
Transportation	464	483	274	280
Communications	102	120	189	183
Utilities	156	233	143	454
Wholesale Trade	201	343	187	692
Retail Trade	1,593	1,858	1,742	2,150
Education	435	561	410	725
Public Admin.	417	420	406	519
Entertain. & Recr.	138	365	145	127
Others	1,749	1,666	1,987	2,947
Totals	10,967	10,934	12,938	15,764

TABLE III

COUNTY AGRICULTURAL DATA

Characteristic	Year 1945	Year 1949	Year 1959
Osage County			
Value of crops	$1,470,000	2,119,000	1,319,000
Value of livestock	9,415,000	10,165,000	10,786,000
Land in farms (acres)	1,431,000	1,327,000	1,293,000
Washington County			
Value of crops	$ 548,000	345,000	426,000
Value of livestock	1,620,000	1,361,000	2,451,000
Land in farms (acres)	240,000	251,000	242,000

Review of Estimated Benefits and Costs of Project

In the project report completed in 1939 and revised in 1947, Hulah Reservoir was estimated to prevent flood losses along the lower Caney River and a proportionate part of flood losses on the lower Verdigris and Arkansas Rivers. The document states that about $305,000,[2] or about 70 percent of the annual flood losses in the lower Caney River, would be prevented. The flood-control storage in Hulah Reservoir comprised about 14 percent of the total flood-control storage authorized for the Verdigris River reservoir system. The estimated annual flood losses prevented in the lower Verdigris River as a result of Hulah Reservoir were computed to be about $64,000, or 14 percent of the total losses prevented by the Verdigris system.

Protection of estimated future development and enhanced values of residential and farm property increased attributable benefits by an additional $138,000.[3] Downstream benefits on the Arkansas and Mississippi Rivers, estimated in studies prior to the Hulah study, amounted to slightly more than $200,000.[4] Summation of these regional amounts showed a total estimated annual benefit for flood control of about $707,000.

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[2] U. S. Army Corps of Engineers, Definite Project Report, Hulah Dam and Reservoir, Caney River, Oklahoma and Kansas, "Economic Studies," Tulsa, Oklahoma, 1939, p. 9.

[3] Ibid., p. 10.

[4] Ibid., p. 11.

The authorizing document indicated the estimated cost of Hulah Dam and Reservoir to be $11,050,000.[5] Actual construction costs, including interest during construction, amounted to $11,686,000.[6]

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[5] Ibid., p. 13 of main report.

[6] Tulsa District Corps of Engineers, January 1970.

CHAPTER IV

PROCEDURE

General

Income redistribution has only recently received attention for its applicability to economic justification of water resources development. In 1946 when construction on Hulah Reservoir was initiated, calculation of such effects was not included in project evaluation at the planning level. However, as mentioned previously, the process of authorization by Congressional action has given some undetermined value to such welfare considerations.

Income redistribution implies that income is shifted from one group to another. Large public investments in water resources projects result in a shift of income from the people paying for the project, the Federal taxpayers in the case of flood control, to a more limited group of people receiving the benefits. This shift is from a group of people with largely dispersed income levels, the average for which can be represented by the national or state income average, to a group with income levels influenced substantially by the economic conditions existing in the locality of the project.

The Social Value of Income Redistribution

Flood-control projects cause income to flow into the area influenced by the project. The aspect of this flow evaluated was that portion resulting from reduction of flood damages. If all other factors are equal, projects benefiting a group poorer than the average Federal taxpayer are preferred over projects benefiting a group richer than the average taxpayer because of the larger welfare value.

The welfare status of benefit recipients in relation to a selected base income was a determinant on the social value of income redistribution. To say that money has a value defined by the income level of its recipient required a value judgement. Support for this judgement was offered by the progressive income tax. The Congressional governing bodies have, in effect, stated that the poor man's income is more essential to his personal well-being than to the national well-being. Value judgement on this basis is accepted by the public.

The utility value of income was measured as a marginal tax rate between adjacent income levels. These marginal tax rates were developed from Federal income tax statistics.

Haveman (5) constructed marginal tax rates for increments of the national income structure. He computed these rates by ascertaining the ratio of the change in income tax paid per return and the change in gross income per return between adjacent income brackets. The procedure followed in this thesis was patterned along similar lines. But because of the limited effects of Hulah Reservoir outside the State of Oklahoma, an income cross-section of Oklahoma, rather than that of the nation, seemed more appropriate to this work.

Since welfare is a relative term, the validity of its measurement is dependent upon the base income selected for that measurement. The base income used in this study was the national average income. Selection of this income as the welfare basis resulted from the following considerations.

Flood-control projects are funded through Federal appropriations with the cost being spread among all states. This results in income being transferred from a group of average taxpayers to the project area. Such a transfer denotes a change in welfare of the project benefactors at the expense of the nation and should therefore be measured relative to the welfare of the nation.

Income distribution is largely a Federal responsibility. Small entities can do little to correct inequitable distributions. The Federal government has accepted this responsibility in past programs and is prepared to initiate national objectives (30) for water resources development that would increase the responsibility. Income distribution as a national objective indicates that the national income structure will be the guideline for measuring "good" and "bad" distributions.

Therefore, the marginal utility of income in relation to the base or national income was equated as the ratio of marginal tax rates. This measure of welfare value was designated welfare equivalent weight, U, and was computed as

$$U = R / r \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

where R is the marginal tax rate at the national average income (utility equals unity) and r is the marginal tax rate at the mean of each income level.

Areal Distribution of Flood-Control Benefits

The geographical area selected for this study encompassed Osage and Washington Counties. Since Hulah Reservoir is the only major flood-control project on the Caney River, flood-damage reduction in the two counties is attributable to this reservoir. The Verdigris River Basin below Caney River was not included in the study area because Oolagah Reservoir, located on the Verdigris River just upstream of its confluence with the Caney River, has resulted in considerably greater flood control in the Verdigris River Basin in comparison with Hulah Reservoir.

The contrasting characteristics of Osage and Washington Counties also contributed to selection of this study area. Washington County has had one of the highest per capita incomes in Oklahoma because of its proximity to Tulsa and because of the large number of technical people living in Bartlesville. The per capita income in Osage County however has been very close to that of Oklahoma. These income characteristics influenced the distribution of flood-control benefits in the counties.

The Tulsa District, Corps of Engineers has made regular flood-damage surveys to evaluate the flood-control benefits of Hulah Reservoir. Data collected in surveys after major floods are used to construct stage-damage curves. During each flood the actual stage was recorded, and by a process of flood routing, the stage which would have occurred without the reservoir was determined. Using actual and modified stages and stage-damage curves, the reduction in flood damages, or project benefits, was then calculated.

The stage-damage curves were adjusted periodically whenever damage

surveys indicated such adjustments were necessary to reflect changed development or land use within the flood plain. Damage reductions determined from these curves were revised by the Corps to reflect increased construction costs and inflation. This was accomplished by multiplying the measured benefits by the ratio of the Engineering News-Record Construction Cost Indexes of the year of the flood and the year of the latest adjustment of the curve.

Areal limits of the selected two-county area had no established correlation with the reaches for which the Corps of Engineers evaluated actual benefits. The Corps has defined its reaches by physiographic features such as tributary streams. Flood routing and stage determination involve less work when this type division exists. The reaches falling within the bi-county study area have been defined as follows: From Hulah Dam to Caney Creek; from Caney Creek to Sand Creek; and from Sand Creek to the Verdigris River. These limits were shown in Figure 1 on page 16.

The boundaries of Osage and Washington Counties did not follow these specified reaches. That is, the area within each county encompassed portions of, all of, or none of any one of the three reaches. Therefore, the problem was one of allocating measured reach benefits according to the applicable area within each county.

The magnitude of flood-damage reduction in a reach is partially affected by the location of the reach and by the rainfall pattern causing the flood. The uncontrolled drainage area above a reach is proportional to the distance the reach lies downstream from the dam site. In large reaches, the rainfall pattern may not encompass the drainage area, thus causing variable flooding throughout the reach. However,

this possibility is lessened in samll reaches and the resulting flooding can be described by some constant relation with the physical characteristics of the reach. Therefore, it was assumed that the floods for which benefits have been compiled were extensive enough to cause a discharge related to some physical feature of the three reaches.

The percent of total reach benefits that accrue to any point within the reach can be determined through two physical features - either the drainage area above the point or the distance from the lower end of the reach to the point in question. The latter feature was selected as the more appropriate relation because of first, drainage areas did not follow regular limits such as county outlines, and second, flood-damage reduction occurred along the stream valley, a feature closely related to stream length.

The Size and Direction of Benefit Flow in Osage and Washington Counties

The flood-control benefits of Hulah Reservoir as computed by the Corps are stated in terms of market prices. Income redistribution caused by these benefits was evaluated as an increase or decrease in the market-price benefits because of individual utility values of the benefit recipients. Therefore, it was necessary to determine both the individuals to whom benefits flowed and the income level of those individuals.

Rosenbaum (17) assumed that persons owning property in the affected flood area receive benefits in proportion to the value of that property. The procedure involved determining the income distribution of people living in the flood plain as opposed to people living

outside the area and then relating the value of property owned to this distribution. He determined property values through inspection of property-assessment records for the affected area.

It was felt that, because of the extensive collection of data required to relate income with property value, some other criterion was necessary. One could assume that all individuals benefited equally. However, since flood damages and flood-damages prevented were measured in terms of the values of real property flooded or protected, the approach by Rosenbaum merited consideration. A further analysis of his approach showed a linear relation between income and property owned at incomes less than twice the median income of that particular study area. At incomes greater than twice the median, the relation became a second order equation. Rosenbaum's conclusions were based on study of a small and somewhat poverty-striken area.

Reid (16), in a detailed study of the relation between housing expenditures and income, concluded that the elasticity of housing with respect to income was between 1.5 and 2.0, with a tendency to be nearer the larger value. Stated otherwise, a 1.0 percent rise in income was accompanied by a 1.5 to 2.0 percent rise in housing. Because of the comprehensive nature of the Reid study, it was felt that the housing-income relation presented therein was more representative than the Rosenbaum study. An elasticity factor of 1.8 was selected for use in this study.

In view of the criteria that benefits are related to property values and that property values are related to income, it was apparent that the distribution of people according to income class was a determinant on the size and direction of the benefit flow. The group that received the flood-control benefits was assumed to have incomes similar

to the income cross-sections of the counties. Therefore, to define this determinant, the income cross-sections for Osage and Washington Counties were developed.

Income Redistribution Factors

Income redistribution factors were calculated to show the social welfare value of a money flow across the income structure of any region. The basic assumption for development of these factors was that equal increments of income had different and measurable welfare significance to whom they accrued.

Sample calculations of the income redistribution factors for Osage County for the years 1949 and 1954 are given in Table IV. The calculations related two parameters of the benefit flow to the appropriate welfare equivalent weight for each income class. One parameter of the benefit flow, direction, was defined by the previously developed county income distribution. The fraction of the population in each income class established the percent of the benefit flow to each class. The other parameter of benefit flow, size, was related to income by an elasticity factor, 1.8 in this case. This factor accounted for the ownership of more property at higher incomes.

The product obtained from multiplication of the property factor and the fraction within each class represented the relative value of property owned by individual segments of the income structure. The product was relative because the property factor established a ratio of property values between income classes, not an assessment value for that property. This procedure was analogous to multiplying the average monetary value of property owned in each class by the number of people

TABLE IV

COMPUTATION OF INCOME REDISTRIBUTION FACTORS FOR OSAGE COUNTY, 1949 and 1954

Income Class ($1000)	Median of Class ($1000)	Property Factor	Fraction in Income Class	Property Factor X Fraction	Weighted Product	Welfare Equivalent Weight	Income Redistribution Factor
			1949				
0 - 1	0.5	1.00	.20	0.20	.021	6.80	.143
1 - 2	1.5	4.60	.20	0.92	.096	2.12	.204
2 - 3	2.5	8.20	.19	1.56	.162	1.11	.180
3 - 4	3.5	11.80	.18	2.12	.221	0.94	.208
4 - 5	4.5	15.40	.07	1.08	.112	0.63	.070
5 - 6	5.5	19.00	.07	1.33	.138	0.38	.052
6 - 7	6.5	22.60	.03	0.68	.071	0.38	.027
7 - 8	7.5	26.20	.02	0.52	.054	0.37	.020
8 - 9	8.5	29.80	.01	0.30	.031	0.35	.011
9 - 10	9.5	33.40	.01	0.33	.034	0.33	.011
10 - 15	12.5	37.00	.01	0.37	.039	0.32	.012
15 - 20	17.5	40.60	.005	0.20	.021	0.29	.006
Totals				9.61	1.000		.944
			1954				
0 - 1	0.5	1.00	.15	0.15	.012	7.50	.090
1 - 2	1.5	4.60	.16	0.74	.061	2.35	.143
2 - 3	2.5	8.20	.16	1.31	.108	2.00	.216
3 - 4	3.5	11.80	.15	1.77	.146	1.15	.168
4 - 5	4.5	15.40	.12	1.85	.152	0.92	.140
5 - 6	5.5	19.00	.08	1.52	.125	0.66	.082
6 - 7	6.5	22.60	.06	1.36	.112	0.62	.069
7 - 8	7.5	26.20	.04	1.05	.086	0.59	.051
8 - 9	8.5	29.80	.02	0.59	.048	0.57	.027
9 - 10	9.5	33.40	.02	0.67	.055	0.55	.030
10 - 15	12.5	37.00	.02	0.74	.061	0.53	.032
15 - 20	17.5	40.60	.01	0.41	.034	0.50	.017
Totals				12.16	1.000		1.065

in each class. The products were added to give a measure of the gross value of property owned in Osage County.

By dividing the individual products by the gross value, the percent of gross value in each class was obtained. These percents were shown as "weighted products." Restatement of the assumption concerning the flow of benefits might clarify the significance of these calculations. The assumed benefit flow was to a group of people in Osage County having incomes similar to a cross-section of the population within that county. In other words, if fifteen percent of the county population was in the $2,000 to $3,000 income class in 1954, fifteen percent of the benefit recipients was also in this class.

Income increments for these calculations were the same as those used in the computation of welfare equivalent weights. This continuity allowed the multiplication of the weighted products for each income class by its respective welfare equivalent weight to establish welfare values for a benefit flow to income increments. These incremental values were totaled to arrive at the income redistribution factor for Osage County. The factor is a measure of the welfare value to those people receiving the benefits.

These calculations were performed for Osage and Washington Counties for the years 1949, 1954, 1959, and 1967 to measure the changes occurring within the counties. The resulting range of values established a curvilinear relation from which redistribution factors applicable to other years were interpolated.

The allocated flood-control benefits multiplied by the portion of the redistribution factor in excess of unity showed positive income

redistribution. Although flood-control benefits were never negative, redistribution benefits developed through this procedure resulted in socially negative amounts when the redistribution factor was less than unity. This was attributed to the selection of a base income for measuring "good," or positive, and "bad," or negative, income redistribution. When people with incomes higher than the base income receive the majority of the benefits, the redistributional consequences will be negative.

CHAPTER V

RESULTS

Welfare Equivalent Weights

To equate the marginal utility of income, marginal tax rates were calculated by using published income tax statistics found in references 26, 27, 28, and 29. Computations of the tax rates applicable to the Oklahoma income structure for the years 1949, 1954, 1959, and 1967 are shown on Tables V and VI. Results of these computations were plotted to show how marginal tax rates vary with income for the four years analyzed. These variations are presented in Figures 3 and 4.

The marginal tax rate for each income level was then related to the marginal tax rate for the national average income. This provided a measure of the welfare equivalency of Oklahoma income structure in regard to the national average income.

Average national incomes were computed to be $3,099; $4,039; $5,062; and $7,045, respectively, for years 1949, 1954, 1959, and 1967. Marginal tax rates for the same incomes within the Oklahoma income structure were scaled from Figures 3 and 4 to be 0.068, 0.120, 0.140, and 0.156. These marginal tax rates were set at a welfare value of unity because the national average income was selected as the base income. Welfare equivalencies throughout the Oklahoma income distribution were obtained by dividing marginal tax rates of each income class into the national marginal tax rate.

TABLE V

COMPUTATION OF MARGINAL TAX RATES
FOR 1949 AND 1954

Gross Income ($1000)	Average Gross Income	Change in Average Gross Income	Average Tax Liability	Change in Average Tax Liability	Marginal Tax Rate
			1949		
Under 1	598		4		
1 - 2	1,493	895	33	29	.032
2 - 3	2,484	991	93	60	.061
3 - 4	3,462	978	163	70	.072
4 - 5	4,455	993	270	107	.108
5 - 10	6,492	2,037	634	364	.179
10 - 15	12,004	5,512	1,638	1,004	.182
15 - 20	17,170	5,166	2,835	1,197	.232
20 - 25	22,246	5,076	5,832	1,406	.277
			1954		
Under 1	534		4		
1 - 2	1,468	934	52	48	.051
2 - 3	2,486	1,018	113	61	.060
3 - 4	3,486	1,000	217	104	.104
4 - 5	4,520	1,034	352	135	.131
5 - 10	6,516	1,996	717	365	.183
10 - 15	11,903	5,387	1,810	1,093	.203
15 - 20	17,291	5,388	3,107	1,297	.241
20 - 30	24,281	6,990	5,396	2,289	.327

TABLE VI

COMPUTATION OF MARGINAL TAX RATES
FOR 1959 AND 1967

Gross Income ($1,000)	Average Gross Income	Change in Average Gross Income	Average Tax Liability	Change in Average Tax Liability	Marginal Tax Rate
			1959		
Under 1	734		5		
1 - 2	1,488	754	49	44	.058
2 - 3	2,490	1,002	121	72	.072
3 - 4	3,478	988	226	105	.106
4 - 5	4,462	984	353	127	.129
5 - 6	5,485	1,023	502	149	.146
6 - 7	6,491	1,006	663	161	.160
7 - 8	7,519	1,028	866	203	.197
8 - 9	8,446	927	1,050	184	.198
9 - 10	9,441	995	1,225	175	.176
10 - 15	11,743	2,302	1,710	485	.211
15 - 20	17,053	5,310	3,000	1,290	.243
20 - 25	22,085	5,032	4,509	1,509	.300
			1967		
Under .6	324		-		0
.6 - 1	787	463	*		
1 - 2	1,500	713	46	46	.065
2 - 3	2,500	1,000	117	71	.071
3 - 4	3,533	1,033	200	83	.080
4 - 5	4,439	906	273	73	.081
5 - 6	5,523	1,084	389	116	.107
6 - 7	6,524	1,001	522	133	.133
7 - 8	7,405	881	671	149	.169
8 - 9	8,434	1,029	830	159	.155
9 - 10	9,500	1,066	949	119	.112
10 - 15	11,911	2,411	1,362	413	.171
15 - 20	16,964	5,053	2,366	1,004	.199
20 - 50	28,558	11,594	5,463	3,097	.267

*Amount not shown because of sampling variability.

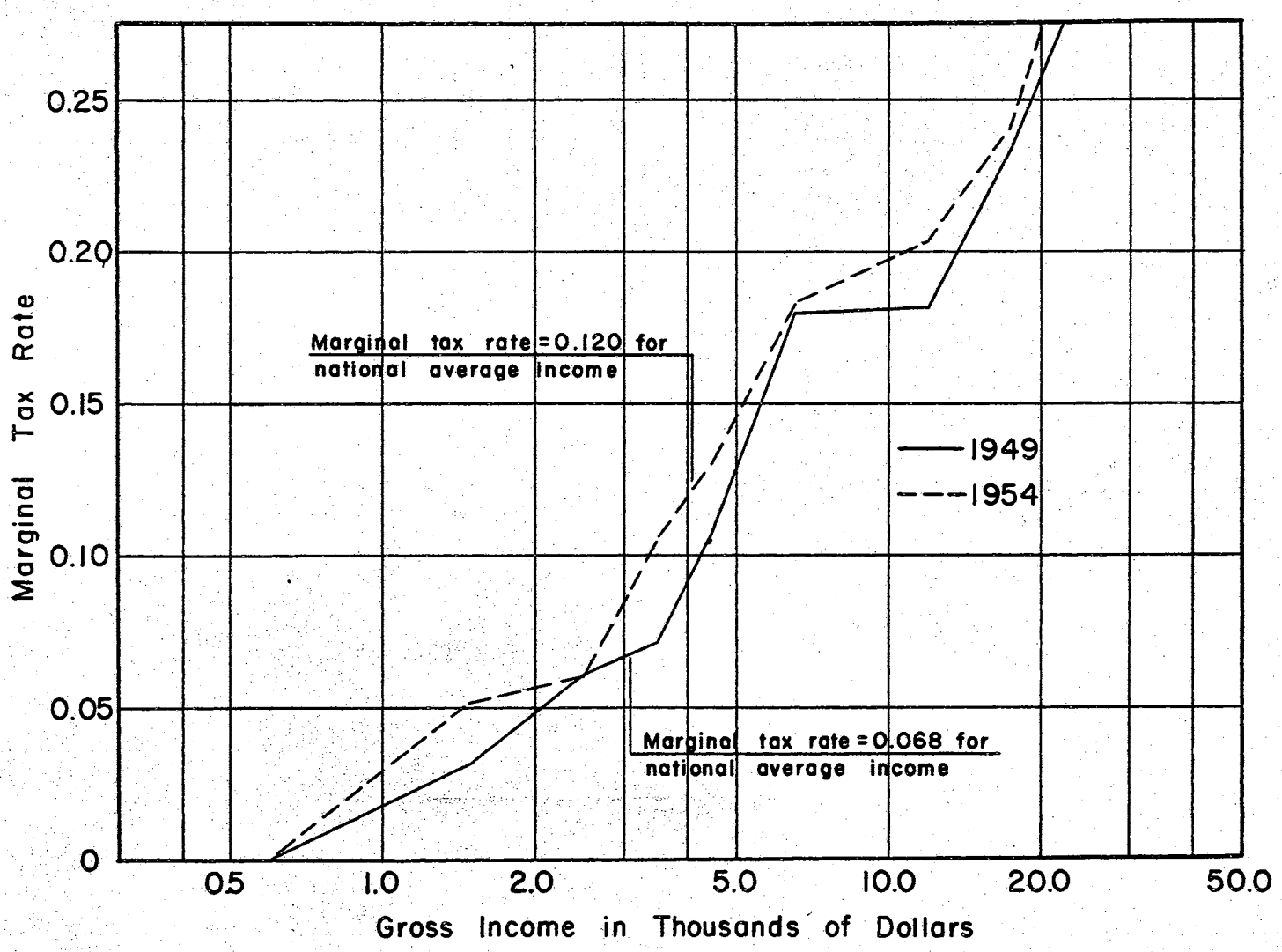

Figure 3. Marginal Tax Rates, 1949 and 1954

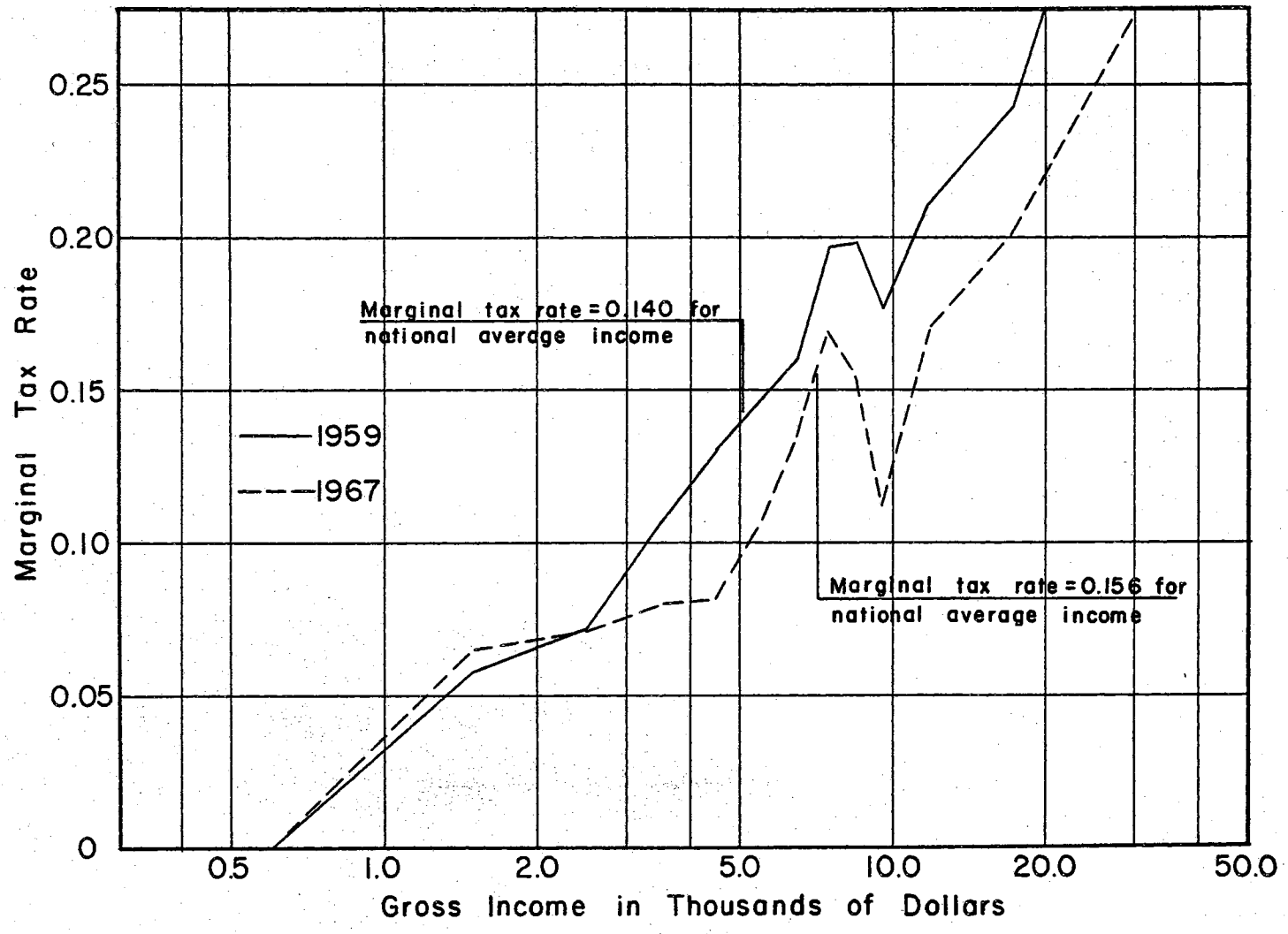

Figure 4. Marginal Tax Rates, 1959 and 1967

The marginal tax rates and the resulting list of welfare equivalent weights are summarized in Table VII. That portion of the welfare equivalent weight in excess of unity for a particular income level signified the percentage of benefit flow to that level which resulted in positive income redistribution. When the welfare equivalency was less than unity, negative income redistribution resulted.

Allocation of Flood-Control Benefits

Determination of measured flood-control benefits for Osage and Washington Counties involved a recompilation of benefits reported by the Corps of Engineers. As previously explained, the Corps of Engineers recorded benefits by geographical reaches. These benefits, in terms of prices at the time of each flood, are presented in Table VIII. Only those floods producing measurable benefits are listed.

The percentages of each reach within Osage and Washington Counties were determined by a linear measurement along the stream. Delineation of reaches within each county showed 66.4 percent of the reach from Hulah Dam to Caney Creek to be in Osage County with the remaining 33.6 percent in Washington County. All the reach from Caney to Sand Creek was in Washington County. The last and most downstream reach, Sand Creek to the Verdigris River, was determined to be 66.5 percent in Washington County and 33.5 percent outside the two-county study area. By multiplying the benefits listed in Table VIII by these percentages, benefits for individual floods were allocated to each county and subsequently summed into yearly totals. Results of these allocations are presented in Tables IX and X.

TABLE VII

SUMMARY OF MARGINAL TAX RATES AND WELFARE EQUIVALENT WEIGHTS

Marginal Tax Rates				
Gross Income ($1,000)	1949	1954	1959	1967
Under 1	.010	.016	.018	.020
1 - 2	.032	.051	.058	.065
2 - 3	.061	.060	.072	.071
3 - 4	.072	.104	.106	.080
4 - 5	.108	.131	.129	.081
5 - 6	.179	.183	.146	.107
6 - 7	.180	.193	.160	.133
7 - 8	.182	.203	.197	.169
8 - 9	.193	.212	.198	.155
9 - 10	.203	.220	.176	.112
10 - 15	.213	.227	.211	.171
15 - 20	.232	.241	.243	.199

Welfare Equivalent Weights				
Gross Income ($1,000)	1949	1954	1959	1967
Under 1	6.80	7.50	7.78	7.80
1 - 2	2.12	2.35	2.41	2.40
2 - 3	1.11	2.00	1.94	2.20
3 - 4	0.94	1.15	1.32	1.95
4 - 5	0.63	0.92	1.08	1.93
5 - 6	0.38	0.66	0.96	1.46
6 - 7	0.38	0.62	0.88	1.17
7 - 8	0.37	0.59	0.71	0.92
8 - 9	0.35	0.57	0.71	1.01
9 - 10	0.33	0.55	0.80	1.39
10 - 15	0.32	0.53	0.66	0.91
15 - 20	0.29	0.50	0.58	0.78
National average income	$3099	$4039	$5062	$7045
Marginal tax rate	0.068	0.120	0.140	0.156

TABLE VIII

ACTUAL FLOOD LOSSES PREVENTED IN CANEY RIVER BASIN
(In Flood-date Dollars)

Date of Flood	Hulah Dam to Caney Creek ($1,000)	Caney Creek to Sand Creek ($1,000)	Sand Creek to Verdigris River ($1,000)
Jul 1950	20.0	-	-
May 1951	59.0	141.0	151.0
Jun 1951	250.0	239.0	223.0
Jul 1951	70.0	66.0	62.0
Sep 1951	24.0	23.0	-
Mar 1952	74.0	83.0	-
1953	-	-	-
May 1954	69.0	171.0	306.0
May 1955	70.0	101.0	343.0
1956	-	-	-
Apr-Jun 1957	140.0	305.0	49.0
Mar 1958	31.0	39.0	280.0
Apr 1958	15.0	16.0	69.0
Jul 1959	146.0	528.0	40.1
Oct 1959	100.0	265.0	56.0
May 1960	18.8	-	-
May 1961	177.2	518.7	61.7
Sep 1961	70.0	-	-
Sep 1961	181.0	852.0	229.0
Oct 1961	27.8	-	-
Nov 1961	63.0	158.0	288.9
Nov 1961	64.0	82.0	215.0
Sep 1962	-	-	33.0
1963	-	-	-
Aug 1964	78.7	-	-
Nov 1964	53.8	375.3	1,456.4
Apr 1965	94.1	512.1	172.4
Jun 1966	142.7	334.9	658.1
Jun 1967	110.0	250.0	519.0
Jul 1967	13.0	-	40.0
Mar 1968	-	-	109.0
May-Jun 1968	64.0	86.0	-
Nov-Dec 1968	2.0	93.0	-
Mar 1969	66.0	303.0	563.0
Apr 1969	23.0	58.0	101.0
May-Jun 1969	20.0	86.0	254.0
Jun-Jul 1969	96.0	343.0	48.0
Oct 1969	75.0	-	282.0
Apr 1970	86.0	265.0	524.0
Totals	2,594.1	6,294.0	7,133.6

TABLE IX

ACTUAL FLOOD LOSSES PREVENTED
IN OSAGE COUNTY

Date of Flood	Flood-date Benefits ($1,000)	Yearly Totals ($1,000)
Jul 1950	13.3	13.3
May 1951	39.1	
Jun 1951	166.0	
Jul 1951	46.5	
Sep 1951	15.9	267.5
Mar 1952	49.2	49.2
1953	-	-
May 1954	45.8	45.8
May 1955	46.5	46.5
1956	-	-
Apr-Jun 1957	93.0	93.0
Mar 1958	20.6	
Apr 1958	10.0	30.6
Jul 1959	96.9	
Oct 1959	66.4	163.3
May 1960	12.5	12.5
May 1961	117.6	
Sep 1961	46.5	
Sep 1961	120.2	
Oct 1961	18.5	
Nov 1961	41.8	
Nov 1961	42.5	387.1
Sep 1962	-	-
1963	-	-
Aug 1964	52.2	
Nov 1964	35.8	88.0
Apr 1965	62.5	62.5
Jun 1966	94.7	94.7
Jun 1967	73.0	
Jul 1967	8.6	81.6
Mar 1968	-	
May-Jun 1968	42.5	
Nov-Dec 1968	1.3	43.8
Mar 1969	43.8	
Apr 1969	15.3	
May-Jun 1969	13.3	
Jun-Jul 1969	63.7	
Oct 1969	49.8	185.9
Apr 1970	57.1	57.1
Totals	1,722.4	1,722.4

TABLE X

ACTUAL FLOOD LOSSES PREVENTED
IN WASHINGTON COUNTY

Date of Flood	Flood-date Benefits ($1,000)	Yearly Totals ($1,000)
Jul 1950	6.7	6.7
May 1951	261.3	
Jun 1951	471.3	
Jul 1951	130.8	
Sep 1951	31.1	894.5
Mar 1952	107.8	107.8
1953	-	-
May 1954	397.7	397.7
May 1955	352.6	352.6
1956	-	-
Apr-Jun 1957	384.5	384.5
Mar 1958	235.6	
Apr 1958	66.9	302.5
Jul 1959	603.8	
Oct 1959	335.9	939.7
May 1960	6.3	6.3
May 1961	619.3	
Sep 1961	23.5	
Sep 1961	1,065.1	
Oct 1961	9.3	
Nov 1961	371.3	
Nov 1961	246.5	2,335.0
Sep 1962	21.9	21.9
1963	-	-
Aug 1964	26.5	
Nov 1964	1,361.8	1,388.3
Apr 1965	658.3	658.3
Jun 1966	820.6	820.6
Jun 1967	632.1	
Jul 1967	31.0	663.1
Mar 1968	72.5	
May-Jun 1968	107.5	
Nov-Dec 1968	93.7	273.7
Mar 1969	699.6	
Apr 1969	132.8	
May-Jun 1969	261.6	
Jun-Jul 1969	407.2	
Oct 1969	212.7	1,713.9
Apr 1970	642.4	642.4
Totals	11,909.5	11,909.5

Income Distributions

The income distributions of families in Osage and Washington Counties and in Oklahoma were determined in order to ascertain the income level of those people receiving benefits. The necessity for the state distribution will be explained later. Results of these distribution analyses, derived from data contained in Characteristics of Population (24) (25), are presented in Tables XI and XII. Information in these tables includes the number of families and the percent of the total population in each income class for 1949 and 1959, respectively.

By reducing the income classes to multiples of the median income for the particular county or the state, the distributions were converted to show cumulative percents below incremental income levels. Then by plotting the multiple of the median income at each level versus the cumulative percent below each multiple, curves depicting the degree of dispersion around the median income were developed. The income distributions for Oklahoma, Osage County and Washington County are shown in Figures 5, 6, and 7, respectively. The similarity between the dispersions for each area can be readily seen.

Median family incomes for Osage County, Washington County, and Oklahoma for 1949 and 1959 were respectively, $2,584 and $4,918; $3,486 and $6,279; and $2,387, and $4,620. Although the medians varied considerably from 1949 to 1959, from county to county, and from county to state, the distributions of the populations around the individual median incomes did not show this large variation. The three curves, when superimposed, showed the distributions of incomes in the three sectors to be comparable. This comparability led to the conclusion

TABLE XI

FAMILY INCOME DISTRIBUTION - 1949[1]

Adjusted Gross Income ($1,000)	Oklahoma		Osage County		Washington County	
	Number of Families	Percent of Total	Number of Families	Percent of Total	Number of Families	Percent of Total
0.0 - 0.5	54,625	9.6	815	10.0	400	4.6
0.5 - 1.0	65,050	11.5	855	10.5	615	7.0
1.0 - 1.5	62,575	11.1	870	10.7	545	6.2
1.5 - 2.0	53,340	9.4	710	8.7	505	5.8
2.0 - 2.5	61,540	10.9	730	8.9	755	8.6
2.5 - 3.0	49,445	8.8	565	6.9	675	7.7
3.0 - 3.5	52,235	9.2	910	11.2	900	10.3
3.5 - 4.0	40,265	7.1	980	12.0	730	8.4
4.0 - 4.5	31,465	5.5	495	6.1	580	6.6
4.5 - 5.0	20,865	3.7	250	3.1	600	6.9
5.0 - 6.0	29,730	5.2	420	5.1	825	9.5
6.0 - 7.0	16,505	2.9	215	2.6	560	6.4
7.0 -10.0	16,220	2.9	225	2.8	650	7.4
Over 10.0	12,685	2.2	110	1.4	400	4.6
Totals	566,545	100.0	8,150	100.0	8,740	100.0
Median Income	$2,387		$2,584		$3,486	

[1] Based on Population Census Statistics.

TABLE XII

FAMILY INCOME DISTRIBUTION - 1959[2]

Adjusted Gross Income ($1,000)	Oklahoma		Osage County		Washington County	
	Number of Families	Percent of Total	Number of Families	Percent of Total	Number of Families	Percent of Total
0.0 - 1.0	43,127	7.0	586	6.7	430	3.8
1.0 - 2.0	78,118	12.7	939	10.7	662	5.8
2.0 - 3.0	68,696	11.2	881	10.1	631	5.5
3.0 - 4.0	72,185	11.8	1,033	11.8	997	8.8
4.0 - 5.0	71,405	11.7	1,024	11.7	1,275	11.2
5.0 - 6.0	72,071	11.8	1,174	13.4	1,329	11.7
6.0 - 7.0	56,117	9.2	960	11.0	1,316	11.6
7.0 - 8.0	39,706	6.5	620	7.1	1,014	8.9
8.0 - 9.0	29,019	4.7	452	5.1	787	6.9
9.0 -10.0	20,378	3.3	341	3.9	614	5.4
10.0 -15.0	41,995	6.9	513	5.8	1,620	14.2
15.0 -25.0	13,722	2.2	174	2.0	559	4.9
Over 25.0	6,191	1.0	62	0.7	149	1.3
Totals	612,790	100.0	8,759	100.0	11,383	100.0
Median Income	$4,620		$4,918		$6,279	

[2] Ibid.

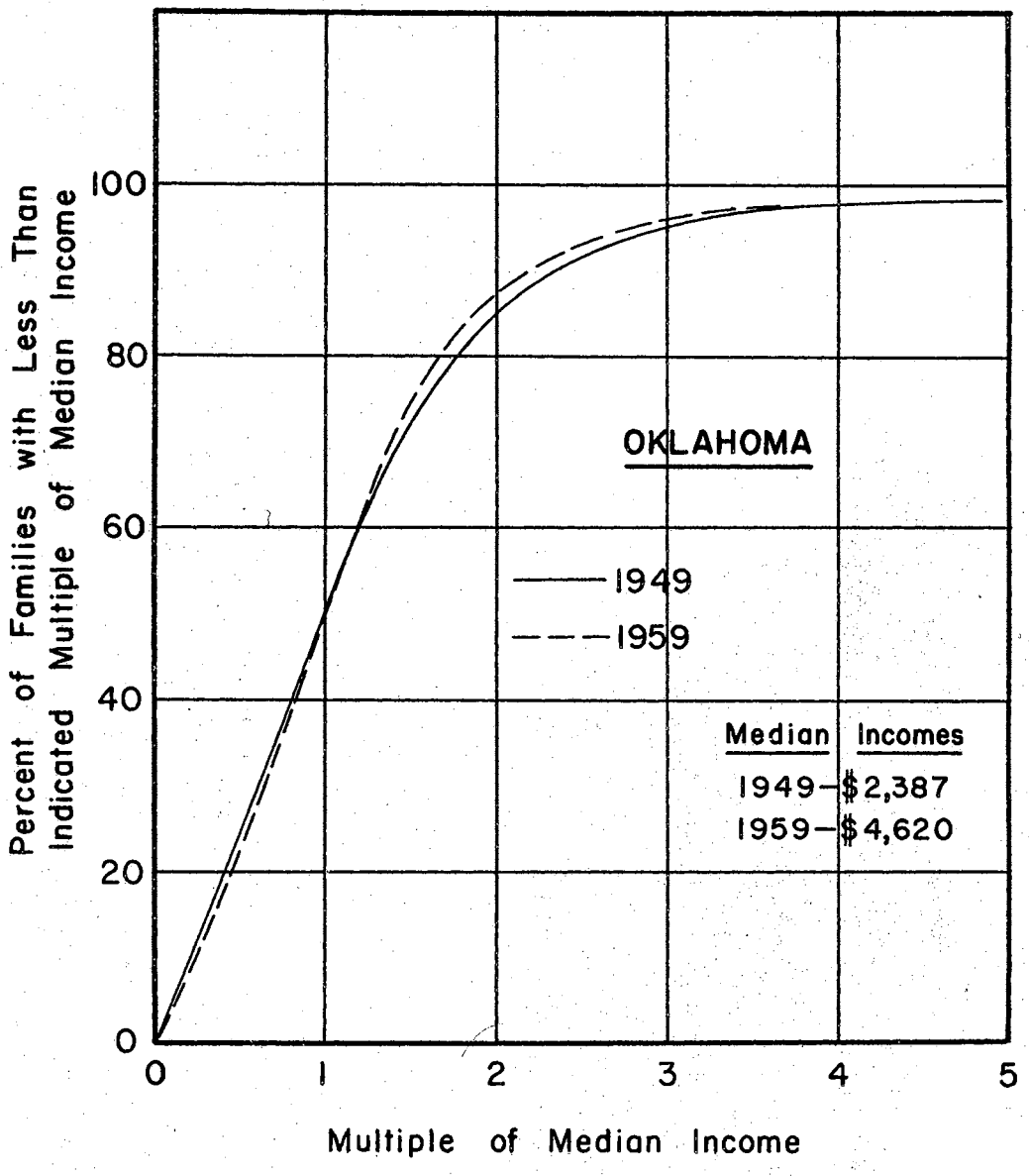

Figure 5. Family Income Distributions, Oklahoma

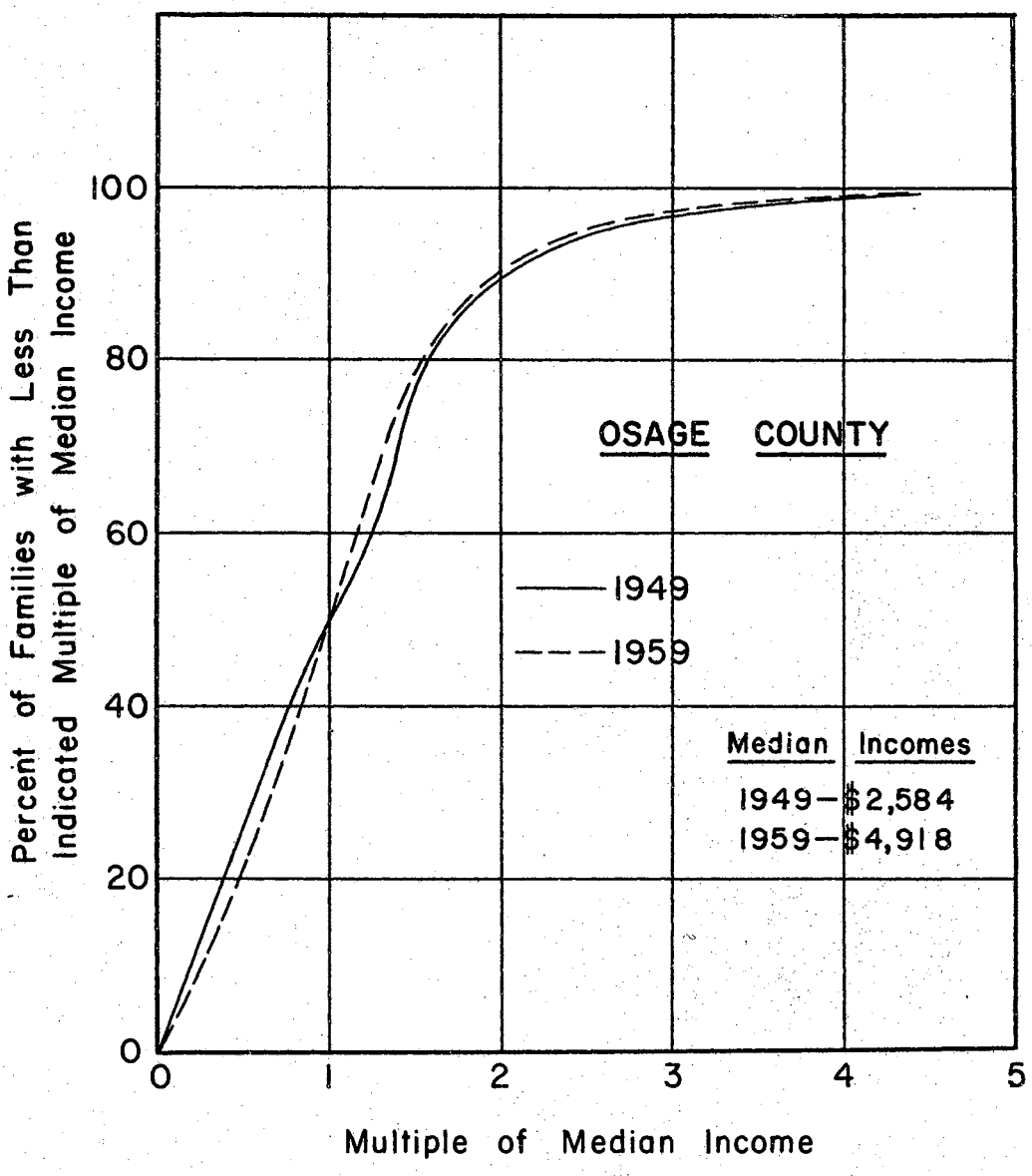

Figure 6. Family Income Distributions, Osage County

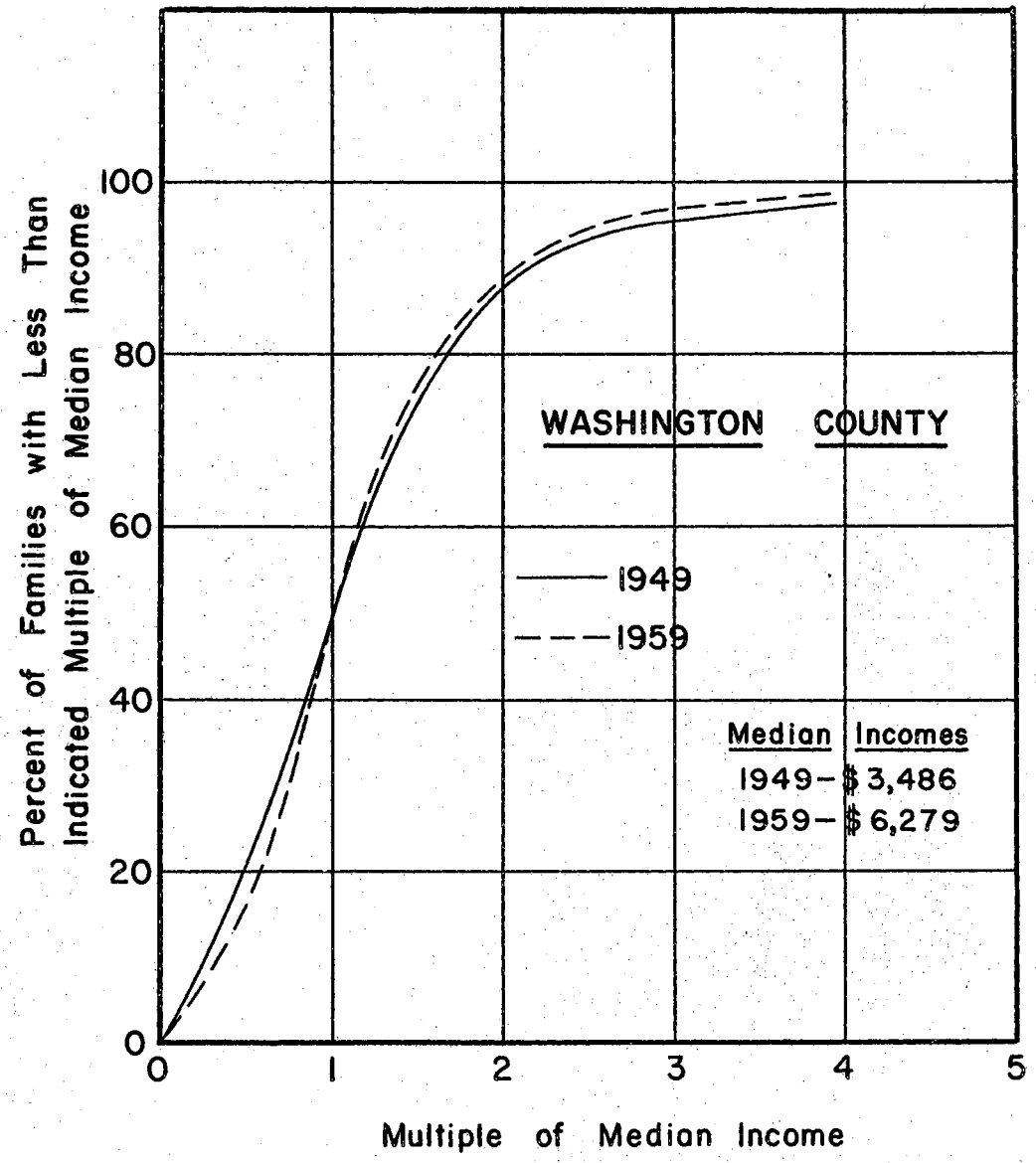

Figure 7. Family Income Distributions, Washington County

that the distribution of incomes as multiples of the median income was not significantly influenced by the value of the median income.

Lack of data on county income distributions, other than that presented in decennial population censuses, limited the flexibility of studies on county incomes. However, the correlation developed between state and county family incomes for 1949 and 1959 allowed an approach which minimized this limitation. The state income distribution has been shown to have a dispersion similar to that of either county. Therefore, reliable estimates of county income distributions for any year can be projected from the state income distribution. The information necessary for the projections included income statistics for Oklahoma individuals to cover the years to be analyzed and the median incomes of Osage and Washington Counties for the same years.

Income statistics for Oklahoma individuals were found in references cited in the computation of marginal tax rates. Published information on county incomes was limited to that previously used in the income correlation studies and was applicable only to family-sized income units.

Individual income statistics showed a consistently lower gross income than did the family income statistics because of varied reporting techniques. The median income obtained from the individual statistics represented a median income per income-tax return, an income slightly less than a family median income.

However, it was not the small numerical difference between the two median incomes but the size of the income-reporting unit which caused concern. The projections of county income distributions are valid only if the median incomes around which the distributions are developed

are based on the same income-reporting unit used to develop the state income distributions. In other words, the median county income had to be extrapolated from family income data to represent an income per return.

The 1949 and 1959 median family incomes for Osage and Washington Counties were converted to median incomes per return by

$$i = (m / M) I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.1)$$

where m is the county median family income, M is the state median family income, and I is the state median income per return. Results of these conversions are shown in Figure 8.

Income distribution studies showed insignificant variations in distributions around the median income. However, to minimize variations not ascertainable in the distribution studies, an average state income distribution was developed. Data was not available for the development of county averages. But the county and state distributions are equivalent; consequently, the average distribution for the state was applicable to the counties.

Published income tax statistics for the state were altered so that they could be plotted in the distribution curve. This involved computing the median incomes in Oklahoma for 1949, 1954, 1959, and 1967, and then reducing the income brackets to multiples of these medians. The number of income-tax returns in each income bracket was converted to a percent of the total returns. Results of these conversions are presented in Tables XIII and XIV.

The multiples of median income were plotted versus the cumulative percent of returns shown opposite the multiple in the tables. A curve drawn through the center of these points defined an average distribution for any year between 1949 and 1967. This curve is shown in Figure 9.

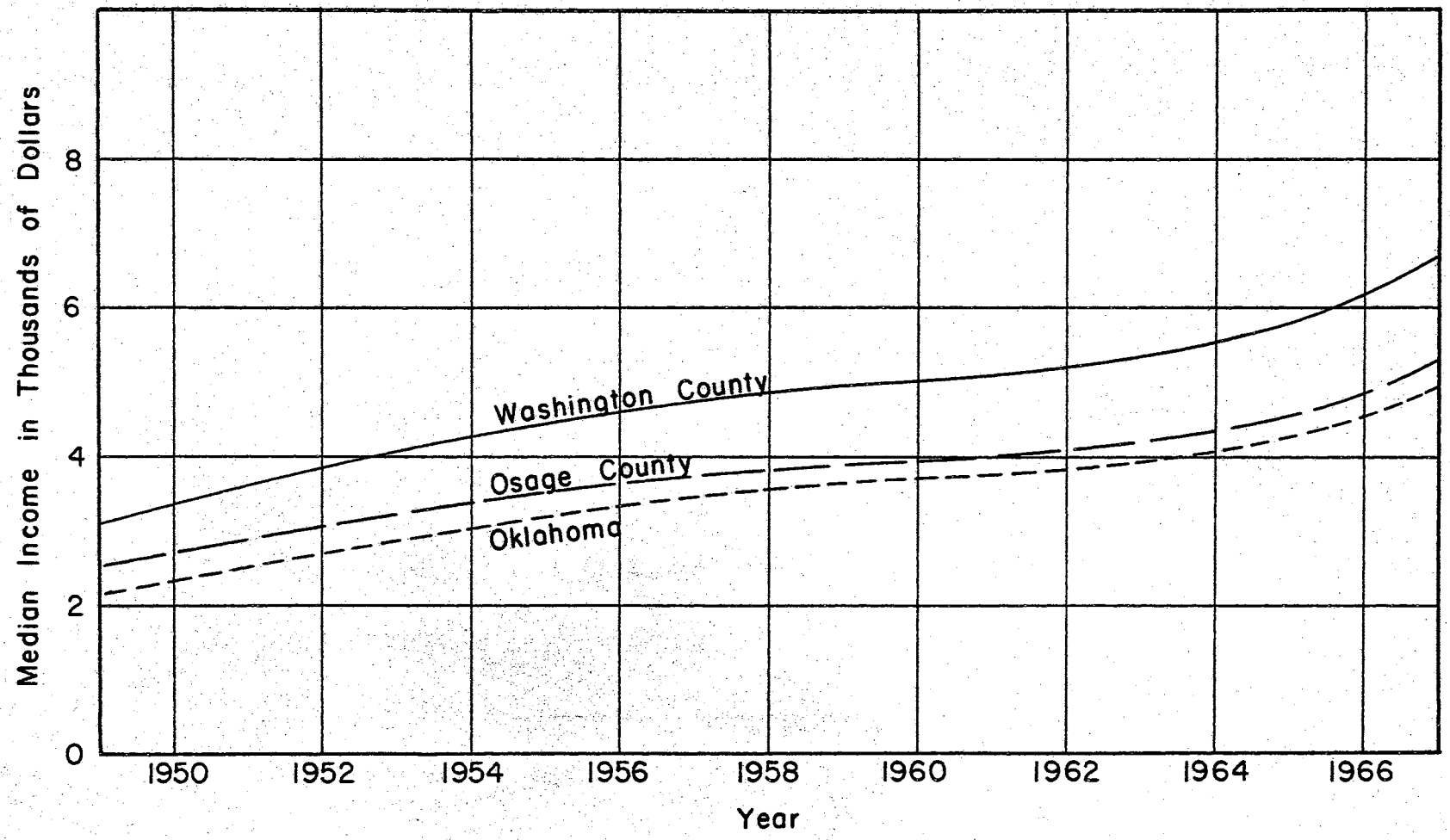

Figure 8. Variation in Median Income Between 1949 and 1967

TABLE XIII

INDIVIDUAL INCOME DISTRIBUTIONS FOR OKLAHOMA, 1949 AND 1954[3]

Income Class $1,000	Multiple of Median Income	Number of Returns	Percent of Total
	1949		
Under 1	.47	109,034	18.1
1 - 2	.94	160,460	26.7
2 - 3	1.41	145,492	24.2
3 - 4	1.87	92,073	15.3
4 - 5	2.34	37,424	6.2
5 -10	4.70	43,016	7.2
10 -15	7.04	6,991	1.2
15 -20	9.40	2,570	0.4
Over 20		3,861	0.7
Median Income - $2,130			
	1954		
Under 1	.33	104,600	15.8
1 - 2	.66	126,259	19.0
2 - 3	1.00	100,310	15.1
3 - 4	1.33	105,810	16.0
4 - 5	1.66	88,815	13.4
5 -10	3.32	118,452	17.8
10 -15	5.00	10,637	1.6
15 -20	6.65	3,606	0.5
Over 20		5,489	0.8
Median Income - $3,010			

[3]Based on Income Tax Statistics.

TABLE XIV

INDIVIDUAL INCOME DISTRIBUTIONS FOR OKLAHOMA, 1959 AND 1967[4]

Income Class $1,000	Multiple of Median Income	Number of Returns	Percent of Total
	1959		
Under 1	.27	104,967	14.7
1 - 2	.55	101,512	14.2
2 - 3	.83	89,647	12.6
3 - 4	1.10	90,983	12.7
4 - 5	1.37	86,741	12.2
5 - 6	1.65	68,745	9.6
6 - 7	1.93	57,572	8.1
7 - 8	2.20	32,965	4.6
8 - 9	2.47	24,870	3.5
9 -10	2.75	13,823	1.9
10 -15	4.13	27,473	3.8
15 -20	5.50	6,110	0.9
Over 20		8,228	1.2
Median Income - $3,640			
	1967		
Under 1	.20	90,478	11.0
1 - 2	.41	106,453	13.0
2 - 3	.61	80,542	9.8
3 - 4	.82	66,882	8.1
4 - 5	1.02	74,252	9.0
5 - 6	1.22	63,898	7.8
6 - 7	1.42	80,378	9.8
7 - 8	1.62	50,435	6.1
8 - 9	1.82	35,476	4.3
9 -10	2.03	41,210	5.0
10 -15	3.05	92,761	11.3
15 -20	4.07	21,618	2.6
Over 20		18,196	2.2
Median Income - $4,930			

[4] Ibid.

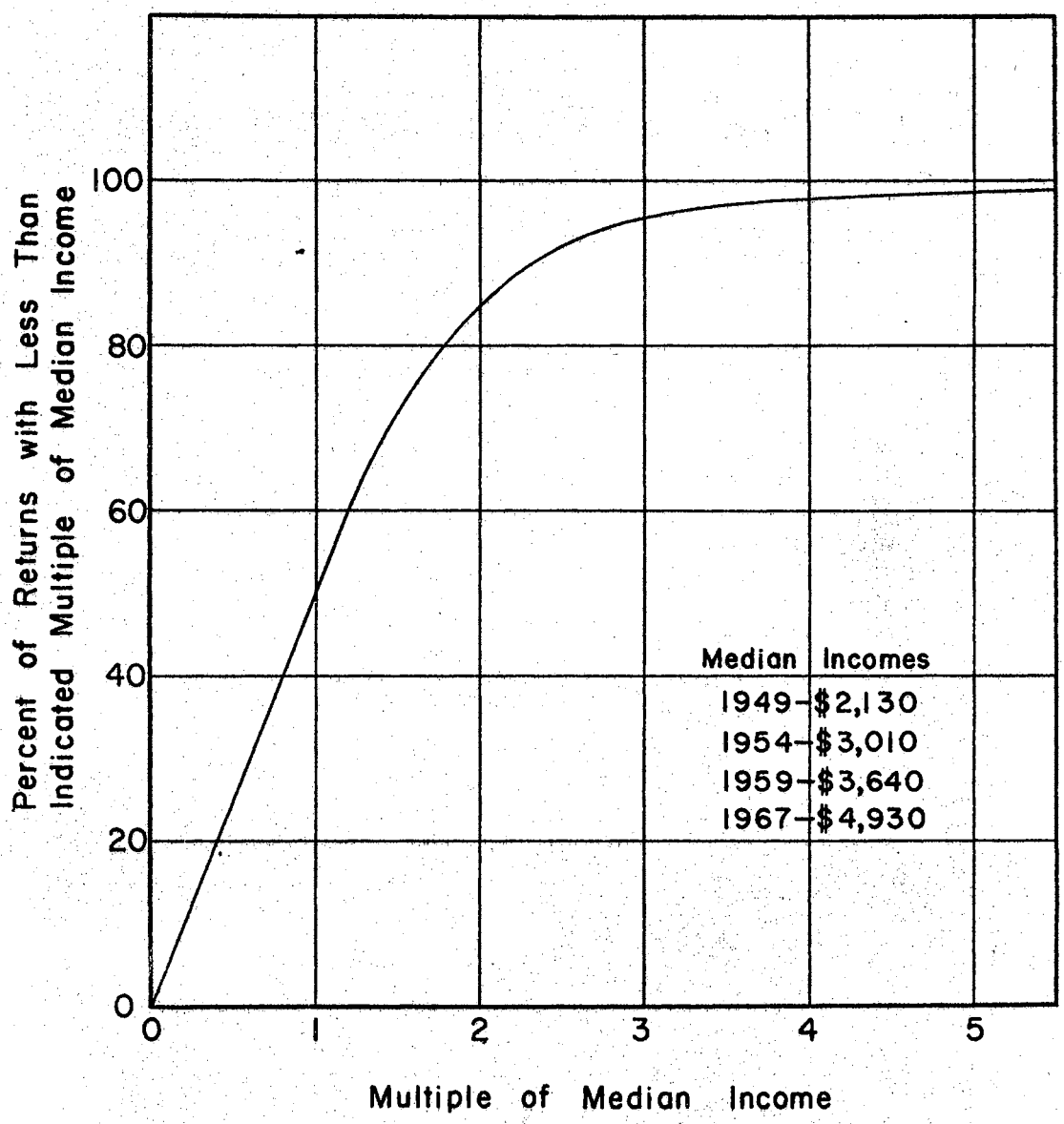

Figure 9. Income Distribution for Oklahoma, 1949-1967

Figures 8 and 9 provided the information required to develop income distributions for Osage and Washington Counties for 1949, 1954, 1959, and 1967. First, a median income was scaled from Figure 8. After converting the mid-points of income brackets to multiples of this median income, Figure 9 was used to determine corresponding percentages in the various income brackets.

Through this procedure the direction of the flow of flood-control benefits was defined. It was assumed that benefits flowed to people distributed as the county populations. Consequently, the total benefits were distributed as indicated by the percentages of populations at each income level. The income distributions, or equivalent benefit distributions, are shown in Tables XV and XVI.

Income Redistribution Benefits

Mathematical definitions of the parameters pertinent to the benefit flow were required prior to computation of income redistribution. This work involved the quantification of social welfare values of incomes at specific income levels, the areal allocation of measured benefits to Osage and Washington Counties, and the determination of the direction and size of the benefit stream to individuals in each county. In this concluding step, the parameters were correlated in computation form to arrive at first, income redistribution factors describing the benefit flow through the income structure of each county and second, a definitive redistribution benefit resulting in each county.

The computational procedures used to develop the redistribution factors are presented in Table IV, the sample calculations cited previously, and Tables XVII, XVIII, and XIX. Such factors were exemplary

TABLE XV

INDIVIDUAL INCOME DISTRIBUTIONS FOR OSAGE COUNTY[5]

Income Class ($1,000)	Multiple of Median Income	Percent of Total	Multiple of Median Income	Percent of Total
	1949		1954	
Under 1	.40	20	.31	15
1 - 2	.79	20	.62	16
2 - 3	1.18	19	.94	16
3 - 4	1.58	18	1.25	15
4 - 5	1.98	7	1.56	12
5 - 6	2.37	7	1.88	8
6 - 7	2.77	3	2.19	6
7 - 8	3.16	2	2.50	4
8 - 9	3.56	1	2.81	2
9 -10	3.96	1	3.13	2
10 -15	5.94	1	4.70	2
15 -20	7.90	.5	6.25	1
Over 20		.5		1
County median	$2,530		$3,200	
	1959		1967	
Under 1	.26	13	.19	9
1 - 2	.51	12	.38	10
2 - 3	.77	13	.57	10
3 - 4	1.03	13	.76	9
4 - 5	1.28	12	.94	9
5 - 6	1.54	10	1.13	9
6 - 7	1.79	7	1.32	9
7 - 8	2.05	6	1.51	7
8 - 9	2.31	4	1.70	6
9 -10	2.56	3	1.89	5
10 -15	3.85	5	2.83	12
15 -20	5.13	1	3.78	3
Over 20		1		2
County median	$3,900		$5,300	

[5]Based on income distribution for Oklahoma.

TABLE XVI

INDIVIDUAL INCOME DISTRIBUTIONS FOR WASHINGTON COUNTY[6]

Income Class ($1,000)	Multiple of Median Income	Percent of Total	Multiple of Median Income	Percent of Total
	1949		1954	
Under 1	.32	16	.23	11
1 - 2	.64	16	.47	12
2 - 3	.97	16	.70	12
3 - 4	1.29	16	.94	12
4 - 5	1.61	12	1.17	12
5 - 6	1.94	8	1.41	10
6 - 7	2.26	5	1.64	7
7 - 8	2.58	4	1.88	6
8 - 9	2.90	2	2.11	5
9 -10	3.23	1	2.35	4
10 -15	4.84	3	3.52	6
15 -20	6.45	.5	4.70	2
Over 20		.5		1
County median	$3,100		$4,260	
	1959		1967	
Under 1	.20	10	.15	8
1 - 2	.40	10	.30	7
2 - 3	.61	10	.45	7
3 - 4	.81	10	.60	8
4 - 5	1.01	10	.75	8
5 - 6	1.21	10	.90	7
6 - 7	1.41	9	1.04	7
7 - 8	1.62	7	1.19	7
8 - 9	1.82	5	1.34	7
9 -10	2.02	4	1.49	6
10 -15	3.03	10	2.24	17
15 -20	4.04	3	2.98	6
Over 20		2		5
County median	$4,950		$6,700	

[6] Ibid.

TABLE XVII

COMPUTATION OF INCOME REDISTRIBUTION FACTORS FOR OSAGE COUNTY, 1959 AND 1967

Income Class ($1000)	Median of Class ($1000)	Property Factor	Fraction in Income Class	Property Factor X Fraction	Weighted Product	Welfare Equivalent Weight	Income Redistribution Factor
			1949				
0 - 1	0.5	1.00	.13	0.13	.009	7.78	.070
1 - 2	1.5	4.60	.12	0.55	.038	2.41	.092
2 - 3	2.5	8.20	.13	1.07	.073	1.94	.142
3 - 4	3.5	11.80	.13	1.53	.105	1.32	.139
4 - 5	4.5	15.40	.12	1.85	.127	1.08	.137
5 - 6	5.5	19.00	.10	1.90	.130	0.96	.125
6 - 7	6.5	22.60	.07	1.58	.108	0.88	.095
7 - 8	7.5	26.20	.06	1.57	.107	0.71	.076
8 - 9	8.5	29.80	.04	1.19	.081	0.71	.058
9 - 10	9.5	33.40	.03	1.00	.068	0.80	.054
10 - 15	12.5	37.00	.05	1.85	.126	0.66	.083
15 - 20	17.5	40.60	.01	0.41	.028	0.58	.016
Totals				14.63	1.000		1.087
			1967				
0 - 1	0.5	1.00	.09	0.09	.005	7.80	.039
1 - 2	1.5	4.60	.10	0.46	.025	2.40	.060
2 - 3	2.5	8.20	.10	0.82	.044	2.20	.097
3 - 4	3.5	11.80	.09	1.06	.057	1.95	.111
4 - 5	4.5	15.40	.09	1.39	.075	1.93	.145
5 - 6	5.5	19.00	.09	1.71	.092	1.46	.134
6 - 7	6.5	22.60	.09	2.03	.110	1.17	.129
7 - 8	7.5	26.20	.07	1.83	.099	0.92	.091
8 - 9	8.5	29.80	.06	1.79	.097	1.01	.098
9 - 10	9.5	33.40	.05	1.67	.090	1.39	.125
10 - 15	12.5	37.00	.12	4.44	.240	0.91	.218
15 - 20	17.5	40.60	.03	1.22	.066	0.78	.051
Totals				18.51	1.000		1.298

TABLE XVIII

COMPUTATION OF INCOME REDISTRIBUTION FACTORS FOR WASHINGTON COUNTY, 1949 AND 1954

Income Class ($1000)	Median of Class ($1000)	Property Factor	Fraction in Income Class	Property Factor X Fraction	Weighted Product	Welfare Equivalent Weight	Income Redistribution Factor
			1949				
0 - 1	0.5	1.00	.16	0.16	.014	6.80	.095
1 - 2	1.5	4.60	.16	0.74	.062	2.12	.131
2 - 3	2.5	8.20	.16	1.31	.110	1.11	.122
3 - 4	3.5	11.80	.16	1.89	.159	0.94	.149
4 - 5	4.5	15.40	.12	1.85	.156	0.63	.098
5 - 6	5.5	19.00	.08	1.52	.128	0.38	.049
6 - 7	6.5	22.60	.05	1.13	.095	0.38	.036
7 - 8	7.5	26.20	.04	1.05	.088	0.37	.032
8 - 9	8.5	29.80	.02	0.59	.050	0.35	.018
9 - 10	9.5	33.40	.01	0.33	.028	0.33	.009
10 - 15	12.5	37.00	.03	1.11	.093	0.32	.030
15 - 20	17.5	40.60	.005	0.20	.017	0.29	.005
Totals				11.88	1.000		.774
			1954				
0 - 1	0.5	1.00	.11	0.11	.007	7.50	.052
1 - 2	1.5	4.60	.12	0.55	.035	2.35	.082
2 - 3	2.5	8.20	.12	0.98	.062	2.00	.124
3 - 4	3.5	11.80	.12	1.42	.090	1.15	.104
4 - 5	4.5	15.40	.12	1.85	.117	0.92	.108
5 - 6	5.5	19.00	.10	1.90	.120	0.66	.079
6 - 7	6.5	22.60	.07	1.58	.100	0.62	.062
7 - 8	7.5	26.20	.06	1.57	.099	0.59	.058
8 - 9	8.5	29.80	.05	1.49	.094	0.57	.054
9 - 10	9.5	33.40	.04	1.34	.085	0.55	.047
10 - 15	12.5	37.00	.06	2.22	.140	0.53	.074
15 - 20	17.5	40.60	.02	0.81	.051	0.50	.026
Totals				15.82	1.000		.870

TABLE XIX

COMPUTATION OF INCOME REDISTRIBUTION FACTORS FOR WASHINGTON COUNTY, 1959 AND 1967

Income Class ($1000)	Median of Class ($1000)	Property Factor	Fraction in Income Class	Property Factor X Fraction	Weighted Product	Welfare Equivalent Weight	Income Redistribution Factor
			1959				
0 - 1	0.5	1.00	.10	0.10	.006	7.78	.047
1 - 2	1.5	4.60	.10	0.46	.026	2.41	.063
2 - 3	2.5	8.20	.10	0.82	.047	1.94	.091
3 - 4	3.5	11.80	.10	1.18	.067	1.32	.088
4 - 5	4.5	15.40	.10	1.54	.087	1.08	.094
5 - 6	5.5	19.00	.10	1.90	.108	0.96	.104
6 - 7	6.5	22.60	.09	2.03	.115	0.88	.101
7 - 8	7.5	26.20	.07	1.83	.104	0.71	.074
8 - 9	8.5	29.80	.05	1.49	.085	0.71	.060
9 - 10	9.5	33.40	.04	1.34	.076	0.80	.061
10 - 15	12.5	37.00	.10	3.70	.210	0.66	.139
15 - 20	17.5	40.60	.03	1.22	.069	0.58	.040
Totals				17.61	1.000		.962
			1967				
0 - 1	0.5	1.00	.08	0.08	.004	7.80	.031
1 - 2	1.5	4.60	.07	0.32	.015	2.40	.036
2 - 3	2.5	8.20	.07	0.57	.028	2.20	.062
3 - 4	3.5	11.80	.08	0.94	.046	1.95	.090
4 - 5	4.5	15.40	.08	1.23	.059	1.93	.114
5 - 6	5.5	19.00	.07	1.33	.064	1.46	.093
6 - 7	6.5	22.60	.07	1.58	.076	1.17	.089
7 - 8	7.5	26.20	.07	1.83	.088	0.92	.081
8 - 9	8.5	29.80	.07	2.09	.101	1.01	.102
9 - 10	9.5	33.40	.06	2.00	.097	1.39	.135
10 - 15	12.5	37.00	.17	6.29	.304	0.91	.277
15 - 20	17.5	40.60	.06	2.44	.118	0.78	.092
Totals				20.70	1.000		1.202

of economic conditions within each county because of the underlying assumptions. They showed subtle changes indicative of these economic conditions. The variation from year to year was illustrated in curvilinear dimensions as shown in Figures 10 and 11.

Annual redistribution factors scaled from these curves are listed in Table XX. The factors do not in any way predict the chance of occurrence of income redistribution. But they do estimate the redistributional consequences resulting from stochastic flood-control benefits.

The annual flood-control benefits for each county were multiplied by the annual redistribution factor. The resulting products include the combined annual flood-control benefits and the unknown annual income redistribution benefits. Income redistribution benefits were obtained by subtracting the annual flood-control benefits from the product. These annual welfare benefits are presented in Table XXI. Although negative in some years, the net income redistribution in both counties for the twenty-year period was positive, being $245,700 in Osage County and $698,800 in Washington County.

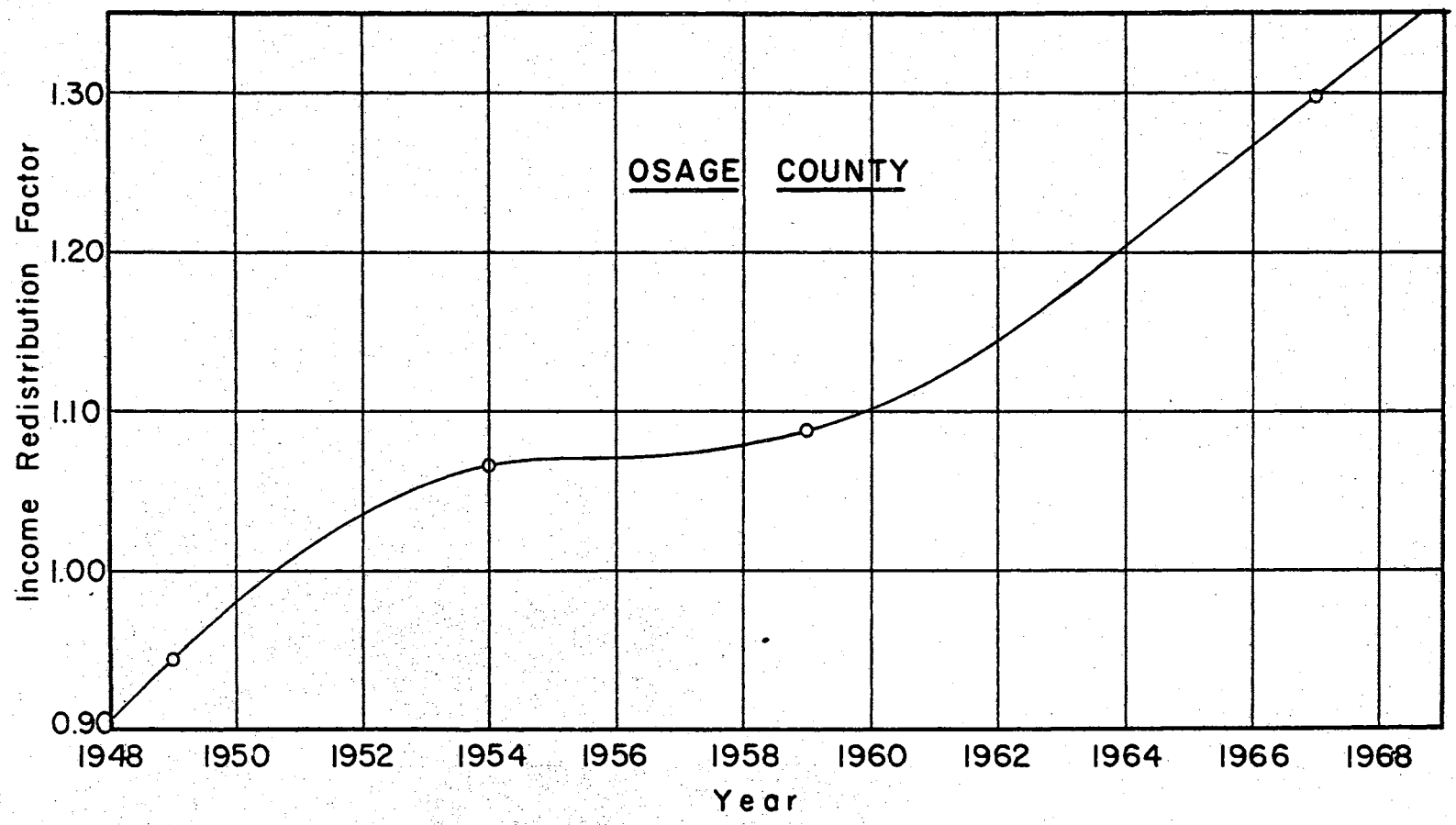

Figure 10. Income Redistribution Factors for Osage County, 1948 – 1969

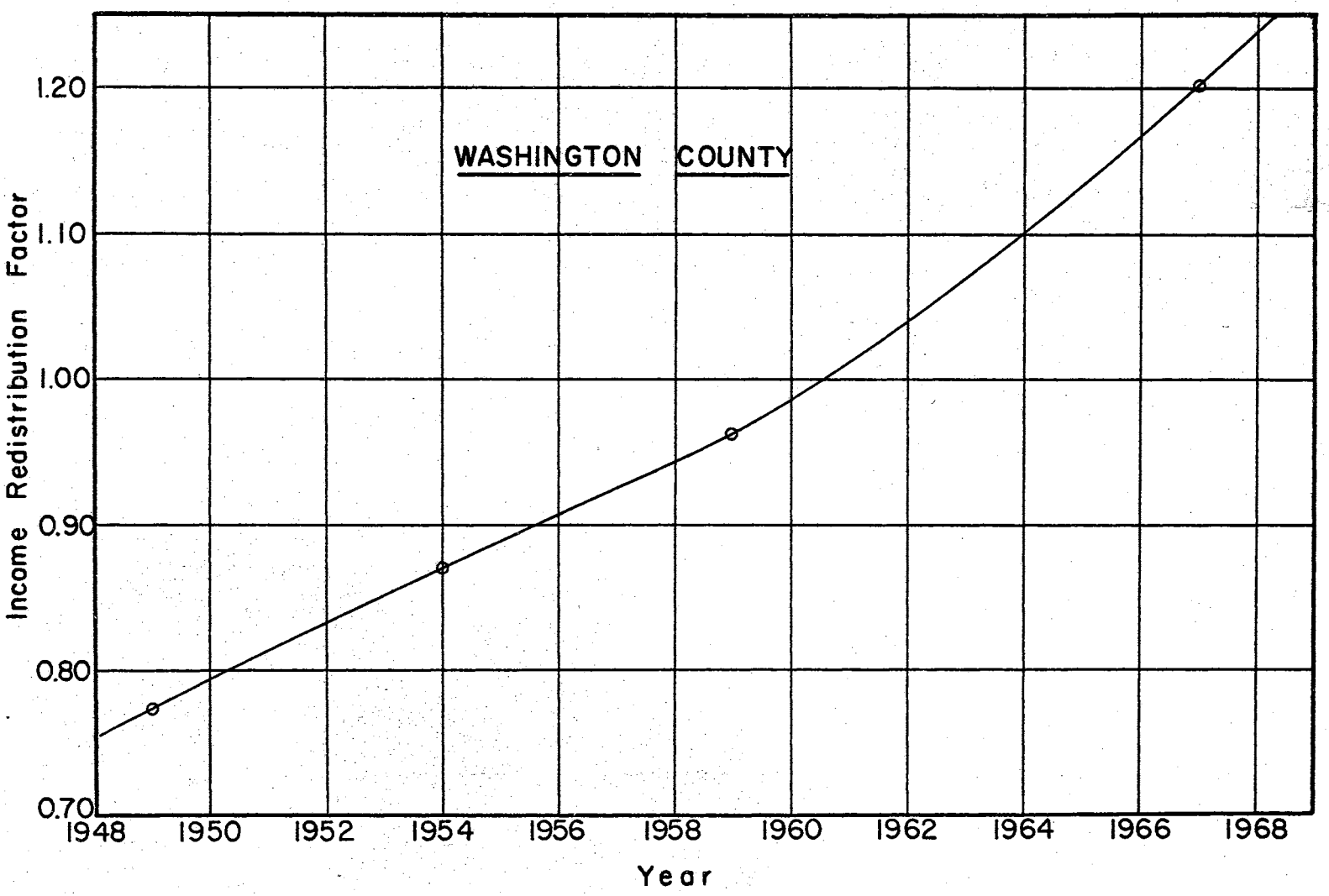

Figure 11. Income Redistribution Factors for Washington County, 1948-1969

TABLE XX

ANNUAL INCOME REDISTRIBUTION FACTORS

Year	Osage County	Washington County
1949	0.944	0.774
1950	0.980	0.794
1951	1.010	0.813
1952	1.035	0.832
1953	1.054	0.850
1954	1.065	0.870
1955	1.070	0.890
1956	1.072	0.907
1957	1.074	0.925
1958	1.079	0.943
1959	1.087	0.962
1960	1.100	0.985
1961	1.119	1.010
1962	1.144	1.039
1963	1.172	1.069
1964	1.204	1.100
1965	1.235	1.132
1966	1.267	1.167
1967	1.298	1.202
1968	1.330	1.240
1969	1.364	1.275

TABLE XXI

INCOME REDISTRIBUTION BENEFITS

Year	Osage County			Washington County		
	Annual Benefits ($1000)	Redistribution Factor	Redistribution Benefit ($1000)	Annual Benefits ($1000)	Redistribution Factor	Redistribution Benefit ($1000)
1950	13.3	0.980	-0.3	6.7	0.794	-1.4
1951	267.5	1.010	2.7	894.5	0.813	-167.3
1952	49.2	1.035	1.7	107.8	0.832	-18.1
1953	-	1.054	-	-	0.850	-
1954	45.8	1.065	3.0	397.7	0.870	-51.7
1955	46.5	1.070	3.3	352.6	0.890	-38.8
1956	-	1.072	-	-	0.907	-
1957	93.0	1.074	6.9	384.5	0.925	-28.8
1958	30.6	1.079	2.4	302.5	0.943	-17.2
1959	163.3	1.087	14.2	939.7	0.962	-35.7
1960	12.5	1.100	1.2	6.3	0.985	-0.1
1961	387.1	1.119	46.1	2,335.0	1.010	23.4
1962	-	1.144	-	21.9	1.039	0.9
1963	-	1.172	-	-	1.069	-
1964	88.0	1.204	18.0	1,388.3	1.100	138.8
1965	62.5	1.235	14.7	658.3	1.132	86.9
1966	94.7	1.267	25.3	820.6	1.167	137.0
1967	81.6	1.298	24.3	663.1	1.202	133.9
1968	43.8	1.330	14.5	273.7	1.240	65.7
1969	185.9	1.364	67.7	1,713.9	1.275	471.3
Totals	1,722.4		245.7	11,909.5		698.8

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Public water resources programs are being reoriented towards social objectives. Although general welfare has been an underlying objective of past programs, the analysis of benefits and costs used to implement this objective has included few if any measures of general welfare. Procedures presently in the formulation stage place stronger emphasis on measuring welfare and changes of welfare. Empirical results such as these on income redistribution will be helpful as new evaluation techniques are developed.

Results of welfare studies can be judged neither right nor wrong. The value judgments instrumental to these results have not been standardized and are therefore the responsibility of the individual conducting the study. The subjective results of this study are correct for the value judgments used. The significance of this study is that a method for quantifying so-called "intangible" welfare benefits has been presented.

Major Results

A technique for equating marginal utilities was examined in this thesis. Marginal tax rates were calculated to show the welfare value of income. The resulting welfare equivalent weights furnished a social

measure of marginal utilities. Utility implications of water resources objectives could be evaluated if techniques such as this were made part of the analysis.

Studies of individual incomes were used to determine the direction of benefit flows. Welfare is a relative measure because of individual desires, therefore, the distribution of benefits to individuals must be considered a determinant on total welfare. Assuming benefits flowed to an average group of persons, the direction of this flow was defined by the income distribution of those people.

Flood-control benefits were distributed to individuals on the basis of income - housing relations. The amount of benefits an individual received was defined in this way because flood-losses prevented were measured in terms of the value of the protected property. Therefore, both the direction of benefit flows, as defined by income distributions, and the size of benefit flows were developed as functions of income. Welfare equivalent weights were used to evaluate this flow in terms of welfare.

Total income redistribution benefits between 1950 and 1969 in Osage and Washington Counties were computed to be $245,700 and $698,800, respectively. These absolute quantities are not indicative of the welfare significance in the two counties.

Income redistribution stated as a percent of actual flood-control benefits in each county better depicts that significance. Flood-control benefits for Osage County were $1,722,400 as opposed to $11,909,500 for Washington County. The $245,700 income redistribution represented 14 percent of actual flood-control benefits in Osage County, while the $698,800 income redistribution represented only 6 percent of

flood-control benefits in Washington County.

Therefore, for equal reductions in flood damages in the two counties, the increase to welfare in Osage County was more than double that in Washington County. Differences in economic statistics for the counties agreed with such a conclusion.

Conclusions

A goal of this study was to develop techniques in welfare measurement that would be applicable to public water resources planning. Income redistribution as determined was dependent upon the sequence of flood-control benefits and the welfare value of the group to which the income shift was directed. However, in a complete analysis, the redistribution would result from all measured benefits, not simply flood control.

Income redistribution is an externality of "primary" benefits such as flood control, recreation, navigation, irrigation, and others. The sequence of these benefits is determined by present evaluation procedures. Consequently, the only ingredient for welfare evaluation not available in standard procedures is the measure of utility. Values of past utilities for Osage and Washington Counties were developed from recorded income statistics. Estimates of income utility during the economic life of proposed projects cannot be based on past income data. Basis for estimating future utilities was not evident in this study.

Some of the problems to be encountered in the subjective quantification of income redistribution were investigated in this study. Significant among these are:

1. Income redistribution must be defined before it can be measured. The definition should state in measurable qualities what will be a favorable or unfavorable income shift.

2. The marginal value of income to an individual as indicated by the Federal income tax structure is perhaps the least argumentive basis on which to quantify income redistribution.

3. The base income to which utility values of income must be related is an issue beyond the decisive capabilities of one person. Perhaps the most accepted and least biased decision on this item should come from Congress.

4. The determination of who is involved in the income shift and the relative status of all such people needs to be more adequately investigated. The assumptions in this study are too broad to be applicable to studies involving diverse economies.

Suggestions for Future Research

Additional research should be undertaken to fully develop the concept of marginal utility of income. Income redistribution is readily determined for any criterion relating income to general welfare. However, much work and data are needed before criteria indicative of society's goals, or less inclusive regional goals, can be established. Income redistribution is a subjective quantity applicable only to the group for which it is measured. Criteria for this measurement should reflect the marginal utilities of the specific group, whether national or sub-regional in scope.

Detailed information concerning income levels of people receiving project benefits versus income levels of people in the region not

receiving benefits is needed. Additional information is needed to substantiate the distribution, both direction and size, of project benefits. Variations in living standards and costs-of-living throughout the nation contribute to fluctuations in relative values of income between regions. More data are needed to adequately define these variations.

Income redistribution studies of other Oklahoma reservoirs should be considered. Comprehensive data would be useful in deriving imperical relations between income redistribution and economic conditions of a region. These studies might indicate methods to relate income redistribution to the procedures of standard economic base studies.

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