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Utah Water Research Laboratory
Utah State University
Logan, Utah

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ABSTRACT

Twelve measures of regional economic growth, including population and three measures of income were compared for areas with and without water investment in 246 counties and 42 water resource subareas in the states of Utah, Colorado, New Mexico, Montana, Wyoming, Idaho, and Nevada. Simple mean comparisons for these measures compiled for the decades 1940-1950, 1950-1960, and 1960-1970 failed to support the hypothesis that economic growth of those counties and subareas receiving water investment was significantly higher than in those areas which did not, with the possible exception of the 1940-1950 decade. This result is obviously tempered by the fact that with-without comparisons taken on a cross-sectional basis may be inaccurate to the extent that spatial units used in the analysis are not homogenous in all respects but the presence or absence of water investment.

Population, farm income, median family income, and per acre agricultural land values as measures of economic growth were regressed on various classes of water investment (Total, M&I, Recreation, and Irrigation investment, and other related variables) for the spatial units. Results obtained from this analysis were inconclusive with respect to the hypothesized role of water investment in effectuating economic growth.

For small areas in New Mexico where more detailed records of water investment were available, a nine equation econometric model was estimated using three-stage least squares analysis. As specified, this model facilitated an examination of the interactive effect of water development as a causal variable and as an endogenous variable which responds to other growth inducements. Test statistics for multi-equation systems are only indicative, and the statistical results were nonconclusive, although expected signs on the coefficients were obtained in most instances.

Input-output and economic base-models were used to examine two case studies of water investment in Western Colorado. The objective was to demonstrate the methodology and the magnitudes of change in regional economic activity (gross regional output, exports, income, and employment) which could be associated with major irrigation-type water developments. In this analysis it was found that total gross output attributable to the projects ranged from zero in the petroleum and mining sectors to a high of 260,302 in the dairy industry. Multiplicative effects on employment income and gross economic activity ranged from 1.06 to 2.30 times their initial magnitude. Income and employment multipliers were of similar magnitude. It should be recognized that these estimates cannot be viewed in the same manner as similar growth increments at the national level, as would typically be done, because of the strong possibility of regional offsets occurring in other regions not participating in water development. To the extent that growth in other areas is reduced by the growth of a particular region, these reductions should be subtracted from the growth measured in the latter set of regions.

In all tests conducted no conclusive evidence was found that water development causes regions to grow faster than those regions which did not receive water investment. This is not to say that growth in those regions receiving water investment was not higher than it would have been had the investment not been made. However, it does provide evidence that, an average among the regions included within this analysis, that those areas which did not receive major water investments grow at a

faster rate than those which did. Thus, the input-output approach shows potential impacts from water investment in a general equilibrium context, but rests on the assumption that other concurrent events which could produce similar or offsetting effects in the region are held constant. The cross-section analysis measures total changes in a regional economy overtime, but the multiplicity of events, other than water investment, may obscure the effects of water investment.

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1.0 INTRODUCTION

1.1 Nature of the Problem

The theory underlying the role of public investment, including investment in water resource development, in the regional growth process although of seemingly great importance, has received relatively little attention. The absence of a well defined theory has hindered the testing and application of quantitative analytic tools which might be used to predict the economic effects of these investments. As the U.S. Bureau of Reclamation, Regional Commissions, Corps of Engineers, Economic Development Administration, and other organizations are engaged in massive investment programs and projects which are at least partially aimed at increasing the pace of regional economic growth, an increasing sense of urgency is affixed to the necessity of extending and testing applications of economic theory which facilitate ex ante appraisal of the regional impacts of public investment. The recommendation of the Water Resources Council to include a regional development account in the water investment evaluation process provides further indication of the need to explore and develop improved means for predicting regional developmental effect. Possible extensions of analytic capability of this sort should serve to supplement rather than to supplant traditional forms of feasibility assessment including benefit-cost and cost effectiveness types of national efficiency and developmental analyses.

1.2 Objectives of the Study

The primary objective of this research is to utilize simple correlations, single and multiple equation econometric models and related analytic techniques to estimate the quantitative relationships, if any, between various types of water resource development and economic growth in water project areas and surrounding regions. At the same time it is desirable to obtain an assessment of the efficacy of these econometric tools in applications of this type and to provide a means for determining the size and type of water development project, if any, which would be most effective in promoting alternate forms (measures) of regional economic development.

Specific study objectives include the following:

(A) To decompose the changes in economic activity caused by water resources investment according to whether they arose from the construction, service, or development impacts of the particular investment, and to establish if there are interdependencies among these impacts.

(B) To identify and delineate appropriate spatial units for analyzing and measuring the several economic impacts of investment in water resources.

(C) To identify those industries which are "water oriented" (i.e., where water and/or water-related services can or do account for a significant part of total production costs and, hence would be influenced by changes in the cost, quality, and/or availability of such services), and to estimate the magnitude and speed of their reaction (as measured by change in employment and/or output) to water resource development.[1]

(D) To classify investment as to being "activity induced" (i.e., made in response to demands in the region for augmented water services) or "activity inducing" (i.e., those which stimulate expansion in output, employment, and/or population).[2]

1.3 Selected Literature Review

A brief review of several empirically based studies of the relationship between water resources and/or investment and changes in economic activity in a region was conducted to gain an understanding of the possible nature of this relationship and to firm up our conceptualization of the questions to be examined.

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[1]If investment in water resources is effective in stimulating regional growth, it is probable that these industries would play a major role as one of the "energizing components" of such growth.

[2]This classification is essential to the proper specification and estimation of the system of equations that comprise the econometric model.

Perhaps the most widely known paper in this area is that by Howe (7), who used analyses of variance techniques to test for significant differences in the rate of economic growth among regions classified with respect to level of water availability during the 1950-1960 time period. Conclusions based on this analysis were generally negative; regions without ample water supply were not characterized by below average growth, while areas with a relatively abundant water endowment were not guaranteed rapid growth.

> While caution is required in drawing policy conclusions from the observations of this study, the evidence clearly indicates that water availability, including water transport, does not outweigh the other attributes possessed by regions which make them attractive or unattractive as the locus of different industries. It is clearly suggested that water resource developments are likely to be poor tools for accelerating regional economic growth if markets, factor availabilities, and other amenities of living are lacking (7, p. 488).

Although the problem examined by Howe is similar to the one addressed in this study, he has really looked only at the relationship between water availability and growth, not investment in water development and growth. The concern of those making public investment decisions is more appropriately one of determining the regional growth response which could be expected to result from augmenting investment in water development; not one of assessing the average response to existing levels of resource supply.

Cox, Grover, and Siskin (2) examined the growth implications of large scale multiple-purpose water projects in 61 counties in the northeastern United States covering the 1948-1958 period. Although qualified because of the limited geographic scope of their study, they conclude that ". . . there was no relationship between project size and economic growth. . . ."

> We concluded it is dubious whether water resources projects serve as stimulus to economic growth for the strictly rural counties of the northeastern United States. We must seriously consider the possibility, as Howe did in his study of larger regions, that water resource developments are likely to be poor tools for accelerating economic growth of small rural regions of the northeastern United States. (2, p. 37)

The Cox, Grover, and Siskin conclusions are based on the fact that variables measuring the availability of water and water related services were not selected out of a larger set of explanatory variables for inclusion in any of several regression equations specified by a stepwise technique. Some rather serious methodological problems associated with technique may have influenced the results obtained. For example, the relative contribution of any one variable to the ratio of explained mean square to unexplained or mean square error is conditional on the variables already included in the equation. Given the large number of explanatory variables under consideration, it is quite probable that variables already in the equation were functionally dependent on the water development variables, hence the explanatory power of the latter have already been largely attributed to the former. Under these circumstances, the addition of the water variables could hardly be expected to result in a significant increase in the equational statistics (F and R^2) and thus they would not be selected for inclusion.

Garrison (5), in a study focusing on the Tennessee Valley area, concluded that water availability significantly influenced the micro-location (i.e., within region) of water-oriented employment. Significant positive relationships were found between employment levels, employment growth, and surplus employment (Garrison's term for the competitive shift) on the one hand, and increasing water availability as measured by 7-day, 10-year minimum flows. Counties were placed into 11 different classes of water availability, which allowed the estimation of a threshold level of water availability at 400 cfs for the concentration of water-oriented employment.[3] The differential magnitude of the competitive element amoung counties with varying water availability was quite dramatic. The shifts were overwhelmingly negative in the non-water counties (those with streamflow less than 400 cfs) and consistently positive in the counties with relatively large water endowments.

While much of the data in the Garrison study are quite convincing, the analysis suffers from a problem that is just the reverse of that in the Cox, Grover, and Siskin study; namely, failure to estimate the relationship between water-oriented employment and a number of relevant explanatory variables, including water, in a multi-variate framework. It would be more convincing to show a significant, positive relationship between water and employment when the influence of a number of other variables had been held constant. A simple regression equation probably is insufficient in attempting to explain a process as complex as regional growth.

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[3]The possible existence of a threshold level of water availability for inducing employment growth constitutes another weakness of the Howe paper. His variables were set up so that any existing threshold might not be identified, and, if present, would be likely to render the water availability variable incapable of reflecting the true relationship.

Although his empirical estimates are somewhat contradictory, Ben-David (1) develops a sound theoretical model of water supply-demand relationships to derive a statistical test of the hypothesis that water accounts for a significant part of the total cost structure in some industries, and, therefore, plays an important role in the location decision of those industries. Data from counties in 14 states in the eastern half of the U.S. were used in a multiple regression analysis, where water-oriented employment was regressed on manufacturing wages, market potential, non-water-oriented employment, and water availability, measured by low-flow miles in all stream segments of the county. Based primarily on the partial regression coefficients on the logarithm of water availability (0.169), Ben-David concludes:

> Water projects that will add to water availability of an area in which water is not abundant (by increasing the minimum low flows) will make the area more attractive to water-oriented industry, and we could expect an increase of 0.169 percent in employment for a one percent change in water availability. (1, p. 78)

This conclusion is based on an equation estimated with data from all industries. Equations estimated for each of five water-using industries (at the 2-digit SIC level) yielded widely varying results in both size and level of significance of regression coefficients. These coefficients and their associated t-values are: food and kindred products—0.039 (0.4); paper and allied products—0.301 (1.6); chemicals and allied products—0.049 (0.2); petroleum and coal products—-2.034 (-0.4); and primary metals—0.549 (3.33). Thus, only one coefficient is statistically significant, one is negative, and only two are of approximately the same order of magnitude. Little wonder that Ben-David chose to emphasize the aggregate equation.

In summary, the empirical research on the subject is somewhat confusing. While there appears to be a relationship between water and employment growth, particularly that which is water-intensive, the degree of the relationship, particularly at the individual industry level, is still unknown.

2.0 STUDY AREA

2.1 Considerations in Study Unit Selection

The identification of appropriate study units for use in this analysis and ultimately in providing a spatial context for planning and evaluation of the impact of water resource investment was a task which received fuller consideration in this study than is found in earlier research (1, 2, 5, 7).

A review of agency feasibility and framework studies suggests a strong hydrologic engineering orientation in the delineation of planning areas. Most water resource development projects have utilized a river basin and/or project service area as the basic spatial unit. In such cases, measures of water volume and flow are the important regional delineators, often to the exclusion of equally important flow variables such as labor and commodities. The latter variables often exhibit only random correspondence to hydrologic boundaries. Since the primary criterion for identifying a "good" water investment is a benefit-cost test and further proposals are to include regional growth and equity considerations, it seems appropriate that the basic spatial unit for analysis be defined primarily from an economic point of view. In virtually all cases small units, such as counties, can be combined to conform to any preselected unit of larger size such as a labor market area of possibly a river basin or subbasin.

Numerous constraints or at least considerations must be addressed in the definition of an appropriate spatial unit for assessing water development impacts. Specific considerations encountered in this study include the following:

(A) Does the unit have a sufficient job access orientation to provide for meaningful consideration of employment, income, and general well-being of people?

(B) Is the unit characterized by a degree of economic autonomy sufficient to distinguish is from neighboring regions?

(C) Can individual units be aggregated with others to form other larger regional entities which capture the full impact of an investment or to conform to hydrologic or other relevant boundaries?

(D) Can current and historical data essential for economic analysis be readily obtained from existing sources?

The selection of a study unit must also give consideration to the effects of multiple purpose projects. The extent of area influenced by the several purposes of such a project are observed to differ significantly, which would require either one very large unit to encompass all project outputs or several relatively small units, possibly overlapping, which correspond to the area served by each project output.

In recognition of the difficulty associated with identification of an ideal spatial unit, this study retained maximum flexibility by assembling the data base, only at the county and OBERS subbasin levels. Although this compromises the possibility of introducing functional homogeneity among spatial units, it has the desirable characteristics of placing the data base in its lowest spatial denominator, and facilitates the assembly of data from secondary sources based on various census publications.

2.2 General Characteristics of the Study Area

The seven intermountain states of Idaho, Montana, Wyoming, Utah, Arizona, and New Mexico were selected as the broad region to be studied. This area offers a number of advantages for a study of this type. For example, it tends to be a sparsely populated area; although there are a number of metropolitan areas in the region (e.g., Denver, Phoenix, and Salt Lake City), the total population of the region accounts for only 3.8 percent of the national total while the area is 21 percent of that in the nation. Population density (person per square mile) in the study area ranges from 3.4 in Wyoming to 21.3 in Colorado compared to the national average of 57.5.

The region is not heavily industrialized. Even the larger metropolitan areas tend not to be dependent on heavy industry at least compared to such cities as Chicago, Detroit, and Pittsburgh. The non-metropolitan subregions are typically dependent on the agricultural sector and industries closely related or linked thereto.[4] In a few subregions there is extensive mineral development activity (i.e., the mining of such products as coal, phosphate, and trona). Caribou County, Idaho, and Carbon and Emery Counties in Utah are cases in point. While the several subregions could not be classified as homogeneous, there is enough similarity among them to expect roughly similar impacts from water resource development.

A comparative description of the industrial structure of the region is shown by the percentage composition of employment by industry in Table 2.2-1. In comparing the Rocky Mountain region (or each of the component states) to the United States, several differences are notable. The manufacturing sector is almost twice as important at the national level (25.2 percent of total employment) than at the regional level (13.0 percent). Alternatively, agricultural employment in the region (6.6 percent) is almost twice as important as it is in the national economy. Government employment also tends to be somewhat larger in the Rocky Mountain area. As expected, relative employment magnitudes in the non-basic sectors (trade, services, transport, etc.) are not significantly different between the region and the country.

Although there are within state and within region industrial structure differences, these tend to be small relative to the nation-region differences. Thus, the region's industrial structure, while not uniformly homogeneous, is sufficiently similar among regions and sufficiently different from that in the nation to allow it to be used as the primary study area.

Climatological conditions are also roughly similar throughout the seven state area. The region varies from being arid to semi-arid; in virtually all subregions, the availability and use of irrigation will greatly increase crop yields and should, therefore, increase incomes in the agricultural sector. This is unlike the situation in some parts of the United States where, in a normal rainfall year, the use of irrigation water would not result in significant increases in crop yields. Selected climatological data on locations within each of the seven states are presented in Table 2.2-2. Average annual precipitation ranges from 7.2 inches in Phoenix to 15.1 inches in Cheyenne. Furthermore, the rainfall tends to be concentrated in the spring and fall months with summers generally characterized by hot dry weather. Of course, there are some parts of the study region that, for all practical purposes, typically receive no rainfall. Rainfall tends to be substantially greater in other parts of the country with annual precipitation ranging from 35 to 60 inches per year.

Although annual snowfall is heavy in many parts of the region, e.g., 58 inches in Denver, 56 inches in Great Falls, and amounts several times those levels at higher elevations, substantial investment must be made in order to control, hold, and direct the runoff to cultivated areas at times when it is needed. Thus, the region has been an obvious place to make various types of water resource investments, and, or course, many millions of dollars have been spent on dams, irrigation systems, and related investments in order to greatly expand irrigated acreage and agricultural production.

Thus, the climatological characteristics of the region, its economic structure, and the long history of a wide variety of water resource investments in it, make the area an unusually good laboratory for empirically measuring the economic effects of such investments on the several regional economies. It is also important to consider the alternatives for subregionalizing the seven state area into a set or sets of units appropriate for a cross-section analysis. That will be the subject of the following section.

2.3 Delineation Within the Multi State Area

Two areal units, counties and water resource subareas (24, p. 23) were selected as the units of observation. Because of incomplete data some counties were excluded leaving a total of 246 counties and 42 water resource subareas. Although there are a number of well-known limitations in the use of counties as observation units in economic studies, they do provide a number of advantages. For example, virtually all census data, including that from the Census of Population, Business, Manufactures, and Agriculture, are provided in great detail for all counties. Furthermore, the county data are easily combined to form any type of multi-county combination that might be desired. County data, or course, have been used in the majority of regional studies, and are widely accepted in the profession.

Since flows of economic activity and water do not conform to county boundaries, it was determined that alternative areal delineation would be useful. The set of water resources subareas as defined by the Regional Economics Division of the

[4]In the 1970-74 period, economic development in the region has taken a substantially different direction. The development of large electric power plants, oil and gas drilling operations, initial efforts toward development of oil shale resources, and expanded coal production have given a different flavor to the regional economy.

Table 2.2-1. Percentage Composition of Industry; United States, Rocky Mountain Region, and Study Area States, 1970 (all units are percents).

Industry	United States	Rocky Mountain	Idaho	Montana	Wyoming	Utah	Colorado	Arizona	New Mexico
Agriculture	3.7	6.6	12.2	12.1	9.5	3.6	4.3	3.7	4.5
Mining	0.8	2.4	1.4	2.3	8.6	3.0	1.6	2.9	5.5
Construction	5.8	6.1	6.3	6.2	6.6	5.3	6.2	7.2	7.4
Manufacturing	25.2	13.0	14.4	9.6	6.5	14.5	13.9	15.1	3.5
Transportation, Communications, and Public Utilities	6.6	7.0	6.9	7.7	8.6	6.5	6.9	5.8	6.8
Wholesale and Retail Trade	19.7	21.3	22.3	21.8	19.9	21.4	21.1	21.1	21.3
Finance, Insurance, and Real Estate	4.9	4.5	3.7	3.8	3.2	4.2	3.4	5.4	4.1
Services	25.6	28.0	25.2	27.5	28.3	27.9	28.9	28.5	35.0
Government	7.8	10.7	6.8	8.0	8.6	13.4	11.7	10.0	13.7

Table 2.2-2. Selected climatological data, major cities in study region.

	Phoenix	Denver	Boise	Great Falls	Albuquerque	Salt Lake City	Cheyenne
Average Temperature:							
January	49.7	28.5	29.1	22.1	35.0	27.2	25.4
July	89.8	72.9	75.2	69.4	78.5	76.9	70.0
Annual Precipitation (inches)	7.2	14.8	11.4	14.1	8.1	13.9	15.1
Average Number of Days With Precipitation of 0.01 Inch or More	35	87	91	99	58	87	99
Average Total Snow and Sleet (inches)	—	58.1	21.4	56.0	9.6	55.3	51.6
Average Percentage of Possible Sunshine	86	70	68	64	77	69	64
Average Relating Humidity at 1:00 p.m. (%)							
January	46	43	47	63	47	69	43
July	48	37	34	38	36	25	34

Source: (23)

U.S. Department of Commerce are appropriate units for a study of this type. A succinct description of how these areas were constructed is provided by the authors of the OBERS study:

> In the publication entitled Water Resources Reform and Subregion for the National Assessment of Water and Related Land Resources, July 1970, the Water Resources Council presented a delineation of the Nation into twenty water resources regions corresponding to major drainage patterns.
>
> By application of a consistent set of criteria using hydrologic boundaries these twenty regions have been further divided into tributary and main stem reaches entitled water resources subregions. Those subregions cut across county lines where drainage conditions so indicate.
>
> In the OBERS program counties and multi-county SMSA's form the geographic building blocks in any geographic classification system. It was necessary, therefore, to conform the water resources subregions to county and SMSA boundaries. The resulting multi-county delineations have been designated as water resources subareas. The water resources subareas, therefore, are county approximations of the hydrologically defined water resources subregions. The territory of the water resources regions as presented in this report is the aggregation of the component subareas. (24, p. 23)

These areas are shown in the map in Figure 2.3-1 and the counties in each subarea are listed in the Appendix.

WATER RESOURCES COUNCIL

WATER RESOURCES SUBAREAS (Subregions Approximated by Counties) 1970

Figure 2.3-1. Water resource subareas used in the analysis.

3.0 THEORETICAL BASE[5]

In addition to the use of appropriately-defined regions, analysis of the economic impacts of water resource investments requires a basic understanding of the regional growth theory. Although considerable research effort has been expended on the development of regional growth models, a construct of general applicability and widespread acceptance among regional economists has yet to be developed. A continued dependence on the outdated and somewhat unrealistic export-base theory is an indication of the rather undeveloped state of this field.

Focusing on growth in one of a set of regions in an open economy introduces several complicating dimensions that tend not to be given explicit consideration in national level growth models. Interregional flows of goods, services, and capital tend to be of greater relative importance than are similar flows among nations. Depending on the area delineation used, regions often are highly specialized in the production of particular commodities or services, and, therefore, a significant proportion of domestic output is exported. Similarly, a large share of domestic consumption and production requirements must be imported. There may also be substantial flows of capital among regions, depending on the saving habits of the region's residents, the size and diversity of financial institutions in the area, and domestic capital requirements.

Interregional movement of human resources presents another important dimension that must be included in regional growth analysis. Such migration is often linked to differential opportunities for employment among the several regions, and, therefore, has important implications for individual welfare considerations. Empirical evidence suggests that labor tends to be less mobile than some forms of capital, and that areas of high unemployment, although typically characterized by out-migration, tend to remain such over periods as long as several generations. There are several possible explanations for this. Individuals may prefer the lower income in the home region to the uncertainty, discomfort, and cost of moving to the "advanced" area. Essentially, this is an assertion that people attempt to maximize utility rather than income and are risk-adverters rather than risk-seekers. In addition, the possibility that technical progress and scale economies are concentrated in growing regions, could result in the demand function for labor (and possibly capital as well) increasing more than enough to offset increases in the factor supply function. Such a situation could result in continuing wage (and profit) differentials among regions despite the existence of equilibrating factor movements. The speed of factor movement reaction to such differentials is critical in the determination of relative factor prices among regions.

These interregional flows, coupled with diversity among regions with regard to resource endowments, spatial location vis-a-vis markets and raw material sources, and climatic conditions, suggest that regional growth models must be somewhat more intricate and detailed than are models developed for a larger, closed economy. Furthermore, the paucity of data on a regional basis, especially on interregional flows of goods, services, labor, and capital, hinders the testing and verification of these regional constructs.

These factors help to explain why regional growth theory is not well developed. Although existing models do cast light on the growth process, many questions still remain unanswered. It is against this background that an assessment of the economic effects of one class of public investment is made. This review of growth theory proceeds with the objective of identifying the important contributions of two basic models to an understanding of the process by which regions grow or decline, and as the basis for empirical work reported in sections 4.0 and 5.0.

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[5]Discussion contained in sections 3.1 and 3.2 is based on two years research effort which was intiated by three of the writers under a contract with the National Water Commission. This work was developed further during the first year of the study reported here under an institutional development grant from the Agency for International Development and University matching funds provided through the Utah Agricultural Experiment Station. A more complete review of this material appears in Lewis et al. (12).

3.1 A Supply Oriented Model of Regional Economic Growth

The neoclassical model of economic growth provides an excellent tool for analyzing the growth impacts of an investment such as water development. Consider an economic system where only one utility-producing product (Y) is produced. Three productive factors are employed, capital (K), labor (N), and resources from the natural environment (L) (including land, air, minerals, and water). Investment in water development may be viewed as the production of a capital good that combines with services of the natural environment (including water) and labor.

The production function can be described as Y = f(K,N,L,T), where T stands for time and thus dates the period of production. T might thus be a proxy for a given "state of the art," and may change from one period of time to another. The output of product Y depends upon the quantities of the inputs available for use in the productive process in time period T and the level of technological advance being employed in period T. Each of the factors is assumed to contribute to output. The respective marginal products for capital, labor, and the natural environment are

$$\frac{\partial Y}{\partial K},\ \frac{\partial Y}{\partial N},\ \text{and}\ \frac{\partial Y}{\partial L},$$

respectively.

Any growth in output between two time periods, say T_0 and T_1, can be expressed in terms of the contributions of the various factors, including technical advance. Thus,

$$\Delta Y = \frac{\partial Y}{\partial K}\Delta K + \frac{\partial Y}{\partial N}\Delta N + \frac{\partial Y}{\partial L}\Delta L + \Delta Y' \quad \ldots (1)$$

where $\Delta Y'$ is the increase in output due solely to technical advance.

Equation (1) can be rewritten as follows:

$$\frac{\Delta Y}{Y} = \frac{K}{Y}\frac{\partial Y}{\partial K}\frac{\Delta K}{K} + \frac{N}{Y}\frac{\partial Y}{\partial N}\frac{\Delta N}{N} + \frac{L}{Y}\frac{\partial Y}{\partial L}\frac{\Delta L}{L} + \frac{\Delta Y'}{Y} \quad \ldots\ldots (2)$$

or

$$y = \alpha k + \beta n + \epsilon l + t \quad \ldots\ldots\ldots (3)$$

where

$$y = \frac{\Delta Y}{Y},\ k = \frac{\Delta K}{K},\ n = \frac{\Delta N}{N},\ l = \frac{\Delta L}{L},$$

$$\text{and } t = \frac{\Delta Y'}{Y},$$

and α, β, and ϵ are respectively the elasticities of production (e.g., $\alpha = \Delta Y/\Delta K \cdot K/Y$) of the factors capital, labor, and natural environment. Roughly, these elasticities represent the percentage changes in output that result from a 1 percent change in the inputs, given that the supplies of the other inputs and technical advance are unchanged.

Under the assumption of perfectly competitive product and factor markets and constant returns to scale, $\alpha+\beta+\epsilon = 1$, and it can easily be shown that α, β, and ϵ represent respectively the proportion of output Y which would be paid out to each of the factors of production as a reward for its contribution to output. Thus, the distribution of income that results from any increased input utilization is determined.

If an investment in water resource development is undertaken, the initial impact on Y will be αk. But this is not all. At least two other types of adjustments will occur over time that will shift the level of output. Due to the increase in the supply of K, factor markets will adjust to new equilibrium positions and in the process Y will be affected; and the increase in K may cause shifts in the production function due to technical advance.

The first point results from the operation of the law of variable proportions. In equilibrium each of the factors is utilized up to the point where its marginal factor cost is equal to its marginal revenue product. In competitive factor markets the marginal factor cost equals the price of the factors. In a competitive market the marginal physical product of the factor is assumed to be a decreasing function of the quantity of the factor employed relative to the quantities of the other factor employed with it.

Symbolically,

$$\frac{\partial Y}{\partial K} = g\left[\frac{K}{L+N}\right],\ \frac{\partial Y}{\partial L} = h\left[\frac{L}{K+N}\right],$$

$$\text{and } \frac{\partial Y}{\partial N} = j\left[\frac{N}{K+L}\right] \quad \ldots (4)$$

Thus, other things being equal, if K increases, $\partial Y/\partial K$ would be expected to decline, and $\partial Y/\partial L$ $\partial Y/\partial N$ would be expected to increase. The values of marginal product for resources from the natural environment and labor might be expected to exceed their prices, and these factor markets would be out of equilibrium. More of these factors would be employed until their marginal physical products declined to those levels required for a new equilibrium position, where the price of the factors equaled their respective values of marginal product. The reverse would hold for capital. Secondary effects on factor employment required for the reestablishment of equilibrium, therefore, must be inserted into Equation (1) in order to estimate the full impact on Y from the initial expenditure ΔK.

A regional variant of the neoclassical model can be developed which makes explicit these sources of growth as well as taking into account interregional considerations. Alter the production function so that labor, capital, and technical progress (T) are the relevant inputs and assume that all are functions of time. Then, from the production function for region i (it is assumed that each region produces a homogeneous output under identical production functions),

$$Y_i = f(K,N,T), i = 1, ..., m \quad \ldots\ldots\ldots (5)$$

the following growth equation can be derived:

$$y_i = a_i k_i + (1 - a_i) n_i + \rho_i \quad \ldots\ldots\ldots (6)$$

where y, k, n, and p are the growth rates of the four relevant variables (e.g., $y = (dY/dt)/Y$), and a and (1-a) are the shares of income accruing to labor and capital.[6]

As the model requires full employment growth, the rate of interest can serve as a mechanism to equate full employment savings with investment. The marginal product of capital must equal the interest rate (r) in equilibrium.

$$MP_k = a(Y/K) = r^e \quad \ldots\ldots\ldots (7)$$

If r is given, Y and K must grow at the same rate if a is to be constant. Thus for steady state growth y_i must equal k_i. Substituting y_i for k_i in (6) yields

$$y_i = \frac{\rho_i}{(1 - a_i)} + n_i \quad \ldots\ldots\ldots (8)$$

and, for the system

$$\frac{\rho_i}{(1 - a_i)} + n_i = \frac{\rho_j}{(1 - a_j)} + n_j ; i,j = 1, ..., m \quad \ldots\ldots (9)$$

Flexibility in the capital-labor ratio which causes changes in a_i is the key feature. Differences in rates of technical changes and/or labor supply can be offset by varying factor intensity.[7]

If factors flow freely across regional boundaries, factor returns and growth rates should converge. Regions with high capital-labor ratios will have a high marginal product of labor and low marginal product of capital. These regions should experience capital outflows and labor inflows. Opposite flows will be experienced in regions with low capital-labor ratios. This should result in convergence of rates of factor returns and growth rates in income among regions. However, reluctance to migrate, rapid natural increase, and/or a shift in marginal production functions may alter the conclusion of equilibrating interregional factor flows. The existence of economies of scale and agglomeration in high-wage urban industrial areas may offset the tendency for factor returns to converge. In this case, moreover, it is clear that the assumptions of identical production functions among regions is no longer valid.

Capital accumulation, an important source of growth in the model, would include private as well as social overhead capital, the latter including water-related capital items such as reservoirs, waterways, hydroelectric power plants, etc. The aggregative nature of the model does not allow identification of the differential effects on regional output of changes in specific types of capital. For example, the economic impact of an investment in a new highway relative to a similar expenditure on an irrigation project is a most relevant comparison, but one that this model is not capable of making. It might be possible to disaggregate the variables in this model to take account of the impact differences, as between private and social capital accumulation, and also the differential growth effects of investment in the several classes of capital goods within each of these broad categories.

Probably the most important feature of the model is its emphasis on supply factors in contrast to the export-base models which are demand oriented. Certainly long-run growth is heavily dependent on growth in supplies of labor and capital inputs. Furthermore, growth in output per

[6]Under the assumption of perfect competition, each factor is paid its marginal product, and, since the production function inhibits constant returns to scale, total output is exhausted by factor payments, thus $a = (dY/dK) \cdot (K/Y)$ and $(1\text{-}a) = (dY/dN) \cdot (N/Y)$.

[7]Note that $[a \cdot (Y/K)] = (dY/dK) \cdot (K/Y) \cdot (Y/K) = dY/dK$.

capita generally requires technological progress or increases in the amounts of capital used per unit of labor. Under the right conditions, a water-resource investment in region should raise the capital-labor ratio sufficiently to increase output and, therefore, income per capita.

If maintenance of aggregate demand sufficient to bring about full employment is largely a national policy goal, then perhaps regional analysis should focus on the supply side, not only in terms of resource quantity but also quality and location. Under such conditions the appropriate framework for analyzing regional growth would be a supply-oriented model.

3.2 Demand-Oriented Models of Regional Economic Growth

Although the export or economic base model is probably the best known and most widely-used regional growth model, it is seriously deficient in that it recognizes only one source of growth, increased demand for regional exports. The theory asserts that the region's basic activities (i.e., those which involve the sale of goods and services to consumers whose source of payment comes from extraregional sources) form the basis for the development of all other (nonbasic) activities. Exogenous changes in demand for output from a subset of the region's industries, arising from outside the region, are the ultimate source of changes in total regional employment with population and labor force adjusting passively. Generally, basic or export activity is concentrated in the manufacturing, extractive, and agricultural sectors.

Total regional employment (E) is identically equal to the sum of employment in the basic (E_b) and nonbasic (E_n) sectors:

$$E \equiv E_b + E_n \quad \ldots\ldots\ldots\ldots\ldots (10)$$

Basic employment is assumed to be an exogenous variable in that it depends on those extraregional forces that determine export demand,

$$E_b = E_b^0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

while nonbasic employment is an increasing function of basic employment,[8]

$$E_n = \alpha_1 + \beta_1 E_b^0, \ldots\ldots\ldots\ldots\ldots (12)$$

where $\beta_1 > 0$.

Solving for total employment yields

$$E = \alpha_1 + (1 + \beta_1)E_b^0 \ldots\ldots\ldots\ldots\ldots (13)$$

where the derivative of E with respect to E_b, $(1 + \beta_1)$ is the total employment multiplier associated with a change in basic employment. β_1 would be interpreted as a nonbasic employment multiplier.

The model is completed by adding an equation where population (P) in the region is a function of total employment,

$$P = \alpha_2 + \beta_2 E \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Substituting (13) into (14) yields an equation for population as a function of basic employment only,

$$P = \alpha_2 + \beta_2\alpha_1 + \beta_2(1 + \beta_1) E_b^0 \quad \ldots\ldots (15)$$

where $\beta_2(1 + \beta_1)$ would be considered a population-basic employment multiplier.

Any change in the region's employment and population must stem from changes in the one exogenous variable, E^0_b. Strictly speaking, this is not a growth model, although it is commonly referred to as such. In a rather trivial sense, a growth model can be developed by assuming basic employment to be increasing at a constant rate r,

$$E_{bt} = E_b^0 e^{rt} \quad \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

where t indexes time periods. Under this condition, growth rates for total employment and population will equal that for basic employment. If Equations (13) and (15) were nonlinear, the growth rates would differ among the three variables.

This model has some very obvious shortcomings. First, there would appear to be no basis for the omission of autonomous spending other than exports. In many regions, automonous components of consumption, investment, and government expenditures would be significant, perhaps more so than the region's exports. Second, the possibility of technical progress[9] is omitted entirely from consideration. Either this factor is not considered as a potential source of growth, or it is of such minor importance compared to export volume, that it need not be given explicit consideration. Third, it is implicitly assumed that the demand functions for both labor and commodities are perfectly inelastic, while the labor supply schedule is

[8]Although the actual relationship may not be linear, as described here, alternative nonlinear forms of Equation (12) would not change the important conclusions to be derived.

[9]Technical progress will be defined to mean either an increase in the maximum level of output attainable with given input levels, or a reduction in the inputs required to produce a given level of output.

infinitely elastic. Increased demand for commodities, ostensibly arising from increased export demand, has no effect on factor price—it influences only the quantity demanded of the factors involved. Fourth, the assumption that export demand is exogenous cannot be maintained when interregional linkages are explicitly identified. In the second variant, developed below, it is evident that exports of one region must be dependent on income levels in all other regions, and, therefore, the former must be endogenous. Finally, the identification of a region's economic base involves difficult measurement problems. Methods for dividing regional activity into basic and nonbasic components include direct survey and questionnaire techniques, as well as indirect estimation methods, such as location quotents and minimum requirements. While all of these techniques have certain problems associated with their use, the measurement problem is thought to be of a lower order when compared to the more fundamental weaknesses discussed above.

The development of a multiregion income determination model should cast additional light on both the economic interrelationships among regions and some of the weaknesses in the export-base theory. Consider an m region economy where regional income is the sum of consumption (C_i), investment (I_i), export (X_i), and government spending in the regions (G_i) less imports into the region (M_i):

$$Y_i = C_i + I_i + X_i - M_i + G_i, \qquad i = 1,...,m \quad \ldots(17)$$

Consumption of regional output is a linear function of regional income,

$$C_i = a_i + c_i Y_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(18)$$

and investment and government spending are determined exogenously.

$$I_i = \bar{I}_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(19)$$

$$G_i = \bar{G}_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(20)$$

Imports to the region are assumed to be a linear function of regional income,

$$M_i = \sum_{\substack{j=1 \\ j \neq i}}^{m} \mu_{ji} Y_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(21)$$

where μ_{ji} is the marginal propensity of region i to import from region j, and, therefore, export volume from the i^{th} region must equal the sum of imports from region i to all other regions j:

$$X_i = \sum_{\substack{j=1 \\ j \neq i}}^{m} \mu_{ij} Y_j \quad \ldots\ldots\ldots\ldots\ldots\ldots(22)$$

If import volume is dependent on income, as generally assumed, then imports must be an endogenous variable. In a closed multiregion economy, total imports must be identically equal to total exports.

$$\sum_{i=1}^{m} M_i \equiv \sum_{i=1}^{m} X_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(23)$$

and, therefore, if the former is endogenous then so must be the latter. Rather than change in export volume causing changes in income, it is more likely that the causal sequence is just the reverse. It would appear that exports are determined by other factors rather than the exogenous factor, i.e., increased export volume is a residual effect of growth and not a primary causal factor.

Solving Equations (17) to (22) for income yields

$$Y_i = \frac{S_i + \sum_{\substack{j=1 \\ j \neq i}}^{m} \mu_{ij} Y_j}{1 - \left(c_i - \sum_{\substack{j=1 \\ j \neq l}}^{m} \mu_{ji}\right)} \quad \ldots\ldots\ldots\ldots 24)$$

where S_i is the sum of exogenous spending components,

$$S_i = a_i + \bar{I}_i + \bar{G}_i$$

A change in regional income can be caused by a change in any autonomous expenditure in the region (i.e., a_i, $\bar{I}_i$, + $\bar{G}_i$); a change in any of these components in another region, say j, which will cause Y_j to change, setting off a series of changes in the volume and pattern of interregional trade; and/or changes in any of the parameters of the system.

Quite often, local officials take a rather parochial view of the development process and concentrate their efforts on attracting industry away from other areas rather than on improving factor productivity, expanding social overhead capital, or engaging in other activities that might be somewhat more fundamental. To be sure, if promotional activities are successful in attracting a new manufacturing plant, the region will almost undoubtedly grow. The addition of, say 200 new jobs in the plant may ultimately lead to the creation of 300 to 400 additional jobs in the region. There will definitely be a multiplier effect.[10] If some industries are attracted to an area because of the existence of certain water resources, then investments in those resources to expand or improve the quality of services flowing therefrom may cause industry location in the region. Regional economic growth could be expected to follow in the way predicted by the export-base model.

Furthermore, population may be attracted to a region because of the availability of water resources, especially for recreation purposes. As studies of the industrial location process have indicated that labor supply availability is a primary locational determinant, such population movement might be followed by the location of new production units in the region. The extent to which water resource availability and cost is important in the industrial location decision is not clear, nor is the relationship between water and migration decisions.

3.3 Implications for This Study

The econometric model, correlations, and related analytic techniques used in this analysis can be roughly categorized in terms of the supply and demand orientations or sources of regional growth discussed above. In the large region analysis simple with/without water investment comparison of the mean values for twelve indicators of regional growth, including population and three measures of income, is conducted among counties and water resource subareas in the seven-state area. The implicit assumption which underlies the hypothesis being tested is that water investment is a policy instrument which can be used to cause positive changes in measures of regional growth. Thus the approach is basically supply oriented, in that water investment could be expected to increase output, increase the productivity of other inputs, reduce uncertainty and costs, and possibly introduce drifts of the production function via the incorporation of technologies not previously available.

In the multivariate analysis, the implied direction of causation between water development, by investment class, is quite explicit since the various classes of water investment are used as independent or explanatory variables in the regression analysis. Hence, this analysis is reasonably classified within the supply orientation explanation for regional growth.

The econometric model, which is utilized in examining the New Mexico data, provides the most appropriate means for describing the role of water development, recognizing the alternative roles of exogenous causal agent and endogenous or lagged development in response to regional growth initiated from sources other than water development. In this case, strict classification as between demand and supply orientation can only be made in terms of the reduced form equations which express each endogenous variable in terms of the exogenous or lagged endogenous variables. Development and interpretation of the reduced forms is contingent upon attaining acceptable statistical results in the simultaneous equations model. Both orientations can be exhibited within this analysis depending on the initial specification of the econometric model.

The analysis reported in section 5.0 utilizes input-output and economic base analysis to evaluate the regional impact of water investment. Quite obviously these approaches are demand oriented. There is a multiplicative effect of expanded levels of final sales from water related sectors and related intermediate purchases in other sectors.

As noted in the discussion above, the focus of our analysis is to measure the relationship, if any, between indicators of regional growth and water development. The possible overriding consideration of national economic efficiency is effectively disregarded but remains a critical point of concern because of the likelihood of regional offsets occurring among regions which would cause what is measured as regional growth to "wash out" when viewed from a national perspective which also includes offsets occurring in other regions not included within our analyses.

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[10]From a national point of view, however, this promotional effort may be regarded as wasteful because the plant would have been located somewhere and, thus, the effect on the national economy may have been approximately the same.

4.0 EMPIRICAL TESTS

Empirical tests of the relationship between regional indicators of economic growth and investments in various types of water development were conducted at two levels of spatial aggregation and for small areas within the State of New Mexico.

4.1 Large Region Analysis

Simple statistical comparison of means, correlation coefficients, and multivariate analysis were applied to data on counties and water resource subareas within the seven states.

A simple comparison of means and correlation coefficients was made using 12 indicators of economic growth and/or economic welfare levels under associated conditions of investment in water development designated as a "with/without" type analysis. The multivariate analysis was conducted using ordinary least-squares regression techniques to estimate equation sets for counties and water resource subareas on regional growth indicators which included population, farm income, median farm income, and per acre agricultural land values.

4.1.1 Correlation and other simple statistical tests

As a first and, admittedly, rough approximation of the effect of various water resource investments on economic growth and welfare levels, a "with/without" type of analysis was made. Twelve indicators of growth and/or economic welfare levels were identified; these are listed in Table 4.1.1-1. Arithmetic means for each variable were calculated for sets of spatial units on the following basis: all units (i.e., an overall mean); units having water investments and units without water investment. If such investment does have a significant positive impact on aggregate growth and welfare, then the means for counties with investment should tend to be significantly higher than those without such investment.

Table 4.1.1-1. Indicators of economic growth and welfare levels.

1. Median Family Income[a]
2. Value of Land and Buildings, Per Farm[a]
3. Value of Land and Buildings, Per Acre[a]
4. Unemployment Rate[a]
5. Percent Change in Population[b]
6. Percent Change in Median Family Income[b]
7. Percent Change in Value of Land and Buildings, Per Farm[b]
8. Percent Change in Value of Land and Buildings, Per Acre[b]
9. Percent Change in Value of Crops Sold[b]
10. Percent Change in Value of Livestock Sold[b]
11. Percent Change in Total Income[b]
12. Percent Change in Manufacturing Income[b]

[a]For 1950, 1960, and 1970.

[b]For the periods 1940-1950, 1950-1960, and 1960-1970.

An appropriate temporal sequence was used in relating the growth-welfare variables to the investment measures. For example, investments made prior to 1947 were related to growth as measured during the 1940-50 period or to levels as of 1950; investments made between 1947-57 were related to 1950-60 growth measures and 1960 level variables; and 1957-67 investment data were compared to 1960-70 growth and 1970 level variables. It is assumed that a lag exists between the time the investment is made and the time that the impact, if any, is observed on the indicators of growth and welfare. Thus, it is expected that the economic impacts of investments made after, say, 1957, would not be manifest until the next decade, that is, 1960-70.

Fifteen tables were developed relating each of the five classes of investment[11] to the twelve indicators, for each of the three time periods 1940-50, 1950-60, and 1960-70. This was done for both data sets, that is for the 246 counties and 42 water resources subareas as defined earlier. Two of these tables are reproduced below as Tables 4.1.1-2 and 4.1.1-3 of this report.

[11]Total, irrigation water, municipal and industrial water, recreation, and other investment.

Table 4.1.1-2. **Mean levels of economic indicators, overall and with and without water resources investment, 1960-1970 (county data).**

Indicator	Arithmetic Mean: Overall ($\bar{x}$)	Counties with Investment ($\bar{x}_1$)	Counties without Investment ($\bar{x}_2$)	Z Value[a]
Median family income	$ 7,734	$ 7,771	$ 7,731	0.12
Value of land and buildings, per farm	164,691	156,629	165,460	-0.38
Value of land and buildings, per acre	102	123	100	0.95
Unemployment rate (percent)	5	5	5	1.37
Percent change in population	2	12	2	1.39
Percent change in median income	60	61	60	0.14
Percent change in value of land and buildings, per farm	162	214	158	1.05
Percent change in value of land and buildings, per acre	75	64	75	-0.75
Percent change in crops sold	29	44	28	0.88
Percent change in livestock sold	73	68	73	-0.22
Percent change in total income	80	77	80	-0.22
Percent change in manufacturing income	176	105	181	-0.31

[a]The test statistic for the hypothesis $\mu_1 - \mu_2 = 0$. Values in excess of 1.96 would indicate significance at the 0.05 probability level (indicated by *); values in excess of 2.58 indicate significance at the 0.01 level (**).

Table 4.1.1-3. **Mean levels of economic indicators, overall and with and without irrigation investment, 1950-1960 (water resources subarea data).**

Indicator	Arithmetic Mean: Overall ($\bar{x}$)	Counties with Investment ($\bar{x}_1$)	Counties without Investment ($\bar{x}_2$)	Z Value
Median family income	$ 5,154	$ 5,481	$ 5,010	2.53 *
Value of land and buildings, per farm	71,653	65,524	74,400	-0.68
Value of land and buildings, per acre	65	60	67	-0.38
Unemployment rate (percent)	5	5	6	-1.03
Percent change in population	20	27	17	1.05
Percent change in median income	81	87	79	0.87
Percent change in value of land and buildings, per farm	131	120	136	-0.82
Percent change in value of land and buildings, per acre	93	88	95	-0.30
Percent change in crops sold	28	17	33	-1.00
Percent change in livestock sold	49	39	53	-0.61
Percent change in total income	70	84	64	1.04
Percent change in manufacturing income	180	188	177	0.18

Table 4.1.1-2 shows the overall mean for each variable and the means for counties with and without water investment (in this case total investment for the 1960-70 period (i.e., 1958-67 investment data). Also shown is the test statistic for the hypothesis that there is no significant difference between the means for counties with and without investment. In this example, one-half of the indicators are higher for counties with water investment. None of the differences are significantly different from zero at the 0.05 probability level. Table 4.1.1-3 presents similar data for the 1950-60 period (1948-57 investment data) except that irrigation investment data are used and the water resources subareas are the spatial units. Again, exactly one-half of the indicators are higher for counties with investment. Only one of these differences, for median family income, is significant at the 0.05 level.

Although these two tables were selected for illustrative purposes only, they are quite representative of the entire analysis. In general, there was no tendency for the economic indicator means to be higher for those spatial units that have had investment projects. A summary of the entire analysis is presented in Table 4.1.1-4. Perusal of these data would suggest that water investments may have had an impact on growth during the 1940-50 period, but that such investment has had a neutral to negative effect on the latter decades. In the 1940-50 period, for example, an average[12] of 6.8 of 12 indicators were higher for the set of counties with water investment and an average of 8.33 of 12 were higher for the multi-county units. In the other two periods the averages were all below six, which would represent 50 percent of the indicators.

In summary then, the data would be consistent with the hypothesis that water investment causes aggregate economic growth only for one time period, and even then the results are somewhat tenuous as few of the differences between means are statistically significant. Actually, the data for the two later periods would be more consistent with the counter-hypothesis that investment is antiethical to growth, but the relationships are simply not strong enough to make a definitive statement either way. In any event, this very preliminary, and, admittedly, gross analysis must be considered as not providing much support for the primary hypothesis being tested in this report.

[12]The average is defined across investment classes within a given time period.

It will be informative to perform a more specific type of with/without analysis that will focus on specific investment categories. In particular, investment in municipal and industrial water supplies and in irrigation projects are related to associated measures of growth. M & I investment is related to each of the following variables: percentage change in median family income, population, total income, and manufacturing income, and the unemployment rate. Irrigation investment is related to the percentage change in each of the following; per acre value of farm land and buildings, value of crops sold, and value of livestock sold. Again the analysis is made for both the county and water resources subarea data sets. The statistics are compiled in Tables 4.1.1-5 and 4.1.1-6.

As before, the data do not support the hypothesis that water investments cause aggregate economic growth. In the analysis of municipal and industrial investment, there are 30 relevant comparisons of means for counties on a with/without basis. Of these, exactly one half show "better" economic performance for counties that had this type of investment. Only one difference was significant at the 0.05 level. This type of investment may be "induced" by economic growth rather than "inducing." That is, in growing areas, demands by residents and industry for water may cause supply-creating investments to be made rather than investments being made first and people and industry then responding to ample and, possibly, lower priced water. To the extent this is true, no significant relationship should be found between investment in one period and population and industry growth in the following period. In fact, the reverse of that propensity should be true.

This reverse causation situation should not be true of irrigation investments, however. Such investment should increase yields, allow a broader range of cropping patterns, increase the flexibility and efficiency of fertilizer applications, etc. It should be expected that irrigation investments would directly and significantly affect the yields and values of the newly irrigated land. This should, in turn, be reflected in increases in the three indicators used herein, i.e., percent change in per acre value of land and buildings, value of crops sold, and value of livestock sold.

Reference to Table 4.1.1-6, however, will show that those indicators did not tend to be higher in spatial units with irrigation investments when compared to those without. In fact, of 18 relevant comparisons, only four indicate better performance in counties with investment. This somewhat curious result may be explained by the fact that

Table 4.1.1-4. **Growth indicators showing positive change arrayed by water investment class for counties and water resource subareas, 1940-1950, 1950-1960, and 1960-1970.**

Time Period	Water Investment Class: Total	Irrigation	M&I	Recreation	Other	Average
1940-1950	9	7			9	8.33
1950-1960	5	6	7	7	4	5.8
1960-1970	6	2	3	3	4	3.6

Water Resources Subareas

Time Period	Water Investment Class: Total	Irrigation	M&I	Recreation	Other	Average
1940-1950	7	6	6	8	7	6.8
1950-1960	4	5	7	3	5	5.8
1960-1970	6	3	3	4	6	5.4

Table 4.1.1-5 **Effect of municipal and industrial water resources investment on selected economic indicators, 1940-1950, 1950-1960, 1960-1970.**

	1940-1950			1950-1960			1960-1970		
	With	Without	Z	With	Without	Z	With	Without	Z
Spatial Unit: Counties									
Percent change, median Family income	74.7	78.8	-0.25	85.8	78.0	0.51	59.2	60.6	-0.14
Unemployment rate	8.0	2.9	2.10	4.6	5.5	-0.58	7.4	5.0	1.51
Percent change in Population	14.2	10.8	0.17	31.3	10.4	1.17	6.50	2.60	0.25
Percent change in total income	47.3	55.3	-0.18	69.8	54.9	0.38	59.7	80.3	-0.69
Percent change in mfg. income	205.0	168.6	0.11	129.9	170.3	-0.14	130.6	176.9	-0.09
Spatial Unit :Water Resources Subareas									
Percent change, median family income	77.3	81.2	0.08	89.3	81.3	0.30	52.5	57.5	-0.94
Unemployment rate	5.5	5.2	0.42	4.9	5.9	-0.46	6.2	5.5	0.86
Percent change in population	39.3	20.3	0.88	45.6	19.5	0.95	6.0	7.3	-0.14
Percent change in total income	89.1	70.4	0.49	118.9	68.4	0.92	62.0	84.7	-1.12
Percent change in mfg. income	135.4	182.0	-1.51	126.4	138.6	-0.31	73.9	92.2	-0.30

Table 4.1.1-6. Effect of irrigation investment on selected economic indicators, 1940-1950, 1950-1960, 1960-1970.

	1940-1950			1950-1960			1960-1970		
	With	Without	Z	With	Without	Z	With	Without	Z
Spatial Unit: Counties									
Percent change in value of land and buildings, per acre	79.7	93.7	-0.95	81.2	92.5	-0.58	67.4	75.3	-0.43
Percent change in crops sold	20.8	35.4	-0.91	17.7	34.6	-0.79	48.1	28.3	0.85
Percent change in livestock sold	56.7	40.3	1.85	40.3	43.0	-0.23	53.6	75.2	-1.32
Spatial Unit: Water Resources Subareas									
Percent change in value of land and buildings per acre	73.5	102.9	-1.42	88.7	95.1	-0.30	64.3	66.8	-0.16
Percent change in crops sold	24.5	30.4	-0.37	17.1	33.5	1.00	31.8	14.2	1.30
Percent change in livestock sold	57.8	45.1	0.58	39.7	53.7	-0.61	53.1	76.9	-0.96

even in those counties with investment, only part, and in some cases probably a small part, of the agricultural lands may have been brought under irrigation systems. This would allow for the possibility that yields and revenues on the newly irrigated land may have increased substantially, but that land was not sufficient in size to cause significant increases in the county or multi-county average.

This, then, is the first indication of the possibility that the spatial units as defined are still too gross to allow definitive judgments on the effects of water investment. This suggests the need to augment this type of aggregate analysis with case studies of specific areas on a with/without irrigation investment basis. This has been done and is reported in section 5.0 of this report.

A logical extension of this with/without analysis is to examine the product-moment correlation coefficients between water investment variables and eight indicators of economic growth. Three classes of water investment (total, irrigation, and municipal and industrial) were correlated with seven economic growth indicators for three different periods of time. The results are reported in Table 4.1.1-7.

Again, the results are somewhat ambiguous. There is no evidence to support the hypothesis that water investment causes economic growth. In general, the correlation coefficients are quite small, in the range of 0.01 to 0.05, which are statistically insignificant. Of the 72 coefficients, only five are significantly different from zero at the 0.05 probability level, and three of these have unexpected signs (negative). For the first two time periods, a majority of the coefficients are positive (18 of 24 in the first period, and 14 of 24 in the second), but in the last period 19 of 24 correlation coefficients are negative.

4.1.2 Multivariate models

Multiple regression equations relating measures of economic progress to various types of water resources investment and other independent variables were estimated using the data drawn on the 246 county units and 42 water resources subareas in the region. The measures of growth, all in terms of percentage changes from 1950 to 1960 and from 1960 to 1970, are population, farm income, median family income, and per acre agricultural land values.

Table 4.1.1-7. Correlation coefficients between water resource investment and measures of economic growth.

Percent change, 1940-50 in:	Water Investment (Pre 1947) Total	Irrigation	M&I
Population	0.11	0.12	0.01
Median income	-0.02	-0.01	-0.02
Value of land and buildings, per acre	0.03	0.00	0.02
Crops sold	0.01	0.03	-0.02
Livestock sold	0.45**	0.49**	-0.08
Total income	0.05	0.05	-0.01
Farm income	0.03	0.03	-0.03
Manufacturing income	-0.02	-0.02	0.01

Percent change, 1950-60, in:	Water Investment (1948-57) Total	Irrigation	M&I
Population	0.04	0.06	0.03
Median income	0.05	0.03	0.03
Value of land and buildings, pre acre	0.04	0.02	0.06
Crops sold	-0.09	-0.07	-0.10
Livestock sold	0.02	0.04	-0.01
Farm income	-0.02	-0.01	-0.05
Manufacturing income	0.00	0.02	-0.01

Percent change, 1960-70, in:	Water Investment (1958-70) Total	Irrigation	M&I
Population	0.03	0.04	-0.00
Median income	-0.03	-0.04	0.00
Value of land and buildings, per acre	0.05	-0.04	-0.13
Crops sold	-0.07	-0.07	-0.02
Livestock sold	-0.05	-0.05	-0.00
Total income	0.06	0.06	-0.02
Farm income	-0.44**	-0.41**	-0.56**
Manufacturing income	-0.02	-0.02	-0.01

Alternative equations for each of these four dependent variables for the county data are reported in Tables 4.1.2-1 through 4.1.2-4. In general, the regression equations show little or no relationship between water resources investment and measures of regional economic growth. In all but two cases the estimated regression coefficients are not statistically significant and small in absolute size. The signs (i.e., positive or negative) tend to be random, and the coefficients of determination (R^2), the proportion of variation in the dependent variable "explained" by variation in the independent variables, is very low in virtually all equations. Only in the farm income equation is a water investment variable (i.e., irrigation) statistically significant, but the coefficient is negative suggesting that irrigation investment leads to a reduction in farm income!

Thus, the null hypothesis that regional economic growth is caused by investment in water resources of various types is given virtually no support from these empirical results. Clearly, however, these data do not show the hypothesis to be false only that they would not support contentions that it is true.

The same equation sets for population, farm income, and median family income, and agricultural land value were estimated using data drawn on the 42 water resources subareas in the region. In general, the results are quite similar to those estimated on county data. There is no strong, positive relationship shown between water resources investment and the several measures of economic growth. The signs of the coefficients on the water investment variables tend to fluctuate randomly between positive and negative, and the equations explain very little of the variation in the dependent variable. There is no case in which an investment variable is statistically significant.

4.2 New Mexico Analysis

In an attempt to refine the focus of the research, the data of a single state were examined using a more detailed specification of the multivariate model utilized in the preceding section. Data from the State of New Mexico was chosen because it provided more detailed water investment data than the other states included in the study.

4.2.1 Study areas

All preliminary examinations of the New Mexico data suggested that many investments in water resource development were made in, and could be expected to have had direct impact on

Table 4.1.2-1. Population equations (county data).

Dependent Variable	Constant Term	Independent Variables: Total water investment, Pre-1948	Total water investment, 1948-1957	M&I investment, Pre-1948	Recreation investment, Pre-1948	Percent Change in Mfg. Income 1950-1960	M&I investment, 1948-1957	Recreation investment, 1948-1957	R^2
Percent Change Population, 1950-1960	9.764**	0.0006	0.0002						0.01
	(4.14)	(1.71)	(0.40)						
	8.545**			0.0004	0.0057	0.0113**			0.04
	(3.57)			(0.19)	(0.75)	(2.92)			
	8.773**			-0.0002	0.0055	0.0113**	0.0198	-0.0447	0.04
	(3.63)			(0.09)	(0.73)	(2.91)	(1.22)	(-1.15)	
		1948-1957	1958-1967	1948-1957	1948-1957	1960-1970	1958-1967	1958-1967	
1960-1970	1.971	0.0006	0.0003						0.01
	(1.09)	(1.25)	(0.51)						
	2.542			0.0091	-0.0157	-0.0006			0.01
	(1.41)			(0.72)	(-0.52)	(-0.34)			
	2.477			0.0020					0.01
	(1.36)			(1.06)					
	2.513			0.0091	-0.0156	-0.0006	-0.0005	0.0007	0.01
	(1.38)			(0.72)	(-0.52)	(-0.34)	(-0.05)	(0.10)	

Table 4.1.2-2. Farm income equations (county data).

Dependent Variable	Constant	Independent Variables: Irrigation Investment, Pre-1947	Irrigation Investment, 1948-1957	Irrigation Investment, 1958-1967	Annual Rainfall	R^2
Percent Change Farm Income 1950-1960	-0.535**	0.0009				0.001
	(6.49)	(0.52)				
	0.0754	0.0009	-0.0011			0.00
		(0.54)	(-0.26)			
	56.51**	0.0004	-0.0012		-0.4061**	0.03
	(2.61)	(0.22)	(-0.29)		(-2.83)	
1960-1970	117.9*		-0.0088			0.00
	(2.17)		(-0.21)			
	281.9**		-2.056	-0.206**		0.17
	(3.69)		(-0.54)	(-7.04		
	167.4		-0.0088		0.075	0.00
	(0.78)		(-0.21)		(0.05)	
	341.9		-0.0208	-0.2071**	-0.4321	0.17
	(1.74)		(-0.55)	(-7.03)	(-0.33)	

Table 4.1.2-3. Median family income equations (county data).

Dependent Variable: Percent Change in Median Income	Constant	Independent Variables: Total Investment, Pre-1948	Total Investment, 1948-1957	%Δ In Mfg. Income 1950-1960	Total Investment, 1958-1967	%Δ In Mfg. Income 1960-1970	R^2
1950-1960	78.80** (4.27)	-0.0001 (-0.28)					0.00
	78.38** (4.24)		(0.0004) (0.75)				0.00
	78.51** (4.17)	-0.0001 (-0.37)	0.0004 (0.79)				0.00
	76.43** (4.02)	-0.0001 (-0.29)	0.0004 (0.79)	0.0122** (4.02)			0.06
1960-1970	60.56** (56.49)		0.0001 (0.21)				0.00
	60.73** (50.97)				-0.0002 (-0.50)		0.00
	60.68** (49.55)		0.0001 (0.18)		-0.0002 (-0.48)		0.00
	60.18** (48.57)		0.0001 (0.24)		-0.0002 (-0.46)	0.0027* (2.08)	0.02

Table 4.1.2-4. Agricultural land value equations (county data).

Dependent variable: Percent Change in Lake Value	Constant	Independent Variables: Irrigation Investment, Pre-1948	Irrigation Investment, 1948-1957	Irrigation Investment, 1958-1967	R^2
1950-1960	91.32** (17.25)	0.0003 (0.29)			0.00
	90.98** (16.77)	0.0003 (0.26)	0.0008 (0.30)		0.00
1960-1970	74.33** (20.18)		0.0015 (0.80)		0.00
	74.71** (19.87)		0.0014 (0.77)	-0.0007 (-0.51)	0.00

Table 4.1.2-5. Population equations (water resources subareas).

Dependent Variable	Constant Term	Independent Variables							
Percent Change Population, 1950-1960		Total water investment, Pre-1948	Total water investment, 1948-1957	M&I investment, Pre-1948	Recreation investment, Pre-1948	Percent change Income 1950-1960	M&I investment, 1948-1957	Recreation investment, 1948-1957	R^2
	9.39			0.0008	0.0022	0.0559*			0.17
	(1.62)			(0.85)	(0.94)	(2.52)			
	10.91					0.0553*	0.0143	-0.0329	0.16
	(1.85)					(2.48)	0.58	(-0.55)	
	8.919			-0.7334	0.0022	0.0579**	0.7924	-0.0428	0.22
	(1.50)			(-1.49)	(0.94)	(2.63)	(1.51)	(-0.71)	
		1948-1957	1958-1967	1948-1957	1948-1957	1960-1970	1958-1967	1958-1967	
1960-1970	3.944			0.0138	-0.0321	0.0385			0.11
	(1.08)			(0.89)	(-0.84)	(1.49)			
	3.402			0.0005		0.0420	-0.0014		0.09
	(0.94)			(0.98)		(1.64)	(-0.44)		
	4.672			0.0152	-0.9357	0.0367	0.0026	-0.0027	0.12
	(1.19)			(0.94)	(-0.91)	(1.37)	(0.34)	(-0.59)	

Table 4.1.2-6. Farm income equations (water resources subareas).

Dependent Variable	Constant	Independent Variables: Irrigation Investment, Pre-1947	Irrigation Investment, 1948-1957	Irrigation Investment, 1958-1967	Annual Rainfall	R^2
Percent Change Farm Income 1950-1960	-9.105	0.0002	-0.0003			0.01
	(-1.43)	(0.51)	(-0.47)			
	10.21	0.0001	-0.0003		-0.1359	0.03
	(0.46)	(0.23)	(0.40)		(-0.92)	
1960-1970	-572.2*		-0.0047		6.204**	0.27
	(-2.37)		(-0.56)		(3.74)	
	546.4*		-0.0047	-0.0069	-6.16**	0.28
	(2.22)		(-0.56)	(-0.67)	(3.68)	

Table 4.1.2-7. Median family income equations (water resources subareas).

Dependent Variable: Percent Change in Median Income	Constant	Total Investment, Pre-1948	Total Investment, 1948-1957	Percent Change in Mfg. Income 1950-1960	Total Investment, 1958-1967	Percent Change in Mfg. Income 1960-1970	R^2
		Independent Variables					
1950-1960	81.57** (19.01)	0.0001 (-0.28)	0.00002 (0.06)				0.00
	81.89** (18.15)	-0.00005 (-0.26)	0.00003 (0.11)				0.00
	78.51** (4.17)	-0.0001 (-0.37)	0.0004 (0.79)				0.00
	73.18** (12.19)	-0.00001 (-0.05)	0.00003 (0.13)	0.0463* (2.09)			0.11
1960-1970							
	57.27** (39.64)		-0.0001 (-0.65)				0.01
	57.75** (38.78)				-0.0002 (-1.27)		0.01
	58.00** (37.48)		-0.0001 (-0.65)		-0.0002 (-1.26)		0.05
	58.53** (28.55)		0.0001 (-0.67)		-0.0002 (-1.26)	0.0056 (-0.39)	0.05

Table 4.1.2-8. Agricultural land value equations (water resources subarea data).

Dependent Variable	Constant	Irrigation Investment, Pre-1948	Irrigation Investment, 1948-1957	Irrigation Investment, 1958-1967	R^2
		Independent Variables			
Percent Change Land Value, 1950-1960	93.05** (8.96)	0.00001 (0.02)			0.00
	92.79**	0.00001 (0.01)	0.0001 (0.09)		0.00
1960-1970					
	67.79** (11.03)		-0.0005 (-0.76)		0.01
	70.20** (10.61)		-0.0005 (-0.98)	-0.0009 (-0.98)	0.04

more than a single county. For this reason, county groupings were made on the basis of probable primary impact, either in terms of investment and construction activity or increased water availability. Table 4.2-1 shows the county composition of study areas used in conducting the statistical analysis. Area 1 includes several counties because numerous large projects have been developed in both the San Juan and Rio Grande basins which overlap either water availability or expenditure impact. No logical basis on which to separate investments between single counties or two-county regions could be found.

Table 4.2-1. County aggregations.

Study Area	Counties Included
Area 1	Bernalillo, Mora, Rio Arriba, Sandoval, San Juan, Santa Fe, Los Alamos
Area 2	Colfax
Area 3	Union, Harding
Area 4	San Miguel
Area 5	Quay
Area 6	Curry
Area 7	Chaves
Area 8	Lincoln
Area 9	Otero
Area 10	Eddy
Area 11	Sierra, Dona Ana
Area 12	Grant
Area 13	Valencia, Socorro
Area 14	De Vaca, Guadalupe
Area 15	Catron
Area 16	Hidalgo
Area 17	Lea
Area 18	Luna
Area 19	McKinley
Area 20	Roosevelt
Area 21	Taos
Area 22	Torrance

4.2.2 Data

County census data were gathered for 1950, 1960, and 1970. From the census of population (1950, 1960, 1970), the following variables were collected: population, agricultural income, manufacturing and industrial income, total income, crops sold, and livestock (agricultural production) sold. From the census of population (1950, 1960, 1970), data were collected on agricultural employment, manufacturing and industrial employment, and total employment. For both income and employment, a residual category designated "other" was calculated. This category includes retail service and government, as well as other miscellaneous activities. Investment in water development, was collected from federal sources, the New Mexico State engineer (14), the Corps of Engineers (22), Soil Conservation Service (25), and the Bureau of Reclamation (18, 19, 20). These expenditures were categorized as agricultural water, municipal and industrial water, total expenditures, and a residual, "other" expenditures. The "other" expenditures included those for flood control, recreation, and miscellaneous activities.

Since the absolute value of each of these variables in each county could have a confounding influence on the statistical analyses (error terms would likely be correlated, particularly if investments took place in counties with smaller absolute values for the census variables), variables were determined on the basis of percentage change from one census year to the next. Investments, however, remained in absolute terms since most investment was discontinuous and percentage changes were not calculable. In addition, investments in water projects not completed three years prior to the end of the decade were included in the following decades investment, so that full impact should be evident. Table 4.2-2 indicates the percentage changes in variables and the absolute value of water investments by area by year.

4.2.3. Econometric model

The econometric model was constructed to determine coefficients for the relationships between water investment and economic activity. Table 4.2-3 lists the variables and equations contained in the simultaneous equation model. Three-stage least-squares regression analysis was used to estimate coefficients for these equations. Since no distribution function for multi-equation models of more than one endogenous and exogenous variables has been developed, no test for unbiasedness or asymptotic properties is possible. Therefore it should be understood that significance tests reported in the discussion may be viewed only as indicative, not conclusive, in interpreting the statistical properties of the various equation sets. Table 4.2-4 lists the correlation coefficients between the 15 variables listed in Table 4.2-2. Since some endogenous variables which are treated in the regression have relatively high correlation

Table 4.2-2. Values of variables for New Mexico by area. [a]

Area	Year	% ΔP	% ΔE_{TOT}	% ΔE_{AG}	% ΔE_{M}	% ΔE_{OTH}	% ΔY_{TOT}	% ΔY_{AG}	% ΔY_{M}	% ΔY_{OTH}	% ΔC	% ΔL	(X1000) ΔW_{TOT}	(X1000) ΔW_{AG}	(X1000) ΔW_{M}	(X1000) ΔW_{OTH}	Note
1	1950-60	63	61	-62	106	84	161	-38	128	174	-22	28	30,730	13,065		17,665	
	60-70	16	22	-19	5	18	82	29	94	81	58	122	161,941	28,218	5,425	128,248	
2	50-60	-23	-24	-42	-22	-7	38	30	131	57	-49	42	*b	*b	*b	*b	} Area 3
	60-70	-22	-12	-28	84	25	6	-16	227	47	133	147	250	*b	*b	250	
3	50-60	-18	-16	51	98	-14	15	-15	311	17	10	27					} Area 2
	60-70	-12	-5	-22	-18	-1	61	62	57	74	-21	26	280			280	
4	50-60	-11	-1	-47	11	14	33	-33	545	45	5	-12					
	60-70	-6	5	-52	-50	18	94	111	-66	104	127	105					
5	50-60	-12	-13	-43	46	-2	-1	-20	117	8	-37	17					
	60-70	-11	1	-7	43	1	54	70	164	45	12	99					
6	50-60	40	48	-27	48	64	111	-18	157	150	-6	104					
	60-70	21	23	-15	16	27	93	34	179	103	50	182					
7	50-60	42	40	-27	101	50	96	82	287	86	97	-10					
	60-70	-25	-32	-17	16	-36	5	91	-14	-5	-37	662					
8	50-60	4	20	-21	-30	44	62	33	78	80	142	14	239			239	
	60-70	-1	1	-48	3	14	75	117	-51	61	-13	65					
9	50-60	148	141	-34	255	155	259	71	141	326	129	33					
	60-70	11	11	-31	-33	19	115	109	127	114	3	17					
10	50-60	25	26	-19	42	33	75	126	-56	96	42	110					
	60-70	-19	-19	-36	-29	-16	25	26	67	23	-52	91					
11	50-60	59	52	-28	226	80	222	72	742	180	14	44	2,950	1,829	796	325	
	60-70	8	13	-32	36	20	64	83	-18	70	-5	252	500	310	135	55	
12	50-60	-14	-9	-52	-63	8	8	27	85	1	-52	31					
	60-70	18	15	-20	-7	19	82	64	4	92	83	51	417			417	
13	50-60	53	69	-70	57	146	161	-16	183	263	-34	49	*b	*b	*b	*b	
	60-70	2	8	-15	70	65	43	19	59	46	74	77	1,260	*b	*b	126	
14	50-60	-17	-20	-54	44	-4	7	-32	0	49	64	-20	3,508	3,400	*b	108	
	60-70	-13	-7	-27	5	-13	66	97	0	51	32	192	*b	*b	*b	*b	
15	50-60	-20	-22	285	45	-25	72	60	582	24	-46	19					
	60-70	-21	-23	-50	-69	36	48	53	-100	137	-12	79					
16	50-60	-2	-4	-1	-48	-4	14	-25	96	40	149	29					
	60-70	-4	-5	-34	0	3	51	45	-100	55	-14	68					
17	50-60	73	66	-4	140	70	143	51	357	179	128	-9					
	60-70	-7	-4	-27	-21	-1	42	104	57	22	-60	180					

Table 4.2-2. (Continued).

Area	Year	% ΔP	% ΔE_{TOT}	% ΔE_{AG}	% ΔE_M	% ΔY_{OTH}	% ΔT_{TOT}	% ΔY_{AG}	% ΔY_M	% ΔY_{OTH}	% ΔC	% ΔL	(X1000) ΔW_{TOT}	(X1000) ΔW_{AG}	(x1000) ΔW_M	(X1000) ΔW_{OTH}
18	50-60	11	21	-16	364	17	72	117	197	51	126	100				
	60-70	19	15	-22	-53	36	93	61	275	102	-24	95				
19	50-60	35	15	-66	11	57	184	-60	550	210	-73	-7				
	60.70	16	25	-81	14	39	57	151	13	58	89	75				
20	50-60	-1	1	-23	42	13	42	18	202	61	4	37				
	60-70	2	1	-36	-8	18	62	44	725	72	-6	211				
21	50-60	-7	-27	-74	-6	12	73	-30	0	97	199	28				
	60-70	10	59	-35	-10	88	149	-79	0	76	-52	-14				
22	50-60	-19	-12	-63	-35	37	55	12	0	51	-40	30				
	60-70	-18	-17	-8	4	-20	55	0	-100	58	119	86				

a. Variables are defined as:
%Δ P: Percent change in population
%Δ E_{TOT}: Percent change in total employment
%Δ E_{AG}: Percent change in agricultural employment
%Δ E_M: Percent change in manufacturing and industrial employment
%Δ E_{OTH}: Percent change in other employment (including service, government, and retailing)
%Δ Y_{TOT}: Percent change in total income
%Δ Y_{AG}: Percent change in agricultural income
%Δ Y_M: Percent change in manufacturing and industrial income
%Δ Y_{OTH}: Percent change in other income
%Δ C: Percent change in crops sold
%Δ L: Percent change in livestock sold
Δ W_{TOT}: Change in total water investment
Δ W_{AG}: Change in agricultural water investment
Δ W_M: Change in municipal and industrial water investment
Δ W_{OTH}: Change in other water investment (including a proportion of M&I investment depending upon the Ratio of non-basic to basic activity in the area).

b. An (*) denotes investment of $1000 or less.

Table 4.2-3. Simultaneous equation model.

No.	Dep Vble	Int	%ΔP	$\%\Delta Y_{TOT}$	$\%\Delta Y_{AG}$	$\%\Delta Y_{M}$	$\%\Delta Y_{OTH}$	%ΔC	%ΔA	ΔW_r	ΔW_{AG}	ΔW_{M}	ΔW_{OTH}
1.	$\%\Delta E_{TOT}$	$b_{2,0}$	$b_{2,1}$	$b_{2,2}$						$b_{2,12}$			
2.	$\%\Delta E_{AG}$	$b_{3,0}$	$b_{3,1}$		$b_{3,7}$	$b_{3,8}$	$b_{3,9}$				$b_{3,13}$		
3.	$\%\Delta E_{m}$	$b_{4,0}$	$b_{4,1}$		$b_{4,7}$	$b_{4,8}$	$b_{4,9}$					$b_{4,14}$	
4.	$\%\Delta E_{oth}$	$b_{5,0}$	$b_{5,1}$		$b_{5,7}$	$b_{5,8}$	$b_{5,9}$						$b_{5,15}$
5.	$\%\Delta E_{TOT}$	$b_{6,0}$	$b_{6,1}$							$b_{6,12}$			
6.	$\%\Delta Y_{ag}$	$b_{7,0}$	$b_{7,1}$					$b_{7,10}$	$b_{7,11}$		$b_{7,13}$		
7.	$\%\Delta Y_{m}$	$b_{8,0}$	$b_{8,1}$									$b_{8,14}$	
8.	$\%\Delta Y_{oth}$	$b_{9,0}$	$b_{9,1}$										$b_{9,15}$
9.	%ΔC	$b_{10,0}$									$b_{10,13}$		

Table 4.2-4. Correlation coefficients between variables.

%ΔP	$\%\Delta E_{TOT}$	$\%\Delta E_{AG}$	$\%\Delta E_{m}$	$\%\Delta E_{OTH}$	$\%\Delta Y_{TOT}$	$\%\Delta Y_{AG}$	$\%\Delta Y_{M}$	$\%\Delta Y_{OTH}$
1.000	.956	.301	.412	.803	.847	.154	.462	.867
	1.000	.312	.437	.852	.819	.163	.440	.850
		1.000	.203	-.239	.158	.265	.086	.123
			1.000	.302	.361	.186	.432	.204
				1.000	.709	-.076	.509	.823
					1.000	.420	.458	.905
						1.000	-.317	.202
							1.000	.398
								1.000

%ΔC	%ΔL	ΔW_{TOT}	ΔW_{AG}	ΔW_{M}	ΔW_{OTH}
-.021	.162	.262	.143	.617	.290
.095	.194	.153	.031	.524	.316
.440	.252	-.222	-.271	.028	.028
.208	.034	.326	.248	.452	.326
-.011	.022	.245	.109	.554	.517
-.039	.201	.291	.143	.752	.344
.177	.394	-.170	-.207	.114	-.143
-.106	-.215	.330	.195	.645	.469
.038	.162	.317	.198	.615	3.79
1.000	-.006	.066	.054	-.079	.331
	1.000	-.288	-.314	-.045	-.126
		1.000	.974	.621	.605
			1.000	.441	.454
				1.000	.650
					1.000

coefficients, the variables for each regression equation were chosen so as to minimize multi-colinearity. For example, no regression was attempted which would include ΔW_{TOT} and ΔW_{AG}, ΔW_M, or ΔW_{OTH}. Neither were ΔE_{TOT} or ΔY_{TOT} included in equations with ΔE_{AG}, ΔE_M or ΔE_{OTH}, or ΔY_{AG}, ΔY_M, or ΔY_{OTH}, respectively.

The regressions were made for all areas, listed in Table 4.2-1, for those areas in which the agriculture to manufacturing employment was greater than or equal to 1, and for those areas in which the agriculture to manufacturing employment ratio was strictly greater than one. The latter two regression sets were considered to reduce the possibility of confounding the result by including areas with industries in which water is a relatively unimportant input and because much of water investment in New Mexico during the 31-year period was for agricultural (irrigation) purposes.

Two different approaches were used in conducting this regression analysis. The first set of estimates was developed by specifying that values for percentage change in income ($\hat{Y}$) be estimated, and then employment utilized as the dependent variable. Tables 4.2-5a, 4.2-5b, and 4.2-5c list the results of the first approach.

The second set of estimates was developed by specifying that the values for percent change in employment ($\hat{E}$) be estimated, and income utilized as the independent variable. The results for the same three area selection alternatives are listed in Tables 4.2-6a, 4.2-6b, and 4.2-6c.

Results of these regressions indicate that the null hypothesis (that $b_{ij} \neq 0$) cannot be rejected at the .10 level since in no case is the standard deviation less than about 80 percent of the coefficients. In addition, coefficient signs, if significant, would indicate that water investment may be counter-productive in terms of both income and employment. When only areas with agricultural employment greater than manufacturing and industry are included, the coefficients are positive in sign, though insignificant.

Two specific problems with the data may be considered. First, the data are for income, investment, and sales unadjusted for price differences. No change would be expected in relative magnitudes for those variables measured in real terms, although if selected deflators were used for each category, a difference in percentages might be generated. However, the use of percentage changes should not compound the deflator problem because deflators "cancel out" in the equational structure; that is, both exogenous and endogenous variables will be deflated.

Secondly, it is apparent that although the New Mexico data are somewhat more refined than those analyzed for the total sample, similar inconsistent and unexpected results were obtained. The data, even at this level of detail, may still lack sufficient refinement in terms of spatial and temporal specificity and thus be too gross to provide evidence of a measurable relationship between investments in water development and regional indicators of economic growth.

Thus, the evidence developed for areal units which extend beyond the project area, even under alternative model specifications and degrees of data refinement, remain inconclusive. The data are either too gross to show regional economic impacts of water investment or investment in water development produces no consistent, positive and significant effect on quantifiable indicators of regional growth. Such an apparently ambiguous result does not negate the possibility of treating regional wealth distribution questions because individual projects may show significant impacts of income and employment, both on short term periods where construction expenditures are large and in the longer term where activity levels of a given industry or sector expand. Growth observed to be related to water investment in a specific area may be only a transfer from other areas within a larger area of the type used as observations in our analyses. Under this circumstance water investment could be used as an effective tool to reallocate and control the pace and distribution of economic expansion among potential project areas within a larger region. However, the analysis is reduced to a "case study" type approach in which individual and/or cumulative, project effects are expanded to a larger areal unit based on techniques which incorporate quantitative estimates of the magnitude of forward and backward economic linkages to other industries within a larger geographic area which contains the project service area.

This "case study" approach is demonstrated in the following section using project level data on two Bureau of Reclamation irrigation projects.

Table 4.2-5a Regression of employment with total data.

	Dependent Variable is $\%\Delta E_{TOT}$					
	Intercept	$\%\Delta P$	Y_{TOT}	ΔW_{TOT}		
B	-11.85	.58	.21	.0004		
SD	28.87	.73	.41	.001		
B/SD	-.41	.79	.52	.46		
	Dependent Variable is $\%\Delta E_{AG}$					
	Intercept	$\%\Delta P$	ΔW_{AG}	Y_{AG}	Y_M	Y_{OTH}
B	18.90	1.70	.00	-1.37	.30	.17
SD	151.00	4.26	.002	3.24	.30	.40
B/SD	.12	.41	.45	-.42	.98	.42
	Dependent Variable is $\%\Delta E_M$					
	Intercept	$\%\Delta P$	Y_{AG}	ΔW_M	Y_M	Y_{OTH}
B	-370.70	-8.61	7.40	-.01	.26	-.68
SD	689.50	19.08	14.44	.04	1.36	1.77
B/SD	-.54	-.45	.51	-.19	.19	-.38
	Dependent Variable is $\%\Delta E_{OTH}$					
	Intercept	$\%\Delta P$	Y_{AG}	Y_M	ΔW_{OTH}	Y_{OTH}
B	58.96	2.05	-.81	-.14	-.0001	.13
SD	141.80	3.94	2.98	.28	-.0004	.37
B/SD	.42	.52	-.27	-.51	-.32	.34

Table 4.2-5b. Regression of employment with $E_{AG}/E_M \geq 1$.

	Dependent Variable is $\%\Delta E_{TOT}$					
	Intercept	$\%\Delta P$	Y_{TOT}	ΔW_{TOT}		
B	1.58	1,23	-.16	-.003		
SD	14.85	.30	.21	.002		
B/SD	1.05	4.11	-.76	-.49		
	Dependent Variable is $\%\Delta E_{AC}$					
	Intercept	$\%\Delta P$	ΔW_{AG}	Y_{AG}	Y_M	Y_{OTH}
B	-14.88	.77	-.005	-.56	.26	.07
SD	37.11	1.16	.006	.97	.26	.14
B/SD	-.40	.66	-.76	-.57	1.00	.53
	Dependent Variable is $\%\Delta E_M$					
	Intercept	$\%\Delta P$	Y_{AG}	ΔW_m	Y_M	Y_{OTH}
B	84.82	2.29	-.89	.29	-.09	-.04
SD	135.20	4.03	3.39	.27	1.10	.59
B/SD	.63	.57	-.26	1.17	-.08	-.07
	Dependent Variable is $\%\Delta E_{OTH}$					
	Intercept	$\%\Delta P$	Y_{AG}	Y_M	ΔW_{OTH}	Y_{OTH}
B	306.80	10.90	-9.25	3.28	-.05	1.29
SD	6203.00	200.00	183.60	53.98	.93	25.65
B/SD	.05	.05	-.05	.06	-.06	.05

Table 4.2-5c. Regression of employment with E_{AG}/E_M 1.

Dependent Variable is $\%\Delta E_{TOT}$

	Intercept	$\%\Delta P$	Y_{TOT}	ΔW_{TOT}
B	-24.40	.30	.43	-.0040
SD	29.85	.70	.44	.003
B/SD	-.82	.42	.90	-1.43

Dependent Variable is $\%\Delta E_{AG}$

	Intercept	$\%\Delta P$	ΔW_{AG}	Y_{AG}	Y_M	Y_{OTH}
B	-1.00	2.89	.02	-2.64	1.79	.33
SD	654.50	35.78	.20	31.64	16.04	3.64
B/SD	-.002	.08	.08	-.08	.11	.09

Dependent Variable is $\%\Delta E_M$

	Intercept	$\%\Delta P$	Y_{AG}	ΔW_M	Y_M	Y_{OTH}
B	4006.00	130.20	-104.50	7.88	32.19	3.07
SD	13070.00	428.70	350.90	26.07	113.30	12.93
B/SD	.31	.30	-.30	.30	.28	.28

Dependent Variable is $\%\Delta E_{OTH}$

	Intercept	$\%\Delta P$	Y_{AG}	Y_M	ΔW_{OTH}	Y_{OTH}
B	67.56	3.08	-.171	.56	.14	.16
SD	43.68	2.069	1.70	.83	.11	.19
B/SD	1.55	1.50	-1.01	.68	1.21	.80

Table 4.2-6a. Regression of Income with Total Data

Dependent Variable is $\%\Delta Y_{TOT}$

	Intercept	$\%\Delta P$	E_{TOT}	W_{TOT}
B	50.52	.81	.68	.0000
SD	15.47	.89	.85	.0002
B/SD	3.27	.91	.80	.22

Dependent Variable is $\%\Delta Y_{AG}$

	Intercept	$\%\Delta P$	ΔW_{AG}	E_{AG}	E_M	E_{OTH}
B	163.50	4.86	-.001	-5.22	3.23	.14
SD	106.40	16.03	.003	15.12	2.38	1.32
B/SD	1.54	.30	-.35	-.35	1.36	.10

Dependent Variable is $\%\Delta Y_M$

	Intercept	$\%\Delta P$	E_{AG}	ΔW_M	E_M	E_{OTH}
B	-100.90	-41.12	40.84	-.02	-1.39	2.06
SD	876.00	134.60	127.60	.18	20.75	10.70
B/SD	-.12	-.31	.32	-.10	-.07	.25

Dependent Variable is $\%\Delta Y_{OTH}$

	Intercept	$\%\Delta P$	E_{AG}	E_M	ΔW_{OTH}	E_{OTH}
B	55.62	.20	1.91	-.38	-.0002	-.17
SD	69.98	10.30	9.75	1.57	.0006	.83
B/SD	.79	.02	.20	-.24	-.38	-.21

Table 4.2-6b. Regression of Income with $E_{AG}/E_M \leq 1$.

Dependent Variable is $\%\Delta Y_{TOT}$

	Intercept	$\%\Delta P$	E_{TOT}	ΔW_{TOT}
B	41.54	.46	1.20	.003
SD	20.55	1.13	1.08	.006
B/SD	2.02	.40	1.13	.59

Dependent Variable is $\%\Delta Y_{AG}$

	Intercept	$\%\Delta P$	ΔW_{AG}	E_{AG}	E_M	E_{OTH}
B	111.50	19.73	-.02	-15.59	-1.49	-1.92
SD	839.60	106.50	.37	85.19	42.32	8.90
B/SD	.13	.18	-.06	-.18	-.04	-.22

Dependent Variable is $\%\Delta Y_M$

	Intercept	$\%\Delta P$	E_{AG}	ΔW_M	E_M	E_{OTH}
B	-212.10	-86.34	65.19	-.35	8.76	12.55
SD	1492.00	360.30	254.40	7.39	68.39	72.09
B/SD	-.14	-.24	.26	-.05	.13	.19

Dependent Variables $\%\Delta Y_{OTH}$

	Intercept	$\%\Delta P$	E_{AG}	E_M	ΔW_{OTH}	E_{OTH}
B	113.20	.45	-.48	1.82	-.02	.59
SD	95.16	10.68	8.40	3.22	.02	1.29
B/SD	1.19	-.04	-.06	.57	-1.01	.46

Table 4.2-6c. Regression of Income with $E_{AG}/E_M < 1$.

Dependent Variable is $\%\Delta Y_{AG}$

	Intercept	$\%\Delta P$	ΔW_{AG}	E_{AG}	E_M	E_{OTH}
B	376.10	6.31	.08	-5.22	8.94	-1.91
SD	797.30	19.79	.13	25.53	24.16	2.12
B/SD	.47	.32	.63	-.20	.37	-.90

Dependent Variable is $\%\Delta Y_M$

	Intercept	$\%\Delta P$	E_{AG}	ΔW_M	E_M	E_{OTH}
B	210.20	-8.64	12.44	2.71	1.21	-6.64
SD	1754.00	61.69	83.11	2.85	55.21	15.58
B/SD	.12	-.14	.15	.95	.02	-.43

Dependent Variable is $\%\Delta Y_{OTH}$

	Intercept	$\%\Delta P$	E_{AG}	E_M	ΔW_{OTH}	W_{OTH}
B	-234.80	-18.87	19.72	-6.25	-.74	2.43
SD	2801.00	194.20	185.90	57.36	7.56	23.85
B/SD	-.08	-.10	.11	-.11	-.10	.10

Dependent Variable is $\%\Delta Y_{TOT}$

	Intercept	$\%\Delta P$	E_{TOT}	ΔW_{TOT}
B	60.79	1.99	-.15	.004
SD	11.20	.64	.61	.006
B/SD	5.43	3.12	-.25	.63

5.0 SELECTED CASE STUDIES

5.1 Introduction

In this section, two isolated Bureau of Reclamation projects are used as case studies in an investigation of local area economic impacts. The projects considered in this analysis are the Silt Project in Garfield County and the Florida Project in Montezuma County, Colorado. Each of these projects is located in rather remote rural areas much like most of the irrigation development in the intermountain west. The total economic impacts of these two water development projects are measured by comparing economic parameters of the larger rural region in which they are located assuming the the projects, (1) do, and (2) do not exist. Changes in economic activity associated with inclusion of the two water projects are measured and attributed to water resource investment. Changes in the level and distribution of economic activity are used as measures of economic development.

The development and application of water to agricultural farm lands creates an economic atmosphere such that both direct and indirect benefits may be produced for local areas. If introduction of additional irrigation water increases net return and/or increases production expenditures and sales of primary products for firms applying the extra water, then linkages among industry groups creates an income multiplying effect directly attributable to public and private investments. Given the interdependent nature of the economic system, these induced impacts do not end with primary recipients, but continue to filter throughout and affect all or nearly all industry groups in the system. Public investment in water development projects represents an exogenous change that would trigger such a change. As each industry group reacts to increased activity in agricultural sectors, an increase in area economic activity can be expected. The relevant question becomes one of measuring, not only the change in economic activity associated with direct beneficiaries, but the direct and indirect, i.e., total economic activity, effects of a micro-area water project.

Direct and indirect changes in economic activity are linked to Bureau of Reclamation projects. The full impact of these linkages and cause and effect relationships are not limited to primary beneficiaries. Employment of the input/output technique and the economic base study yields information about changes in income, employment, growth, etc., for each sector in the model as well as the entire region.

The multiplier concept developed by Keynes (6, 9) is one method that can be used to measure the magnitude of change that results from an exogenous public investment. Multiplier analysis is based on the principle that an exogenous dollar injected into the hands of a consuming public is used to purchase commodities over and over again with some small amount of leakage. This results in the total purchasing power of one dollar being multiplied several times.

5.1.1 The input/output model

A derivative of the multiplier principle of measuring economic activity is the input/output technique developed by Leontief (10). The input/output analysis is a mathematical representation of an economic system depicting the flows (from-to, monetary or physical) from each industry to all other industires in the region. In addition to the processing sector, the total input/output model is made up of final demand, i.e., purchases for final consumption and/or additions to inventory; and payments to households and other sectors for services and imports. This systematic representation of economy yields a means for assessing a variety of exogenously introduced influences which result in regional impacts. In addition, the input/output model yields a variety of output, income, and employment multipliers.

Application of the input/output technique to the specific problem examined in this report is somewhat different from the normal application. The economic impacts attributed to the two Bureau of Reclamation projects are analyzed using the input/output model already developed for a larger region, i.e., the Upper Main Stem (UMS) subbasin of the Colorado River Basin. The Upper Main Stem subbasin contains 25,606 square miles of land and includes the following counties: Delta, Dolores, Eagle, Garfield, Grand, Gunnison, Hinsdale, Mesa, Montrose, Quray, Pitkin, San Miguel, and Summit in Colorado and Grand County in Utah (17).

5.1.2. Economic base study

The economic base study is a systematic method of describing economic activity within a well defined region. This technique resembles, and to some extent was a forerunner of the input/output technique. An economic base study provides many useful pieces of information about an area which can be beneficial to both private and public decision-makers.

Results obtained from a base study are dependent upon classifying producing industry groups, or a portion of their output, as basic (export) or non-basic (for consumption within the area) production. In general, a base study can provide information about employment, income, weak spots or gaps in the economy, set goals, and aid in decision-making.

5.2 The Project Areas

Agriculture is the major economic activity in the area of the Silt and Florida projects. Both projects are located in higher mountain valleys that limit farm enterprises to predominantly range livestock, cow-calf operations, and dairy farms with complementary forage crops and small grains. Very little cash cropping exists in either project area and that which does occur is limited to sales of small grains, forage, and related crops.

Project lands are located in rural areas near Grand Junction (Silt project) and Durango (Florida project), Colorado. The Silt project consists of about 6,000 acres of irrigated land, and the Florida project has about 16,000 acres. The 22,000 irrigated acres in the two project areas vary topographically from flat to gently rolling farm land. Elevation at Silt and Florida is about 6,000 and 6,600 feet above sea level, respectively. This altitude results in a short growing season (Silt, 101 days; Florida, 96 days) which limits the type and variety of crops that can be grown, and tends to encourage livestock enterprises. Population in Garfield and Montezuma Counties was 14,821 and 12,952, respectively, for each area in 1970 (21).

These two projects areas appear to have fairly strong ties to the rest of the region and population centers of the Upper Main Stem subbasin. Each area is separated by mountains from the Eastern Slope population centers. These conditions tend to reinforce the notion of using economic models of the Main Stem subbasin to capture the total effects of the projects.

The Silt project is located in the North-Central part of the UMS subbasin. The nearest town is Rifle, Colorado, about 6 miles west, population in 1970 of 2,150. The largest town on the western slope is Grand Junction with a population of 20,170 in 1970. Grand Junction is about 75 miles west and south from the Silt project. Much of the economic activity from the Silt area is linked to Rifle and Grand Junction.

The Florida project is located just out of the UMS subbasin drainage area. This project is located 50 miles south and slightly east of Rico, Colorado. Rico is located in the southernmost central part of the UMS subbasin. Durango, Colorado, is the nearest city to the Florida project. It is located about 10 miles north and west of the project area. Population of Durango was 10,333 in 1970. Economic activity stemming from the Florida project is linked to Durango and to the UMS subbasin.

The UMS subbasin is a vast expanse of land that ties into the Colorado River system. There are 3,343,459 acres of land in the UMS subbasin. Of this total, 449,785 acres are irrigated. Thus, 22,000 acres of irrigated land under the two projects is 4.4 percent irrigated acres in the UMS subbasin. Population in the UMS subbasin was 142,906 in 1970 (21). County populations for the two project areas in 1970 were 14,821 for Garfield (Silt project) and 12,952 for Montezuma (Florida project). Population of the two counties was only about 17.8 percent of the UMS subbasin.

In general, the entire UMS region including Durango is isolated from much of the economic activity of other areas. Because of topography, distances from other metropolitan areas, and relationship of Durango to the UMS subbasin, it has been assumed that no biases are incorporated into results if the economic models of the UMS are used to derive before and after effects of the Silt and Florida water projects.

5.2.1 Data from the project areas

Individual farm records were obtained from each project site before the projects were constructed and several years after water deliveries were made. Individual farm records contained information about crop and livestock enterprises, water availability and use, and inventories of real and personal property (27, 28). These data were supplemented with other information about labor and machine requirements per unit for typical crop and livestock activities.

Farm budgets have been developed from individual farm records obtained from Silt and Florida area farmers. These primary data have been arranged in such a way the ex ante/export conditions and economic changes have been identified, i.e., before and after project conditions. These changes in farm economic patterns that are directly linked to the irrigation projects were then superimposed upon the UMS models.

It has been assumed that sampled ranchers in the project area were representative of the entire project area as well as the UMS subbasin. Production techniques used in crop and livestock enterprises are near identical for the entire subbasin. Farmers have had sufficient time to adjust their production and consumption habits to correspond to increased water supplies. Price adjustments, management, and other factors have been accounted for and appropriate compensation in actual benefits received have been made for both pre- and post-project time periods.

Several different sources of secondary data were employed to check data used. County Records, Census of Agriculture, Bureau of Reclamation annual summaries, and other state and county data were used to supplement farm surveys. Estimated changes in agricultural activity (range livestock and dairy sectors) were based on primary data collected at each project site for two time periods. Changes in agricultural activity and thus, the direct and indirect additions to economic activity in the project areas and the UMS subbasin have been attributed singly to supplemental water supplies.

5.3 The Analysis

Much knowledge already exists concerning the measurement of direct and indirect changes in economic activity and the impact that these changes will have on recipients. Small area studies have been conducted to determine how the distribution of income will change among irrigating farmers following development of supplemental water.[13] Input/output and economic base studies are used in this study to identify and measure changes in sectoral income that can be linked to exogenous public investments in water projects.

5.3.1 Adaptation of the Upper Main Stem

Various forms of the input/output technique have been successfully applied in regional analysis and problem solving (4, 8, 26). In general, these models are adaptations of the Leontief model of the U.S. economy (11). The transactions table of an input/output model of this type contains three sectors: the processing sector, the final demand, and the payments sector (13).

This analysis utilized an input/output model developed by Udis et al. (17) for the UMS subbasin of the Colorado River Study. The processing sector of this model is a 31 by 31 matrix, i.e., the processing sector has been divided into 31 producing industry groups. The first eight industry groups are agriculture and forestry. Industry groups 9 through 13 are the extractive or mining groups. Manufacturing includes industry groups 14 through 19, and industry groups 20 through 26 are the service sector. Transportation, utilities, construction, retail, and finance complete the industry groups. Gross industry flows and direct coefficients from Udis' model are utilized in this study without alteration. Thus it was necessary to assume that technology, management, and production techniques were invariant over time since estimates by Udis are not significantly changed by introduction of the two irrigation projects.

The input/output technique is static. Therefore, calculation of before and after project effects resemble two instantaneous snapshots of economic conditions in the region. It is assumed that the total impact of change in economic activity may be attributed to water development at Silt and Florida projects. This assumes that capital, natural resource, and other inputs were available in sufficient quantity to satisfy the increased demand. Measurement of sectoral changes and the effects of additional water have been based on the levels of economic activity that existed in the UMS subbasin in 1970.

5.3.2 Changes introduced into the model

Information obtained from farm surveys revealed that dramatic changes had occurred in range livestock and dairy sectors in response to the two projects. Although increases in average crop yields and livestock production accounted for the greatest change in benefits, some additional irrigated acres were added for the increase in benefits attributed to the two water projects.

Udis' 1970 input/output model provided an estimate of direct and indirect benefits in a preproject sense. Final demand for range livestock and dairy was increased by the amount that increased sales from the two projects were allocated to final demand sectors assuming the same distribution of sales as without the projects. New

[13]For a discussion of technological and pecuniary externalities, see reference (27), and for a discussion of the distribution of primary benefits among irrigating farmers, see reference (28).

estimates of total gross output for each sector were computed to provide direct and indirect changes in economic activity attributable to the water projects.

5.3.3 Results of input/output analysis

Several economic variables can be efficiently used to isolate and measure micro-regional aggregate and sectoral changes in economic activity that occur in response to a change in the autonomous sector. The interdependent relationship of industry groups and the degree to which they are linked together are shown in Table 5.3.3-1 by observing changes in total gross output in the several industries in response to a hypothetical increase in final demand associated with only the agricultural industries.

Those sectors showing the largest positive change were range livestock ($144,972) and dairy ($260,302). Nearly all other industry groups reflected increased economic activity because of changes in range livestock and dairy sectors and obvious linkages among them.

Dollar increases in seven of the remaining industry groups amounted to $10,000 or more. These included feed and field crops ($10,000), food and kindred products ($11,549), all other manufacturing ($11,530), and other retail ($9,803), agricultural services ($33,131), transportation ($18,607), and rentals and finance ($14,255). Changes of less than $10,000 in the total gross output ranged from $5 in fabricated metals to $6,257 in the electrical energy sector. Smallest increases were in truck crops ($16), forestry ($56),

Table 5.3.3-1. Total gross output of processing sector industries showing the impacts of supplemental water development in Silt and Florida areas of the Upper Main Stem subbasin, 1970.

Industry	Without Irrigation Water Impact	With Irrigation Water Impact	Difference	Percent Change
Range Livestock	$ 47,022,379	$ 47,167,351	$144,972	.3083
Feeder Livestock	4,640,870	4,641,110	241	.005287
Dairy	3,617,497	3,877,799	260,302	7.195644
Feed and Field Crops	8,380,024	8,381,045	10,020	.120611
Truck Crops	1,072,013	072,029	16	.001521
Fruit	4,345,385	4,350,708	5,324	.122514
Forestry	6,195,353	6,195,409	56	.000902
All Other Agriculture	1,998,867	1,999,443	576	.028821
Coal	11,819,958	11,820,581	623	.005271
Oil and Gas	3,675,292	3,675,292	0	.0
Uranium	87,551,872	87,551,872	0	.0
Zinc	18,594,000	18,495,000	0	.0
All Other Mining	17,287,214	17,287,227	13	.000075
Food and Kindred Products	24,024,831	24,036,380	11,549	.048071
Lumber and Wood Products	7,671,191	7,671,283	92	.001201
Printing and Publishing	5,528,754	5,529,774	1,017	.018402
Fabricated Metals	2,546,969	2,546,974	5	.000181
Stone, Clay and Glass	3,419,140	3,419,148	9	.000254
All Other Manufacturing	34,790,472	34,802,002	11,530	.033141
Wholesale Trade	31,139,812	31,144,860	5,048	.016211
Service Stations	4,957,562	4,962,206	4,644	.093683
All Other Retail	63,229,476	63,239,279	9,803	.015504
Eating and Drinking Places	24,049,811	24,050,207	396	.001647
Agricultural Services	4,653,172	4,686,303	33,131	.712002
Lodging	27,134,130	27,134,230	100	.000369
All Other Services	48,146,158	48,148,583	2,425	.005037
Transportation	49,656,320	49,674,927	18,607	.037472
Electric Energy	17,646,072	17,652,329	6,257	.035458
Other Utilities	23,540,841	23,542,701	1,860	.007901
Contract Construction	104,295,260	104,295,880	620	.000594
Rentals and Finance	73,770,002	73,784,257	14,255	.019324

all other mining ($13), lumber and wood ($92), fabricated metals ($5), and stone, clay and glass ($9). Three industry groups, oil and gas, uranium, and zinc, have no change in total gross output, i.e., they are completely independent of the ramifications or the cause and effect conditions resulting from changes in the range livestock and dairy industries.

Direct and indirect coefficients and changes in total gross output derived from the input/output model describe the interdependent relationships that exist. A variety of multipliers and other useful information can be developed from the input/output model to further analyze the regional economic ramifications stemming from investments in water development.

5.3.3.1 Output multipliers

Output multipliers for each sector in the model have been computed and are listed in Table 5.3.3.1-1. These multipliers measure the change in total output when there is a one dollar change in final demand for the output of that given industry. Output multipliers range in magnitude from 1.06 to 2.30. For each on dollar change in final demand for range livestock products that industry group will require $1.30 of direct and indirect purchases. Likewise, the dairy industry require $1.45 of direct and indirect purchases to satisfy a one dollar change in final demand. Note that the largest multipliers are generally in the agricultural and agricultural supply and processing sectors which are presently quite well developed in the subbasin as compared to other sectors.

5.3.3.2 Income multipliers

Direct coefficients for the household component in each sector were computed and used to derive estimates of Type 1[14] income multipliers. Type I income multipliers measure only the direct and indirect changes in income resulting from a one dollar increase in income for any given sector in the model. The income multipliers found in Table 5.3.3.2-1 range in value from a low of $1.05 for rentals and finance to a high of $26.60 for feeder livestock. The large value for the feeder livestock industry income multiplier could be erroneous, but is much larger than any other sector multiplier because of the magnitude of the direct coefficient for households. Type I income multipliers for range livestock and dairy are $1.29 and $1.57, respectively. These values indicate that for each one dollar change in income there will be direct and indirect income effects of $1.29 and $1.57, respec- range livestock and dairy sectors are $.48 and $.31, respectively, for each dollar of increase in final demand. Hence, an initial change in range livestock and dairy will increase income earned by households by $.62 (1.29 x .48) and $.49 (1.57 x .31) (3). Total direct and indirect changes in household income in the UMS subbasin attributed to the Silt and Florida project are $51,765 and $12,758 annually for range livestock and dairy industry groups.

[14]See reference (13) for a discussion of input/output related multipliers.

Table 5.3.3-1. Output multipliers for the Upper Main Stem subbasin, 1970.

1.	Range Livestock	1.3041
2.	Feeder Livestock	2.3019
3.	Dairy	1.4475
4.	Food and Field Crops	1.2731
5.	Truck Crops	1.6063
6.	Fruit	1.5976
7.	Forestry	1.0783
8.	All Other Agriculture	1.6454
9.	Coal	1.1008
10.	Oil and Gas	1.2782
11.	Uranium	1.4237
12.	Zinc	1.0881
13.	All Other Mining	1.1035
14.	Food and Kindred Products	1.7560
15.	Lumber and Wood Products	1.6324
16.	Printing and Publishing	1.0908
17.	Fabricated Metals	1.1089
18.	Stone, Clay, and Glass	1.4443
19.	All Other Manufacturing	1.0650
20.	Wholesale Trade	1.2285
21.	Service Stations	1.1798
22.	All Other Retail	1.3128
23.	Eating and Drinking Places	1.3893
24.	Agricultural Services	1.1466
25.	Lodging	1.3059
26.	All Other Services	1.1959
27.	Transportation	1.2726
28.	Electric Energy	1.2969
29.	Other Utilities	1.1200
30.	Contract Construction	1.5706
31.	Rentals and Finance	1.0810

Table 5.3.3.2-2 contains the distribution of direct and indirect increase in household income for each sector. These are net values that are linked to supplemental irrigation water from the Silt and Florida projects, and are produced by changing (increase in output due to irrigation water) final demand in sectors 1 and 3. Direct and indirect increases in household incomes range from a low of zero to a high of $79,660. Eighteen sectors (less than $1,000) exhibit little or no interdependent relationship with range livestock or dairy. Food and field crops ($5,199), all other retail ($831), agricultural services ($13,217), transportation ($7,440), and rentals and finance ($10,473) had fairly large changes in household incomes that were linked to the irrigation projects.

The distribution of direct and indirect irrigation benefits are concentrated in range livestock ($69,412) and dairy ($79,770). Three other sectors: agricultural services, transportation, and rentals and finance are linked quite close to the agricultural industry. All other sectors exhibit varying degrees of interdependent linkages back to the range livestock and dairy sectors. The input/output model demonstrates how level of economic activity in many other sectors of a region are affected by public investment. Total aggregate direct and indirect household incomes are $205,022.

5.3.4 Results of the economic base study

Fundamental to the base study is defining a region boundary and determining activity or the proportion of total output going to exports. The base study output is dependent upon industry grouping, the existence of proportionality between

Table 5.3.3.2-1. Processing sector industry type I income multipliers in the Upper Main Stem subbasin, 1970.

Industry	Household Direct Coefficient	Σ[Row entry X HH Coef]	Multiplier
Range Livestock	0.47880	.6181	1.2909
Feeder Livestock	0.02186	.5814	26.5965
Dairy	0.30603	.4795	1.5668
Feed and Field Crops	0.51886	.6188	1.1927
Truck Crops	0.32897	.5707	1.7349
Fruit	0.32230	.5603	1.7384
Forestry	0.53898	.5761	1.0690
All Other Agriculture	0.28102	.5173	1.8409
Coal	0.53162	.5698	1.0718
Oil and Gas	0.13288	.2591	1.9501
Uranium	0.24937	.3803	1.5252
Zinc	0.40865	.4350	1.0644
All Other Mining	0.56509	.6027	1.0666
Food and Kindred Products	0.19538	.5432	2.7804
Lumber and Wood Products	0.27010	.3804	1.4082
Printing and Publishing	0.39207	.4252	1.0845
Fabricated Metals	0.27490	.3042	1.1066
Stone, Clay, and Glass	0.24222	.4535	1.8722
All Other Manufacturing	0.18801	.2135	1.1354
Wholesale Trade	0.33746	.4384	1.2991
Service Stations	0.62786	.7031	1.1199
All Other Retail	0.49284	.6343	1.2871
Eating and Drinking Places	0.28417	.4161	1.4642
Agricultural Services	0.39893	.4547	1.1399
Lodging	0.38450	.4966	1.2915
All Other Services	0.35511	.4329	1.2192
Transportation	0.37859	.4675	1.2349
Electric Energy	0.27563	.3970	1.4403
Other Utilities	0.33480	.3776	1.1277
Contract Construction	0.23360	.3946	1.6891
Rentals and Finance	0.73472	.7722	1.0511

basic and non-basic production, and the assumption of a linear relationship between expansion of goods and services production in the region and employment.

Table 5.3.3.2-2. Direct and indirect increases in household income when supplemental water is added to Silt and Florida areas of the Upper Main Stem subbasin, 1970.

Industry	Direct and indirect increase in household
Range Livestock	$ 69,412
Feeder Livestock	5
Dairy	79,660
Feed and Field Crops	5,199
Truck Crops	5
Fruit	1,716
Forestry	30
All Other Agriculture	162
Coal	331
Oil and Gas	0
Uranium	0
Zinc	0
All Other Mining	7
Food and Kindred Products	2,256
Lumber and Wood Products	25
Printing and Publishing	399
Fabricated Metals	1
Stone, Clay, and Glass	2
All Other Manufacturing	2,168
Wholesale Trade	1,704
Service Stations	2,916
All Other Retail	4,831
Eating and Drinking Places	112
Agricultural Services	13,217
Lodging	38
All Other Services	861
Transportation	7,044
Electric Energy	1,725
Other Utilities	623
Contract Construction	145
Rentals and Finance	10,473
Total	$205,022

Table 5.3.4-1 shows regional economic indicators calculated from the base study utilizing industry grouping and estimates of industry exports from Udis' input/output model.

5.3.4.1 Exports

Exports as used in the base study refer to exports from the region under study to any other region, state, or country. Estimates of pre-project and post-project exports for each industry group are shown in Table 5.3.4.1-1. The difference between pre- and post-project exports or the change attributed directly to the projects and the percentage changes are also found in Table 5.3.5.1-1. The basic part of industry output is used to calculate employment multipliers.

5.3.2-4. Employment multipliers

The level of employment commands much attention in the United States because of the apparent high priority placed on provision of employment opportunities for all individuals. Fiscal techniques including water resources investmen have been employed to provide employment opportunities. Public investments in water development projects have direct and indirect effects on the level of employment in each sector and on how many new jobs such as investment will create. Employment multipliers measure the total change in employment with respect to a one unit change in the employed labor force in response to an exogenous change in demand for output for any given industry's product. The mathematical relationship that has been used to express changes in employment is:

$$E = \frac{1}{1-b} E_b$$

where:

E = equilibrium employment
b = ratio of non-basic to total employment (15, 16)
E_b = basic employment

Employment was estimated for each industry group. Total employment was divided in relation to the proportion of industry output being produced in response to basic (export) and non-basic demand. The estimated employment multiplier for the agriculture-forestry sector is 1.82. This multiplier infers that when direct employment is changed by 1 unit that direct and indirect labor requirements will create 1.82 new jobs.

Table 5.3.4-1. Changes in the magnitude of exports outside the Colorado River Basin when supplemental water is added to Silt and Florida areas of the Upper Main Stem subbasin, 1970.

Industry	Without Project Exports	With Project Exports	Difference	Percent Increase
Range Livestock	$31,415,651	$31,512,507	$96,856	0.3083
Feeder Livestock	4,158,683	4,158,899	216	0.0052
Dairy	499,938	535,911	35,973	7.1955
Food and Field Crops	4,813,486	4,814,072	586	0.0122
Truck Crops	801,544	801,556	12	0.0015
Fruit	3,021,781	3,025,483	3,702	0.1225
Forestry	2,236,522	2,236,543	21	0.0009
All Other Agriculture	622,247	622,426	179	0.0288
Coal	7,445,392	7,445,784	392	0.0053
Oil and Gas	502,412	502,412	0	0.0
Uranium	6,636,432	6,636,432	0	0.0
Zinc	17,775,544	17,775,544	0	0.0
All Other Mining	10,055,972	10,055,980	8	0.0001
Food and Kindred Products	5,773,167	5,775,942	2,775	0.0481
Lumber and Wood Products	6,797,744	6,799,825	2,081	0.0306
Printing and Publishing	44,783	44,791	8	0.0179
Fabricated Metals	902,391	902,393	2	0.0002
Stone, Clay, and Glass	0	0	0	0.0
All Other Manufacturing	12,107,084	12,111,097	4,013	0.0331
Wholesale Trade	3,559,280	3,559,858	578	0.0162
Service Stations	975,152	976,066	914	0.0937
All Other Retail	4,324,896	4,325,567	671	0.0155
Eating and Drinking Places	16,034,009	16,034,273	264	0.0016
Agricultural Services	0	0	0	0.0
Lodging	22,027,487	22,027,586	108	0.0005
All Other Services	12,806,878	12,807,523	645	0.0050
Transportation	17,449,231	17,455,769	6,538	0.0375
Electric Energy	1,595,205	1,595,770	565	0.0354
Other Utilities	0	0	0	0.0
Contract Construction	0	0 0	0	0.0
Rentals and Finance	11,065,500	11,067,638	2,138	0.0193

Employment multipliers that could be computed for other sectors range from a low of 1.13 for lumber and wood products to 2.84 for transportation industry.

Table 5.3.4.1-1. Employment multipliers for processing sector industries in the Upper Main Stem subbasin, 1970.

Industry	Employment multiplier
Aggregation of all agriculture and forestry sectors	1.82
Aggregation of all mining sectors	2.10
Lumber and Wood Products	1.13
Fabricated Metals	2.80
Eating and Drinking Places	1.50
Transportation	2.84

6.0 SUMMARY AND CONCLUSIONS

In the conduct of this study, care was exercised to be certain that apparent weaknesses identified in earlier empirical studies of the relationship between regional economic growth and water resources development were not repeated. These include problems associated with model specification (threshold levels of resource availability, joint dependence, etc.), and analytical technique (stepwise variable selection). However, the essential result obtained in this analysis is only marginally different than that obtained in earlier work. Thus we concluded the study without convincing evidence that water resource investments can or cannot have a significant influence on regional economical growth. Further, the mixed results obtained in these initial phases of the empirical work effectively preclude difinitive treatment of the "investment criteria" question because a statistically significant relationship between investment in water development and several indicators of regional economic status was not established. The plausibility of the existence of a positive and significant relationship between these variables prompts us to investigate other factors which could account for the "failure" of the current study. A summary of this deliberation is presented in section 6.1.

At the individual project level (case study) it is possible to estimate real primary increments in income and employment which are rather directly attributable to a water development project and to predict approximate extra service area output, income, and employment changes associated with water development. The key weakness appears to hinge on the reliability of these projection or expansion techniques and their inability to deal explicitly with the problem of regional offsets which wash out the regression analysis. Section 6.2 which follows provides a summary of the information which is generated by input/output and economic base studies.

6.1 Large Region Analysis

It is important to at least attempt to explain the unexpected statistical results that have been general throughout this report. Although we have argued that the statistical findings do not support the hypothesis that regional growth is induced by water investment, we have been somewhat reluctant to offer them in support of the alternative hypothesis, i.e., water resource investments do not result in economic growth impacts. In other words, it is conceivable that such investment does have regional growth effects but that our data and analysis have failed to pick it up because of a variety of problems.

Virtually all regional analyses suffer from the problem of inadequate data; the present study is no exception. As there is virtually no time series data for county or multi-county units the researcher must, therefore, depend on cross section data and such sources as the census of population, census of agriculture, census of business, and census of manufacturers. These censuses are taken in different years, and have different time intervals between censuses. For example, the census of population is taken every ten years, i.e., 1940, 1950, 1960, and 1970. Whereas the census of agriculture is taken every five years, 1954, 1959, 1964, etc. The census of manufacturers and the census of business are taken at five year intervals, 1963, 1968, etc.

Obviously it is very difficult to put these kinds of data together when they are collected for disparate years. Furthermore, the length of time between observations allows for a variety of impacts to occur that may obscure the relationships being sought. An example will be useful. Assume that a water resource investment is made, say, in the years 1961 and 1962 and is operational at the beginning of 1963. The impacts of the investment, if any, should begin to be felt in 1963 and 1964 and indirect impacts perhaps beginning in 1964 and 1965. Our observations, however, on population and regional income may be for 1960 and for 1970. Clearly by 1970 a variety of things could have happened to increase or reduce income that would have nothing at all to do with the water resource investment. Obviously, it would be preferable to have consistent quarterly steerings for all relevant regional economic variables, but they don't exist.

Data for water resources investment is virtually impossible to compile on a consistent basis. The annual reports of the Bureau of Reclamation, Soil Conservation Service, and Corps of Engineers provide a substantial amount of detail on projects but it is often difficult to tell when a project was started, when it was completed and when the various services began to flow from that project. A number of problems can occur. A project may be started in one year and when construction is one half finished the project is delayed for a three or four year period. Furthermore the cost allocation to the various services (e.g., irrigation, recreation, municipal and industrial, etc.) are notoriously random. The researcher cannot assume that the cost allocations will necessarily bear any resemblence to the relative services provided by the project.

Furthermore it is difficult to identify the precise areas served by the project. For example, the annual report of the Bureau of Reclamation simply states that a given project will provide irrigation water for a four-county area; it does not provide information on exactly how much of each county is being brought under irrigation. It might be a very small percentage of one county and a very large percentage of another. How then is the researcher to allocate the investment to each of those counties without additional information? Certainly these questions must be answered in further research in this area.

The last problem mentioned would be sufficient to explain a lack of statistically significant relationships between investment and regional economic growth. If, for example, a project provides irrigation water for perhaps 10 percent of the agricultural land in a county the effect of those services in terms of increased agricultural output, agricultural land values, and total income could well be swamped by other developments affecting the other 90 percent of the county land area. Of course, the problem is one of an inadequate spatial unit. If investments are just going to cover parts of counties we perhaps should be looking specifically at the impact on that part of the county especially in regards to agricultural production and land values. Since there exists no published data for parts of counties a case study might may be called for. We have done this in the report for two selected area in the Colorado River Basin. Here we find, given the usual qualifications pertinent to the use of input/output and economic base analysis, that impacts on selected growth measures are assignable to water resources investments.

6.2 Case Studies

As estimate of total benefits flowing from public investments is not a sufficient criteria to make choices concerning whether to invest or not to invest in public irrigation projects. Within the past few years much emphasis has been placed on regional development and possible means for redistributing income among industry groups and regions of the county. Information and measures of change pertaining to these questions is provided by the input/output and economic base analysis described above.

A summary of the regional effects associated with the two "case studies" is as follows:

> Total annual economic impact in the UMS Sub-Basin is $543,491 increase in total gross output $217,344 increase in output going to final demand, and $205,022 increase in household income.

Direct and indirect increases in total output in the range livestock and dairy sectors are $144,972 and $270,302, respectively. Of the 29 other sectors, three sectors (oil and gas, uranium, and zinc) appeared not to be affected by the water projects. Twelve sectors had computed impact of less than $1,000. Direct and indirect impacts in the remaining sectors are: $10,020 in feed and field crops, $5,324 in fruit, $11,439 in food and kindred products, $11,530 other manufacturing, $5,048 wholesale trade, $4,644 service stations, $9,803 all other retail, $33,131 agricultural services, $18,607 transportation, $6,257 electric energy, and $14,255 rentals and finance. As might be expected, multiplicative effects are largest in agriculture related industries.

Output multiplier's range from a high of 2.30 in feeder livestock to 1.06 in "all other manufacturing." Range livestock and dairy, the two sectors to receive the exogenous impact of the project, have output multipliers of 1.30 and 1.45 respectively. Type I income multipliers correspond very closely in magnitude to output multipliers.

Industry employment multipliers derived from the economic base analysis are as follows; agriculture 1.82, mining 2.10, lumber and wood 1.13, metals 2.80, eating and drinking 1.50, and transportation 2.84.

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APPENDIX

Listing of Water Resources Subareas and Their Component Counties

1002 - Missouri Headwaters

Jefferson (Montana)
Gallatin
Madison
Beaverhead

1003 - Missouri - Marias

Glacier (Montana)
Toole
Liberty
Pondera
Teton
Chouteau
Lewis and Clark
Cascade
Meagher
Board Water

1004 - Missouri - Musselshell

Judith Basin (Montana)
Fergus
Petroleum
Wheatland
Golden Valley
Musselshell

1005 - Milk

Hill (Montana)
Blaine
Phillips
Valley

1006 - Missouri - Poplar

Daniels (Montana)
Sheridan
Roosevelt
McCone

1007 - Upper Yellowstone

Sweet Grass (Montana)
Stillwater
Carbon
Yellowstone National Park

1008 - Bighorn

Park (Wyoming)
Big Horn
Washakie
Hot Springs
Fremont

1009 - Tongue - Powder

Sheridan (Wyoming)
Campbell
Johnson

1010 - Lower Yellowstone

Richland (Montana)
Dawson
Wibaux
Prairie
Fallon
Custer
Rosebud
Treasure
Yellowstone

1018 - North Platte

Natrona (Wyoming)
Converse
Carbon
Albany
Platte
Goshen
Scotts Bluff (Nebraska)
Banner
Morrill
Garden
Jackson (Colorado)

1019 - South Platt

Larimer (Wyoming)
Kimball (Nebraska)
Cheyenne
Denel
Lanimer (Colorado)
Weld
Logan
Sedgwick
Boulder
Gilpin

Clear Creek
Park
Jefferson
Douglas
Denver
Morgan
Adams
Arapahde
Elbert
Washington

1102 - Upper Arkansas

Lake (Colorado)
Chaffee
Teller
Fremont
Custer
El Paso
Lincoln
Pueblo
Huerfana
Crowley
Las Animas
Otero
Kiowa
Bent
Prowers

1108 - Upper Canadian

Colfax (New Mexico)
Mora
Harding
Quay

1301 - Rio Grande Headwaters

Saguache (Colorado)
Mineral
Rio Grande
Alamosa
Conejos
Costilla

1302 - North Rio Grande

Rio Arriba (New Mexico)
Taos
Los Alamos
Sandoval
Santa Fe
Berralillo
Valencia
Socorro

1303 - Rio Grande - Mimbers

Sierra (New Mexico)
Luna
Dana Ana
El Paso (Texas)

1305 - Rio Grande Closed Basins

Torrance (New Mexico)
Lincoln
Otero
Hudspet (Texas)

1306 - Upper Pecos

San Miguel (New Mexico)
Guadalupe
De Baca
Chaves
Eddy

1401 - Upper Green

Sublette (Wyoming)
Lincoln
Uinta
Sweetwater
Daggett (Utah)

1402 - Yampa - White

Moffat (Colorado)
Routt
Rio Blanco

1403 - Lower Green

Duchesne (Utah)
Uintah
Carbon
Emery

1404 - Gunnison

Delta (Colorado)
Gunnison
Ouray
Hinsdale

1405 - Colorado Headwaters

Grand (Colorado)
Summit
Eagle
Pitkin
Meas

1406 - Colorado - Dolores

Grand (Utah)
Montrose (Colorado)
Miguel
Dolores

1407 - Upper San Juan

Montezuma (Colorado)
San Juan
La Plata
Archuleta
San Juan (New Mexico)

1408 - Colorado - San Juan

Wayne (Utah)
Garfield
Kane
San Juan

1501 - Little Colorado

Navajo (Arizona)
Apache
McKinley (New Mexico)

1502 - Colorado - Lake Mead

Mohave (Arizona)
Coconino
Clark (Nevada)
Lincoln

1502 - Upper Gila

Carton (New Mexico)
Grant
Hidalgo
Greenlee (Arizona)
Graham

1504 - Gila - San Pedro

Pinal (Arizona)
Pima
Santa Cruz
Cochise

1505 - Gila - Salt

Yavapal (Arizona)
Maricopa
Gila

1506 - Colorado - Lake Mohave

Yuma (Arizona)

1601 - Bear

Oneida (Idaho)
Franklin
Bear Lake
Box Elder (Utah)
Cache
Rich

1602 - Great Salt Lake

Tooele (Utah)
Weber
Davis
Morgan
Salt Lake
Summit
Utah
Wasatch

1603 - Sevier Lake

Juab (Utah)
Sanpete
Millard
Sevier
Piute
Beaver
Iron

1701 - Kootenai

Lincoln (Montana)
Boundary (Idaho)

1702 - Pend Oreille

Flathead (Montana)
Sanders
Mineral
Lake
Missoula
Powell
Granito
Ravalli
Deer Lodge
Silver Bow
Bonner (Idaho)
Pend Oreille (Washington)

1703 - Spokane

Kootenai (Idaho)
Spokane (Washington)
Benewah (Idaho)
Shoshone

1705 - Upper Snake

Clark (Idaho)
Fremont
Butte
Jefferson
Madison

Teton
Bonneville
Bingham
Blaine
Camas
Gooding
Lincoln
Jerome
Twin Falls
Cassia
Minidoka
Caribou
Bannock
Power

1706 - Middle Snake

Adams (Idaho)
Valley
Washington
Payette
Gem
Boise

Canyon
Ada
Elmore
Owyhee
Baker (Oregon)
Malmeur

1707 - Salmon

Idaho (Idaho)
Lemhi
Custer

1708 - Lower Snake

Latan (Idaho)
Clearwater
Nez Perce
Lewis
Whitman (Washington)
Garfield
Asotin
Wallowa (Oregon)
Union