AN ECONOMIC ANALYSIS OF DIFFERENTIAL LAND USE CHANGE ASSOCIATED WITH WATER RESOURCE DEVELOPMENT: KEYSTONE LAKE, OKLAHOMA

By

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CHAPTER I

INTRODUCTION

In past years, there have been many large scale public investments in water resource development projects in all sections of this country. The justification for such projects includes flood protection, provision of water for irrigation and consumption, generation of electric power, augmentation of low flows for navigation, and provision of improved fishing and recreational opportunities.

The objective of a large scale public investment may be to increase national or regional economic efficiency, to attain a more desirable distribution of income earning capabilities among various subsets of society, or to enhance the physical environment. The impacts from such investments may be evaluated at the national, regional, and local levels. The most detectable and interesting effects of public investments are at the local level.

Decisions to build projects of this nature are often evaluated using a benefit-cost analysis. With this type of analysis a public investment may be viewed as a production process; that is a process of consuming inputs to produce outputs (1). By comparing the appropriate values of the inputs and outputs, it may be determined if the project would be beneficial to society. An investment may be economically justified if the present value of the flow of future benefits exceeds operating and development costs at an appropriate social discount rate.

The decision maker is required to choose among a limited range of available public projects in order to obtain the maximum public program performance. The decision maker's choice must also consider not only the costs and benefits of the project itself, but also the externalities of the initial investment. This study will focus on one such externality, the change in land use patterns associated with the development of water resource projects.

The Problem

In Oklahoma, the construction of multi-purpose water resource development projects has been a major type of public investment since the dust bowl days (2). Previous research indicates substantial economic impact in the immediate vicinity of a lake following construction.[1] One of the principal economic effects associated with reservoir development is its impact on land use patterns. Several studies have shown that reservoir construction significantly influences the value of land surrounding the reservoir (3 4). Prebble (5) found that land use change varies with the general location around the periphery of the reservoir; the specific location on a given peninsula; physical characteristics of the site; and, road access to the site. Another study found that the change in business activity in the vicinity of a reservoir was small, and that the principal impact was on the residential rather than the commercial sector (6).

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[1] The terms lake, reservoir, and project will be used interchangeably throughout this study. These terms will be used to refer to the development of Keystone Lake and other related activities.

Static analyses have demonstrated the importance of land use changes associated with water resource development projects, but there is no known research that attempts to measure the dynamic or differential impact of reservoir construction on the pattern of land use change in the immediate vicinity.[2] Also neglected is the rate of change of land transformation from agricultural to non-agricultural uses as the result of reservoir construction.

With increased attention being focused on land use planning and with pending land use legislation in this country, land use planners will increasingly be faced with these types of land use questions concerning the impact of water resource development projects on land use patterns (7). An investigation of these land use questions will provide valuable insights into the expected land use changes associated with and resulting from reservoir construction. Moreover, such an analysis will provide professional planners with an improved conceptual understanding of the land use impacts of water resource development projects.

Objectives

The general objective of this study is to estimate the impact of reservoir development on land use patterns and the amount of property wealth within the vicinity of a reservoir. The specific objectives are to:

1. Identify and measure historical land use change in a reservoir impacted area.

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[2]The term differential is used here to signify the difference between land use patterns that actually exist after the construction of the reservoir and the land use pattern that would have existed in the same time period if the reservoir had never been constructed.

2. Project future land use patterns in the reservoir area.
3. Project land use patterns that would have existed in the area had the reservoir not been constructed.
4. Estimate and evaluate the actual differential land use change directly associated with reservoir construction.
5. Estimate the projected differential land use change resulting from reservoir construction.
6. Estimate and evaluate the actual differential change in private property wealth in the reservoir area due to land use pattern adjustments.
7. Estimate the projected differential change in private property wealth in the reservoir area associated with future land use adjustments.

An introductory discussion of the procedures used to meet these objectives will follow a brief description of the study area.

Identification and Description of the Study Area

Keystone Lake was chosen as the study area. It is a large multiple-purpose dam project located approximately 20 miles west of Tulsa, Oklahoma. The project has been in existence long enough to have significantly influenced land use patterns in the surrounding area. In Figure 1, the approximate study area is the area bounded by the heavy dark lines. The area was chosen according to the availability of aerial photographs and encompasses an area of approximately four miles around the perimeter of the lake.

The Flood Control Act of 1950 authorized the Keystone Lake project for construction by the Corps of Engineers. Construction of Keystone

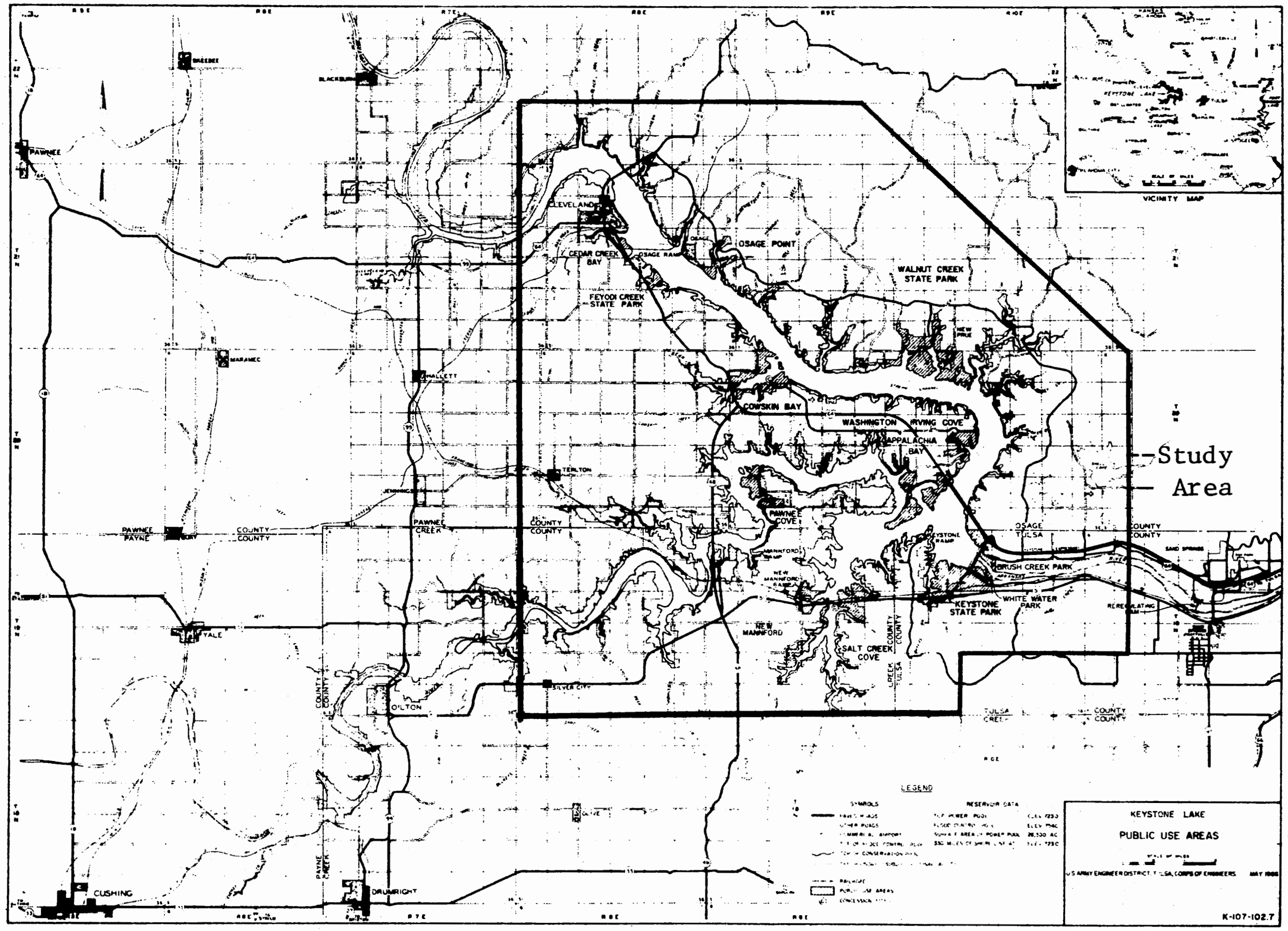

Figure 1. Approximate Land Use Study Area, Keystone Lake, Oklahoma

dam began in January of 1957 and was completed for flood control operation in 1965. Since being placed in flood control operation, the lake has prevented an estimated $47,853,000 in flood damages through June 1974 (8). In addition to flood control, the reservoir also provides aid to navigation of the McClellan-Kerr Arkansas River Navigation System. Other benefits include hydroelectric power, ample storage capacity for control and retention of upstream sediment, recreation and wildlife enhancements.

The reservoir is located in Pawnee, Creek, Osage, and Tulsa counties, and in Payne county at flood times. Keystone dam crosses the Arkansas River channel in the northwest corner of Tulsa County, about two miles downstream from the mouth of the Cimarron River. The reservoir inundates an area of 26,300 acres and has 300 miles of shoreline at the top of the powerpool. The landscape along its shores varies from rocky, wooded hills to rolling, grassy pastures and provides an esthetic attraction for visitors.

General Procedures

For the most part, previous analyses have used either the with and without or the control area technique coupled with regression analysis to estimate land use changes associated with reservoir construction (9). The with and without approach is considered inappropriate because of the difficulty of distinguishing land use change associated with reservoir construction from land use change associated with changing economic conditions and other factors. The control area approach suffers from two limitations: finding a comparison area similar in all respects but without the presence of a reservoir; and, assuming the difference in land uses between the two areas is soley due to reservoir construction. Neither of these comparative static approaches is appropriate for meeting the objectives of this study.

A more accurate evaluation of the impact of reservoir construction on land use patterns requires the estimation of differential land use change. Differential land use change may be estimated by comparing the projected land use pattern had the reservoir not been constructed with actual or observed land use patterns following reservoir construction. The difference between the two is the differential land use change which is attributable only to the construction of the reservoir, ceteris paribus.

Projections of what the land use pattern would have been had the reservoir not been constructed are based on the pre-investment (prior to reservoir construction) pattern of land use change. The projected differential impact of reservoir construction on surrounding land use change is estimated using the same basic approach. In this case, a post-investment (i.e., following reservoir construction) pattern of land use change is used to project future land use patterns existing after reservoir construction. The difference between estimates of future land use patterns based on pre-investment and post-investment land use change patterns is a measure of the future differential impact of the reservoir.

An appropriate method for projecting land use patterns is the stationary, finite Markov chain process (10). This is a statistical technique which may be used to project future land use patterns based on previous patterns of observed land use change. Markovian projections of land use patterns are based on observed land use change in the

Keystone Lake area between 1948-58 and 1964-70 -- the pre-investment and post-investment time periods respectively. It is assumed that patterns of change observed during the sample periods are due to endogenous forces that remain constant over time.

Land uses are defined and grouped into land use categories. Land use patterns in approximately 3,000 sample areas are quantified at the beginning and end of each subperiod using aerial photographs obtained from the Army Corps of Engineers. Land use flow matrices for each subperiod are derived from these data and used by the Markov model to obtain land use projections.

Organization of the Study

This study is divided into five remaining chapters. In the following chapter, the literature in which the Markov chain process has been used and the theoretical concepts of the technique is reviewed. The differential land use model is then developed using the Markov chain process. The procedures used in the collection and analysis of the data are presented in Chapter III. Empirical findings are presented in Chapters IV and V. A summary of the study and a discussion of some of the broader implications of the study are presented in Chapter VI.

CHAPTER II

THE MODEL

The purpose of this chapter is to discuss the theoretical concepts underlying the procedures used to project land use patterns and estimate differential land use change in this study. The procedure used to project future land uses is the stationary Markov chain process. Land use projections obtained from the Markov model are used in the differential land use model to estimate land use change associated with reservoir construction.

Review of Literature

Economists are frequently interested in measuring the change in economic variables through time and in estimating what paths these variables may take in future periods of time. The Markov process is a statistical procedure which may be used to generate such information. Although the basic concepts of Markov chains were introduced in 1907, their use by economists is a relatively recent phenomenon.

The Markov process has been used by several authors to project farm numbers (11 12 13). Of those studies, Krenz (13) in 1964 used the process to project farm numbers in North Dakota for the years 1975 and 2000. He made use of several different base periods for each projection and concluded that Markov chains have important advantages over traditional procedures when used to project farm numbers: (1) projections can be made more conveniently for each size category of farms; and, (2) the method provides additional information which is not readily obtainable with traditional techniques.

Bostwick (14) considered dryland wheat yields as a Markov process and concluded that the analysis is applicable to yields of wheat on fallow or other dryland cropping systems. Judge and Swanson (15) used the process to study the size distribution of hog producing firms. They suggested that the Markov process might be appropriate for the analysis of the size distribution of agricultural producing firms, market structure, and economic growth and development.

Hallberg (16) employed the technique to analyze the size distribution of plants manufacturing frozen milk products in Pennsylvania during the period 1944-1963. He suggested a method based on multiple regression techniques of replacing the constant transition probabilities with probabilities which are a function of various factors including structural characteristics in the industry.

More recently, Burnham (10), has used the Markovian framework to project future land use patterns in the Southern Mississippi Alluvial Valley. He concludes that the process can be adapted to project the future implications of past land use trends provided appropriately specified data are available. In addition, the model provides a framework for analyzing alternative institutional policies designed to attain specific land use futures.

Theoretical Concepts of the Finite Markov Chain Process

A stochastic process may be described as a sequence of experiments in which the outcome of each individual experiment in the sequence depends on some probability, P. A finite stochastic process exists when the range of possible outcomes is finite. If the probability, P, does not depend on the history of the systems prior to the previous time period, a special type of stochastic process called a Markov process exists. According to Kemmeny (17)

> A Markov chain process is determined by specifying the following information: There is given a set of states (S_1, $S_2 \ldots, S_r$). The process can be in one and only one of these states at a given time and it moves successively from one state to another. Each move is called a step. The probability that the process moves from S_i to S_j depends only on the state S_i that it occupied before the step. The transition probability p_{ij}, which gives the probability that the process will move from S_i to S_j is given for every ordered pair of states. Also an initial starting state is specified at which the process is assumed to begin (p. 148).

Assume the variable of interest is land use. The finite Markov chain process requires that r different land use categories be defined and that movements between these land use categories over time be summarized in a land use flow matrix. Land use transitions must be regarded as a stochastic process. Once the land use flow matrix is estimated, the probability (p_{ij}) of moving from one land use category (S_i) to another land use category (S_j) is computed as:

$$P_{ij} = \frac{S_{ij}}{\sum_i S_{ij}} \qquad [1]$$

Each p_{ij} represents the fraction of land that started in land use category S_i in period t and moved to land use category S_j in the following period. Therefore, p_{11} represents the proportion of land that started in S_1 in time t and continued in S_1 in time t + 1. Similarly, p_{12} is the proportion of land that was in S_1 in time t and S_2 in time t + 1. These transition probabilities may be expressed in the form of a matrix such as :[1]

$$P = \begin{array}{c} \\ S_1 \\ S_2 \\ \cdot \\ S_r \end{array} \begin{array}{c} \underline{S_1} \quad \underline{S_2} \; \cdot \cdot \cdot \; \underline{S_r} \\ \begin{pmatrix} p_{11} & p_{12} \cdot & \cdot \cdot & p_{1r} \\ p_{21} & p_{22} \cdot & \cdot \cdot & p_{2r} \\ \cdot & \cdot \cdot & \cdot \cdot & \cdot \\ p_{r1} & p_{r2} \cdot & \cdot \cdot & p_{rr} \end{pmatrix} \end{array} \qquad [2]$$

where P is a transition probability matrix.

An important kind of Markov process and the one of concern in this study is the regular Markov chain process. A Markov chain process is regular if the p_{ij} elements of each row sum to unity and are non-negative. These two assumptions are appropriate for projecting land uses since they imply land is neither created nor destroyed during the land use transition process.

A Markov chain process may also have the property of stationarity. Stationarity in a Markov chain process means that the transition probabilities in P do not change over time. In a land use analysis, this means that factors influencing land use change over the time period in which the transition martix is constructed remain the same throughout future time periods. It is assumed that all land use processes analyzed in this study are characterized by stationary transition probabilities.

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[1]This matrix notation is taken from (17).

The transition matrix given in [2] and an initial vector of land uses completely defines the Markov chain process. Given this information it is possible to project land uses in the n^{th} time period or step. If Q_o represents the initial land use vector, then the following procedure may be used to project land use patterns in each future time period.

$$Q_o P = Q_1$$

$$Q_1 P = Q_2$$

$$\begin{matrix} . & & . \\ . & & . \\ . & & . \end{matrix}$$

$$Q_{n-1} P = Q_n$$

or Q_n may be written as:

$$Q_n = Q_o [P]^n$$

The Markov chain process is also used to project eqilibrium land use distributions. If a Markov chain process is regular, then as the transition matrix is raised to sucessively higher powers, all rows converge to a unique row vector termed the equilibrium vector. The equilibrium vector represents the unique organization of land uses in which net movements from one land use category to another is zero, i.e., land use movements out of each state are exactly equal to movements into that state. More specifically, if P is a regular transition matrix, there exists a matrix T, consisting of identical rows, to which P^n will converge as n approaches infinity. Each row of T is the same vector t, and all elements of t are non-negative.

One method for calculating the equilibrium vector is to multiply the P matrix times itself a large number of times until some power of P reaches the equilibrium configuration; however, this would be a tedious process. Alternatively Judge and Swanson (15) propose another method for calculating the equilibrium vector. They note that in equilibrium the distribution vector must be invariant, i.e.,

$$tP = t$$

$$\text{therefore } t(P-I) = 0 \qquad [3]$$

where I is an identity matrix. [3] forms a system of n-1 linearly independent equations and n unknowns. They further note that since t is a probability vector,

$$\sum_j t_j = 1 \qquad [4]$$

These two equations (equations [3] and [4]) form a system of n linearly independent equations and n unknowns from which it is possible to solve for the unique values of t.

In addition to obtaining projections and equilibrium states, other measures may be derived from the Markov transition matrix. These measures include the mean first passage times, mean recurrence times, and mean stay times. This study is primarily concerned with the use of the Markov chain process for purposes of obtaining land use projections; therefore, the mathematical and theoretical aspects of the other measures will not be discussed.[2]

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[2]For a complete explanation and mathematical derivation of the mean first passage times, mean recurrence time, and mean stay times see (18).

Differential Land Use Change Model

In this section, the Markovian framework is used to develop a differential land use model (hereafter referred to as the DLUM) which may be used to estimate future land use change. The DLUM quantifies and projects land use trends with the aid of a Markov model. Trends in land use patterns before reservoir construction are compared to actual and projected land uses following the construction of the reservoir to estimate differential land use change.

Estimating Actual Differential Land Use Change

Estimates of future land use patterns are determined by the transition probability matrix and the original state, or original distribution of the land among use categories. The initial state is designated as vector Q_a of length r, and the land use pattern at the end of the time period (i.e., the period over which the r by r transition probability matrix $_{ab}P$ is computed) is Q_b. Then it follows that:[3]

$$Q_b = Q_a \cdot {}_{ab}P \qquad [5]$$

Assuming that land use transition is a stochastic process in which any future movement is independent of past movements and that $_{ab}P$ is both regular and stationary, then [5] can be generalized to predict land

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[3] In the notational conventions used in this study, all subscripts refer to either points in time or time periods. A left subscript is the time period (base period) over which the variable is estimated or measured, while the right subscript is the time at which the variable is estimated or measured. Land use vectors (Q) for which there is no left subscript are observed. Those with a left subscript are estimated by the Markov model. A superscript is the power to which the variable is to be raised.

use patterns in n, where $n \geq b$ ($n = 0$ in a).

$$ {}_{ab}Q_n = Q_a \cdot {}_{ab}P^n \qquad [6] $$

${}_{ab}Q_n$ denotes an estimated land use vector in time period n based on a transition probability matrix constructed over the time period a,b. The land use prediction model in [6] is valid only if the stability of P is assumed between b and n. With this requirement, it is assumed that the rate of change of economic and other factors influencing land use change patterns remains constant over the projection period. This assumption is maintained throughout the remainder of this study.

Suppose that a large scale public investment such as the construction of a reservoir occurred in the study area in time period m_1 to m_2 where $b \geq m_1 > m_2 > n$. Then the land use pattern predicted by [6] for time period n (${}_{ab}Q_n$) may deviate from the actual land use pattern observed in n (Q_n). The difference between 1) the predicted land use pattern that would have existed in n in the absence of the reservoir construction during m_1 to m_2, and 2) the actual observed land use pattern in n is the differential land use change caused by development of the lake. Thus the differential land use impact (D_n) of the reservoir in time period n is:

$$ D_n = Q_n - {}_{ab}Q_n = Q_n - Q_a\,[{}_{ab}P]^n \qquad [7] $$

Vector D_n in [7] provides a more accurate estimate of the differential land use impact of reservoir construction than "with and without" techniques frequently used in project analysis. This is because the pattern of land use change in the pre-investment time period a to b is projected to time n, thereby accounting for land use changes that would have occurred, ceteris paribus, if the reservoir had never been constructed.

The DLUM technique given in [7] may be represented graphically. Actual differential land use change (D_n) for a single land use category i is illustrated in Figure 2. The actual quantity of land use i follows the solid line over time while the projected land use i had the reservoir not been constructed follows the broken line. Actual differential land use change associated with reservoir construction at any time from m_1 to n is the vertical distance between these two lines. Figure 2 is a two dimensional representation of differential land use change for a single land use while estimates generated from the DLUM are r + 1 dimensional. In the DLUM, net land use change is estimated for each land use category simultaneously with the restriction that the sum of all changes must be equal to zero.

Projecting Future Differential Land Use Change

The DLUM model may be extended to project the future impacts of land use change associated with reservoir construction. Projected differential land use change impacts of reservoir construction are differential land use changes resulting from reservoir construction at some future time period where it is not possible to measure actual observed land use patterns. In this case actual observations of Q_n in [7] are replaced by Markovian estimates of future land use patterns based on a post-investment (a time period following reservoir construction) matrix of transition probabilities. The difference between estimates of land use patterns at time n based on pre-investment and post-investment transition probabilities is a measure of the projected differential impact of the investment at time n.

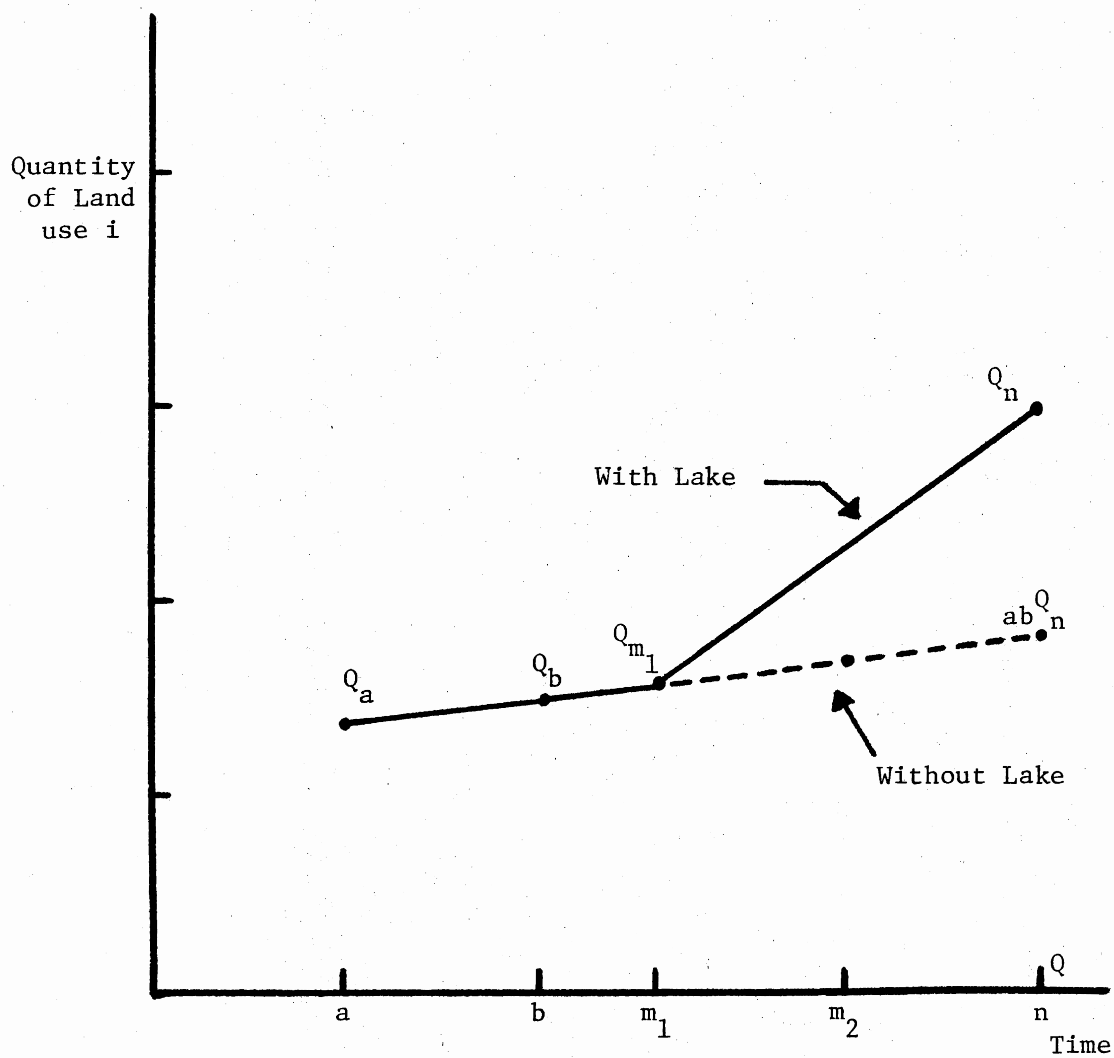

Figure 2. Illustration of Actual Differential Change in Use i Associated with Reservoir Construction

More specifically, let ${}_{ab}P$ (where $a < b \leq m_1$) be the transition matrix reflecting the land use transition patterns before the lake was initiated and ${}_{cd}P$ (where $m_2 \leq c < d$) be the transition probabilities derived over a time period following completion of the lake. If the presence of the lake affects the land use transition process, then ${}_{ab}P \neq {}_{cd}P$.

The estimated land use pattern in n (where $n \geq d$) that would have occurred if the investment had not been made is estimated using pre-investment transition probabilities.

$$ {}_{ab}Q_n = Q_a \, [{}_{ab}P]^n \qquad [8] $$

The land use pattern that is projected to exist in n is a consequence of reservoir development is estimated using post-investment transition probabilities and a post-investment original state (Q_c):

$$ {}_{cd}Q_n = Q_c \, [{}_{cd}P]^{n-c} \qquad [9] $$

The difference between the estimates in [9] and [8] is the projected differential land use impact ($\hat{D}_n$) of the investment at time (n).

$$ \hat{D}_n = {}_{cd}Q_n - {}_{ab}Q_n = Q_c \, [{}_{cd}P]^{n-c} - Q_a \, [{}_{ab}P]^n \qquad [10] $$

The procedure used to determine projected differential land use change for one land use is illustrated in Figure 3. The actual quantity of land in use i is shown by the solid line while the projected land use i had the reservoir not been constructed in the area follows the broken line. Projected differential land use change for land use i resulting from reservoir construction at time n is the vertical distance between ${}_{cd}Q_n$ and ${}_{ab}Q_n$.

Since ${}_{cd}P$ and ${}_{ab}P$ are regular transition matrices, [10] may be estimated for any $n \geq d$ including n at infinity. As n approaches

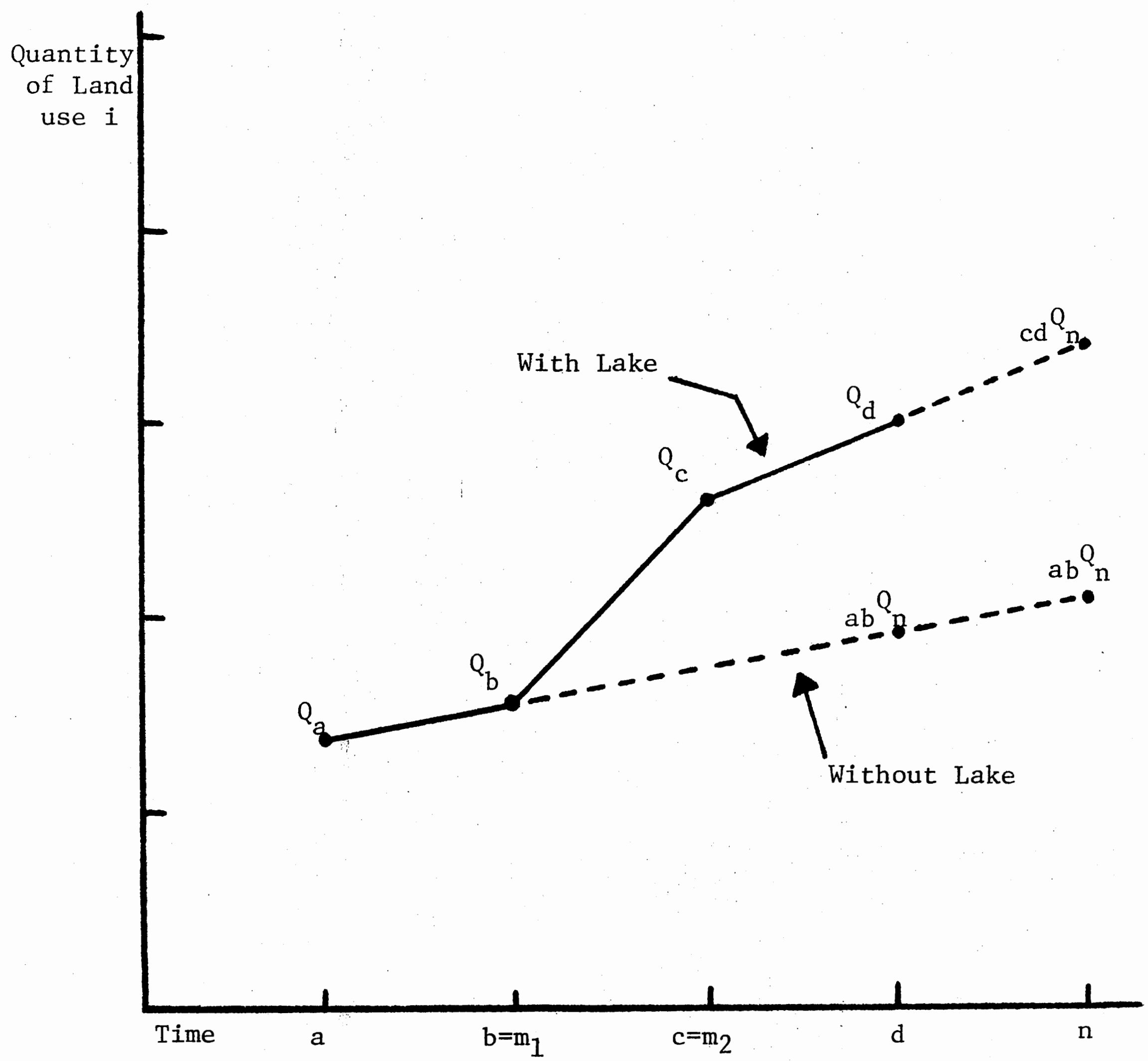

Figure 3. Illustration of Projected Differential Change in Land Use i Associated with Reservoir Construction

infinity, ${}_{ab}P$ and ${}_{cd}P$ approach equilibrium states in which net land use transitions in each will be zero. Projected differential land use change at n = ∞ provides an estimate of the eventual, total land use impact of the reservoir development in which all land use adjustments attributable to the lake are considered. These estimates should be of special interest in analyzing and evaluating the long-term impacts of reservoir construction and are comparable to estimates of lifetime benefits usually computed in benefit-cost analyses.

Differential Property Wealth Change Model

In the following discussion actual and projected differential land use changes estimated by the DLUM are used to estimate the differential change in property wealth resulting from lake development. Property wealth is defined to include the sum of all land and improvements at market values in the reservoir area. Differential change in property wealth at any point in time is the difference between estimated property wealth in the area and the estimated property wealth in the same area had the lake not been constructed.

Actual Differential Property Wealth Change

Actual property wealth is estimated using the actual land use pattern (Q_n) and per unit market values of land and improvements. Aggregate property wealth in the reservoir area is estimated by

$$W_n = Q_n V'_n + Q_n I'_n \qquad [11]$$

where Q_n is a vector of r land use quantities existing in the reservoir area at time n. V'_n and I'_n are transposed vectors (of length r) of per unit values of land and improvements respectively at time n. It is assumed that V_n and I_n do not vary with n.

Projected land uses ($_{ab}Q_n$) in the study area had the reservoir not been constructed are estimated from [6]. Using these estimates, the property wealth had the reservoir not been constructed ($_{ab}W_n$) is:

$$_{ab}W_n = {}_{ab}Q_n V'_n + {}_{ab}Q_n I'_n \qquad [12]$$

Actual differential change in property wealth (P_n) is estimated by obtaining the difference between actual property wealth estimated by [11] and property wealth had the reservoir not been constructed estimated by [12].

$$P_n = W_n - {}_{ab}W_n \qquad [13]$$

P_n in [13] is the estimated actual differential change in property wealth at time n resulting from the changes in land use patterns caused by the construction of Keystone Lake.

Projected Differential Property Wealth Change

The projected differential change in property wealth associated with reservoir construction is estimated using a procedure similar to that described above. In this case, actual property wealth in [13] is replaced by projected property wealth in the reservoir area. Projected property wealth is estimated using land use projections generated by the post-investment transition matrix. Projected property wealth ($_{cd}W_n$) at time n where $n \geq d$ is:

$$_{cd}W_n = {}_{cd}Q_n V'_n + {}_{cd}Q_n I'_n \qquad [14]$$

The difference between the estimates in [14] and [12] is the projected differential change in property wealth ($\hat{P}_n$) at time n is:

$$\hat{P}_n = {}_{cd}W_n - {}_{ab}W_n \qquad [15]$$

where ${}_{cd}W_n$ and ${}_{ab}W_n$ are property wealth projections in the study area based on land use projections from post-investment and pre-investment land use transition matrices.

CHAPTER III

PROCEDURE FOR ESTIMATING PRE-INVESTMENT AND POST-INVESTMENT LAND USE FLOW MATRICES

The primary objective of this chapter is to describe the procedure for estimating pre-investment and post-investment land use flow matrices in the Keystone Lake area. These matrices are necessary for estimating transition probability matrices ($_{ab}P$ and $_{cd}P$) and initial starting land use quantities (Q_a and Q_c) for the respective sub-periods.

Collection of Primary Land Use Data

Land use data of the type needed in this study are not available from secondary sources, so primary data were obtained through the use of aerial photographs. Earlier studies indicate that aerial photography is a feasible means of collecting reliable land use data (19 20). Another study concludes that aerial photographic imagery proved adequate for land use identification in the study area, and forest land, urban uses, linear features (roads, drainage ditches), and land clearings were interpreted without difficulty (21). Varieties of tones, patterns, and spatial organizations of land use depicted in aerial photographs reflect the uses of land. Consistent with the data requirements of the Markov chain process, aerial photography makes it possible for the researcher to evaluate land use patterns at two or more distinct points in time, thereby enabling the measurement of land use change or land use flow between two points in time.

The study area surrounding Keystone Lake was chosen according to the availabliity of aerial photographs in each of the four years, 1948, 1958, 1964, and 1970. Identification of land uses in each year permits the measurement of land use changes in the pre-investment (1948-58) and the post-investment (1964-70) sub-periods.

Identification of land uses at each point is made possible through the joint use of aerial photographs and a topographic map. Using the topographic map, a system of sample observations measuring one-half kilometer square (500 X 500 meters or 61.78 acres) are located in a grid system. The grid system consists of a system of parallel north-south and east-west intersecting lines drawn on the topographic map with each line assigned a specific coordinate. The system of intersecting lines forms approximately 3,000 sample observations covering almost 200,000 acres in the Keystone Lake study area. This procedure permits any sample observation to be located by tracing the east-west and north-south coordinates to their point of intersection in the southwest corner of the sample observation. Each sample observation is delineated on an aerial photograph and land uses present within the observation area are coded.

Land use categories identified for this study are given below:

Residential	Institutional
Commercial	Agricultural
Extractive	Lake Water
Highway Transportation	Impoundments
Utilities	

The agricultural land use category is further sub-divided and coded according to the proportion of cropland, pastureland and woodland present in a sample observation. The variable lake water is coded as land used for the conservation pool or land used for flood control. The conservation pool is the actual water in the lake while flood control refers to the area surrounding the reservoir which is managed by the Army Corps of Engineers. The remaining land use categories are coded only with regards to their presence or absence in each sample observation. If one of these land uses is present in a sample observation, then that variable is coded 1, but if not present in the sample observation the variable is coded 0. In addition to coding the presence of the above land uses, a count of all man-made structures for each sample observation is made. A copy of the land use coding sheet and a more complete explanation of the land use coding process are given in Appendix A.

Land use information for each sample observation in the study area is coded for each of the four years. These land use data provide a basis for the development of pre-investment and post-investment land use flow matrices.

In the remainder of this chapter, primary land use data of the type described above are used to estimate the acreage occupied by each land use in each sample observation. The method used to collect land use data in this study is unique to other land use quantification processes in that land uses are not estimated directly from aerial photographs. The method used in this study is less tedious and involves less time and resources than alternative methods.

Method of Estimating the Sample Land Use Flow Matrix From Primary Land Use Data

Primary land use data are not consistent with the assumptions of a Markov chain process. Primary Land use data merely indicate the existence or non-existence of a specific land use. What is needed are data showing the specific quantity (or acreage) of land in each use category. To meet this requirement, primary land use data are converted to land use acreage estimates which are subsequently formulated into a land use flow matrix.

There are essentially three steps in estimating a sample observation land use flow matrix from primary land use data. These steps are:

1. Estimate average acreage values for respective land uses.
2. Allocate average acreage values to primary land use data.
3. Formulate a land use flow algorithm to estimate land use flows between alternative uses at two points in time.

For each land use category, several sample observations in which the land use had been coded as being present were examined to determine the average acreage occupied by that specific use. Land uses in the sample are quantified by assigning these estimated average acreage values to corresponding coded land uses. Using these quantified land uses at two points in time and appropriate land use flow assumptions, the sample land use flow matrix is estimated. The land use flow algorithm which was used to estimate the land use flow matrices is discussed in Appendix C.

Non-Agricultural Land Use Acreage Values

Non-agricultural average acreage values for this study are estimated and given in Table I.[1] In Table I, the value of rural residential means that if a rural residence is coded as being present in a sample observation, then this land use was found to occupy 1.17 acres in the sample observation. Similarly, an average city residence occupied .795 acres when present in a sample observation.

Allocation of Non-Agricultural Land Use Acreage Values to Sample Observations

Non-agricultural land uses in a sample observation are quantified by allocating average acreage values discussed in the preceeding section to corresponding primary coded land uses. An example of this procedure is given in Table II. In the example, average acreage values from Table I are assigned to respective non-agricultural land uses present in the sample observation. The acreage for agricultural is the residual land in the sample after all other non-agricultural land uses have been assigned their respective acreage values. See Appendix B for a more complete explanation of non-agricultural land use allocations.

In the example in Table II, primary land use data in 1948 indicate that no rural residential or commercial land uses are present in the sample observation. However in 1958, rural residential and commercial land uses are assigned 1.2 and 4.0 acres respectively because primary land use data now indicate the presence of these land uses in the sample.

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[1] For a complete explanation of the procedure used in estimating these values, see Appendix B.

TABLE I

ESTIMATED AVERAGE ACREAGE OCCUPIED BY NON-AGRICULTURAL LAND USE CATEGORIES WHEN PRESENT IN A SAMPLE OBSERVATION, KEYSTONE LAKE, OKLAHOMA, 1964

Land Use Variable	Average Acreage Value
Rural Residential	1.170
City Residential	.795
Commercial	4.012
Extractive	1.098
Highway Transportation	2.232
Railroads and Utilities	1.979
Institutional	2.654
Lake Water	
Conservation	23.106
Flood	14.250
Both Conservation and Flood	37.356
Other Impoundments (Ponds)	.712

TABLE II

AN EXAMPLE OF THE PROCEDURE USED TO CONVERT PRIMARY NON-AGRICULTURAL LAND USE DATA INTO ACREAGE ESTIMATES FOR A SAMPLE OBSERVATION

	Primary Land Use Data		Acreage Value Estimates for Each Land Use[a/]	
Land Use	1948	1958	1948	1958
Non-Agricultural				
Rural Residential	0	1	0	1.2
Commercial	0	1	0	4.0
Extractive	0	0	0	0
Transportation	1	1	2.2	2.2
Sub-Total			2.2	7.4
Agricultural (assumed to be residual)			59.6	54.4
Total			61.8	61.8

[a/] Acreage value estimates are rounded off to the nearest tenth of an acre.

Allocation of Agricultural Land Use Acreage Values To Sample Observations

After all non-agricultural land use acreages are allocated in the sample observation, the residual land is assigned to agricultural land uses. This residual is allocated to cultivated land, pastureland, and woodland in accordance with the relative weightings given to each in the primary land use data coding process.

Acreage values for agricultural land uses are estimated and allocated in a different manner than non-agricultural land uses. A series of percentage area values which sum to one hundred percent were estimated based on sample data for each possible agricultural land use coding combination. These percentage area values are given in Table III. The method used in developing these values is discussed in Appendix B. For example, in Table III percentage area values for agricultural land use combination number 16 are 19.69, 65.31, and 15.00. These values are interpreted to mean that if agricultural land use combination 16 exists for a sample observation, then 19.69 percent of the agricultural (residual to the sample) land in the sample observation is assumed to be cultivated land. Similarly, 65.31 and 15.00 percent of the agricultural land in the sample observation are pastureland and woodland respectively.

An example illustrating the precedure used to allocate agricultural land among its uses is given in Table IV. In the example, primary land use data for agricultural land uses for both years correspond to land use combination numbers 16 in Table III. Each agricultural land use acreage in Table IV for a given year is obtained by taking its corresponding percentage area value times total agricultural land (values in

TABLE III

PERCENTAGE AREA VALUES WITHIN A SAMPLE OBSERVATION CORRESPONDING TO EACH AGRICULTURAL LAND USE COMBINATION, KEYSTONE LAKE, OKLAHOMA, 1964

	Agricultural Land Use Combination			Percentage Area Values [a]		
Number	Cultivated	Pastureland	Woodland	Cultivated	Pastureland	Woodland
1	0	0	0	15.38	26.92	57.69
2	0	0	1	2.00	1.33	96.67
3	0	0	2	.41	1.81	97.78
4	0	1	0	8.70	81.52	9.78
5	0	1	1	.35	42.81	56.84
6	0	1	2	.50	28.14	71.36
7	0	2	0	0.00	93.37	6.63
8	0	2	1	1.61	72.08	26.31
9	1	0	0	76.70	9.71	13.59
10	1	0	1	51.40	3.27	45.33
11	1	0	2	30.41	3.13	66.46
12	1	1	0	43.63	53.43	2.94
13	1	1	1	23.61	36.34	40.05
14	1	1	2	18.87	17.92	63.21
15	1	2	0	21.00	75.07	3.94
16	1	2	1	19.69	65.31	15.00
17	2	0	0	91.29	4.52	4.19
18	2	0	1	69.67	2.00	28.33
19	2	1	0	69.18	25.79	5.03
20	2	1	1	56.88	22.50	20.63
21	0	2	2	.35	42.81	56.84
22	2	0	2	51.40	3.27	45.33
23	2	2	0	43.63	53.43	2.94

[a] Percentage values for combinations 21 through 23 are taken from combinations 5, 10, and 12.

TABLE IV

AN EXAMPLE OF THE PROCEDURE USED TO CONVERT PRIMARY AGRICULTURAL LAND USE DATA INTO ACREAGE ESTIMATES FOR A SAMPLE OBSERVATION

Land Use	Primary Land Use Data		Acreage Value Estimates For Each Land Use	
	1948	1958	1948	1958
Non-Agricultural				
Rural Residential	0	1	0	1.2
Commercial	0	1	0	4.0
Extractive	0	0	0	0
Transportation	1	1	2.2	2.2
Sub-Total			2.2	7.4
Agricultural				
Cultivated Land	1	1	11.7	10.7
Pastureland	2	2	38.9	35.5
Woodland	1	1	8.9	8.2
Sub-Total[a]			59.6	54.4
Total			61.8	61.8

[a] Column sub-totals may not equal column sub-total sums because of rounding error.

Table II) in the sample observation.[2] Between 1948 and 1958, agricultural acres (agricultural sub-totals) in Table IV decreases because of the increase in non-agricultural land uses. This land use allocation process assures that all land is allocated within a sample observation and at the same time prevents land uses from occupying more land than is present in the sample.

Formulation of a Land Use Flow Algorithm for Quantifying Land Use Flows Between Two Points in Time

In the previous section, land uses were quantified in a sample observation at two points in time. However, the development of a land use flow matrix requires that land use flows be estimated between these two points in time. For example in Table IV, commercial land uses increased and cultivated land decreased between 1948 and 1958. It is not directly evident what portion of cultivated land moved to commercial uses. These land use flows over time are estimated by formulating an algorithm to estimate the flow of land between alternative uses. In this section, a brief summary of the procedure is presented. A detailed account of the technique used to construct the land use flow matrices in this study is given in Appendix C.

The quantified land uses given in Table IV are again repeated in Table V which illustrates the procedure in estimating a land use flow

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[2]The 11.7 acre land use value for cultivated land in Table IV in 1948 is obtained by taking 19.69 percent (from agricultural land use combination 16, Table III) of 59.6 acres (total agricultural land in sample, Table II). Other agricultural land uses are computed in a similar way.

TABLE V

EXAMPLE OF THE ESTIMATION OF A SAMPLE OBSERVATION LAND USE FLOW MATRIX FROM LAND USES IN TWO TIME PERIODS

Land Use	Acreage Value Estimated for Each Land Use		Land Use Flow Matrix								
			Land Use	Land Use in 1958							
	1948	1958	in 1948	A.	B.	C.	D.	E.	F.	G.	Total[a/]
A. Rural Residential	0	1.2	A.	0	0	0	0	0	0	0	0
B. Commercial	0	4.0	B.	0	0	0	0	0	0	0	0
C. Extractive	0	0	C.	0	0	0	0	0	0	0	0
D. Transportation	2.2	2.2	D.	0	0	0	2.2	0	0	0	2.2
E. Cultivated Land	11.7	10.7	E.	0.2	0.8	0	0	10.7	0	0	11.7
F. Pastureland	38.9	35.5	F.	0.8	2.7	0	0	0	35.5	0	38.9
G. Woodland	8.9	8.2	G.	0.2	0.5	0	0	0	0	8.2	8.9
Total	61.8	61.8	Total	1.2	4.0	0	2.2	10.7	35.5	8.2	61.8

[a/] Row totals of land use flow matrix may not equal row sums because of rounding errors.

matrix for the sample observation between 1948 and 1958. The land use flow matrix is estimated by assuming that non-agricultural land use increases come proportionally from agricultural land use decreases. Column A of the land use flow matrix indicates that of the 1.2 acre increase in residential land uses, 0.2 acres came from decreasing cultivated land, while 0.8 and 0.2 came from decreasing pastureland and woodland acreages.[3]

By using the land use flow algorithm given in Appendix C, a pre-investment land use flow matrix for each sample observation is estimated by comparing existing land uses in 1948 with those of 1958. Similarly, a post-investment land use flow matrix for each sample observation is estimated by comparing land uses in 1964 with those existing in 1970.

Estimated Pre-Investment and Post-Investment Land Use Flow Matrices

The pre-investment land use flow matrix for the study area is estimated by summing the individual sample observation land use flow matrices for the respective time period. Similarly, the post-investment land use flow matrix for the study is the sum of the individual sample observation land use flow matrices for the respective time period. The sample observations to be included in this summing process are those with land use flow matrices for each sub-period which

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[3] The 0.2 acre land use flow from cultivated land to residential land is obtained by taking 19.607 percent (cultivated land use decrease expressed as a percent of the total agricultural land use decrease) of 1.2 acres (the increase in rural residential land uses). Pastureland and woodland use flows are obtained in a similar way.

included no lake water in 1970. There are 1,484 sample observations in the study area that meet these requirements.

The pre-investment and post-investment land use flow matrices are shown in Tables VI and VII respectively. The non-diagonal elements of the land use flow matrices represent flows of land from one use to another while the diagonal elements represent the land uses remaining in the same land use category throughout the period. For instance, in Table VI the element at the intersection of row (H) and column (A) indicates that 2.7 acres of cropland shifted to commercial uses while the element at the intersection of row (H) and column (H) indicates that 2,391.6 acres of land remained in cropland throughout the time period. Row totals represent land use quantities (Q_a) at the beginning time of the sub-period while column totals are land use quantities (Q_b) at the end of the sub-period. The summation of row totals is equal to the summation of column totals indicating that the total land in the study area remains constant.

The transition probability matrix ${}_{ab}P$ is computed from the pre-investment land use flow matrix using [2]. ${}_{ab}P$ along with the initial starting state Q_a constitute a Markov chain process from which future land use projections ${}_{ab}Q_n$ are estimated using [2.6]. Similarly, ${}_{cd}P$ is estimated from the post-investment land use flow matrix and is used to estimate ${}_{cd}Q_n$.

TABLE VI

PRE-INVESTMENT LAND USE FLOW MATRIX,
KEYSTONE LAKE, OKLAHOMA,
1948-1958

(Units in Acres)

Land Use in 1948	Land Use in 1958										
	A	B	C	D	E	F	G	H	I	J	Total
A. Commercial	24.1	0.1	0.0	0.5	0.0	0.0	3.7	0.3	15.5	3.8	48.1
B. Extractive	0.0	41.7	3.5	1.1	0.0	0.1	*	3.5	13.3	14.6	78.0
C. Transportation	0.3	3.1	966.4	3.0	3.9	3.1	3.7	42.2	112.2	94.2	1,232.1
D. Utilities	0.7	3.7	12.2	308.7	0.4	2.2	1.8	11.8	89.1	75.9	506.6
E. Institutional	3.2	0.2	0.0	0.2	18.6	0.0	5.3	1.7	7.4	3.3	39.8
F. Impoundments	1.0	3.2	6.3	2.2	0.0	127.4	1.3	12.1	43.7	40.0	237.1
G. Residential	1.6	6.5	3.4	2.3	0.0	3.0	601.6	24.2	120.4	64.5	827.5
H. Cultivated Land	2.7	19.4	38.9	8.9	2.8	17.8	50.0	2,391.6	2,380.9	1,194.5	6,107.7
I. Pastureland	12.0	67.0	74.7	44.6	8.5	66.9	165.5	2,347.3	22,997.6	4,199.0	29,983.0
J. Woodland	30.7	135.1	171.1	123.4	13.6	97.6	65.8	1,650.1	8,624.1	41,698.7	52,610.2
Total	76.2	280.0	1,276.7	494.7	47.8	318.2	898.8	6,484.7	34.404.3	47,388.7	91,670.0

Note: Totals may not be equal to row or column sums because of rounding error.
*less than 0.05

TABLE VII

POST-INVESTMENT LAND USE FLOW MATRIX,
KEYSTONE LAKE, OKLAHOMA,
1964-1970

(Units in Acres)

Land Use in 1964	Land Use in 1970										
	A	B	C	D	E	F	G	H	I	J	Total
A. Commercial	60.2	6.7	4.1	0.4	0.3	2.3	9.0	20.9	43.3	49.3	196.6
B. Extractive	1.8	207.5	7.1	2.6	0.1	1.4	2.2	4.4	34.7	51.2	312.9
C. Transportation	1.1	2.7	1,287.8	2.5	0.0	1.6	2.9	8.9	71.7	95.9	1,475.4
D. Utilities	4.9	4.5	4.0	577.8	0.0	3.7	4.3	3.3	49.1	62.7	714.3
E. Institutional	0.0	0.2	0.0	0.0	47.8	0.7	4.9	0.1	8.4	4.2	66.4
F. Impoundments	0.3	4.9	2.1	2.1	0.0	333.8	2.1	6.6	37.2	52.2	441.4
G. Residential	17.2	5.5	5.6	0.2	0.0	0.1	1,083.4	11.4	53.9	62.1	1,239.6
H. Cultivated Land	21.1	14.2	8.2	4.9	3.6	6.1	23.3	1,391.5	1,483.4	536.2	3,492.5
I. Pastureland	57.9	47.8	79.3	36.6	11.8	31.6	189.1	999.3	26,803.9	4,896.4	33,153.8
J. Woodland	24.0	52.7	92.7	61.4	2.8	40.9	133.0	436.3	4,261.3	45,472.0	50,577.2
Total	188.6	347.0	1,491.0	688.6	66.4	422.1	1,454.2	2,882.7	32,847.2	51,282.4	91,670.0

Note: Totals may not be equal to row or column sums because of rounding error.

CHAPTER IV

THE EMPIRICAL LAND USE RESULTS

This chapter presents an analysis of land use and land use change in the Keystone Lake area. Pre-investment and post-investment land use flow matrices developed in the previous chapter are used to estimate actual and projected land uses in the study area. These land use estimates are then used to estimate actual and projected differential land use change associated with the construction of Keystone Lake.

Actual Land Uses

Acre quantities of actual land use between 1948 and 1970 are obtained from the land use flow matrices estimated in the previous chapter. In the pre-investment (1948-1958) land use flow matrix, the row totals represent 1948 quantities of land while column totals represent 1958 land use quantities. Similarly, land use quantities for years 1964 and 1970 are found by obtaining the appropriate row and column totals of the post-investment (1964-1970) land use flow matrix. These actual land use quantities for each of the respective years are given in Table VIII.

Projected Land Uses

The pre-investment and post-investment land use flow matrices developed in the previous chapter are used by the Markov model to

TABLE VIII

ACTUAL LAND USES WITHIN THE KEYSTONE LAKE STUDY AREA, OKLAHOMA

(Units in Acres)

	Pre-Investment Time Period		Post-Investment Time Period	
Land Use	1948	1958	1964	1970
Commercial	48.1	76.2	196.6	188.6
Extractive	78.0	280.0	312.9	347.0
Transportation	1,232.1	1,276.7	1,475.4	1,491.0
Utilities	506.6	494.7	714.3	688.6
Institutional	39.8	47.8	66.4	66.4
Impoundments	237.1	318.2	441.4	422.1
Residential	827.5	898.8	1,239.6	1,454.2
Cropland	6,107.7	6,484.7	3,492.5	2,882.7
Pastureland	29,983.0	34,404.3	33,153.8	32,847.2
Woodland	52,610.1	47,388.7	50,577.2	51.282.4
Total[a]	91,670.0	91,670.0	9.,670.0	91,670.0

[a] Column totals may not equal column sums because of rounding error.

obtain land use projections in the Keystone Lake area.[1] The projections obtained using the pre-investment land use flow matrix estimate the land uses that would exist in the area if the reservoir had not been constructed, while projections obtained from the post-investment land use flow matrix represent the land uses that are estimated for the reservoir area. These land use projections are given in Tables IX, X, and XI.

Table IX gives land use estimates for 1964 and 1970 without the presence of the reservoir.[2] These projections reflect the same general land use trends as the pre-investment land uses given in the first two columns of Table VIII. Land use projections with and without the presence of the reservoir for years 1976 and 2000 are given in Table X.[3]

As discussed in Chapter II, if the pre-investment and post-investment transition matrices are regular, then land use projections from each matrix may be estimated for any future time including time infinity. At time infinity, land use movements into a land use category are equal to land use movements out of the category, thus projected land uses at this time are in a stable equilibrium. Land use projections at time infinity are given in Table XI.

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[1]Solutions were obtained using a computerized package developed at Oklahoma State University (18).

[2]Without the reservoir, means an estimate of what the land patterns would have been if the reservoir has not been constructed. These estimates are based on the pre-investment (1948-1958) land use flow matrix.

[3]With the reservoir, means an estimate of what the land use patterns will be in the reservoir area. These estimates are based on the post-investment (1964-1970) land use flow matrix.

TABLE IX

LAND USE PROJECTIONS FOR 1964 AND 1970 BASED ON PRE-INVESTMENT TRANSITION MATRIX, KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

Land Use	1964 Based on 1948-58 Transition Matrix	1970 Based on 1948-58 Transition Matrix
Commercial	84.6	91.6
Extractive	344.5	399.0
Transportation	1,302.4	1,327.0
Utilities	489.8	485.4
Institutional	50.1	52.1
Impoundments	345.6	369.0
Residential	944.7	989.6
Cropland	6,692.9	6,883.0
Pastureland	36,057.0	37,506.7
Woodland	45,358.3	43,566.5
Total[a]	91,670.0	91,670.0

[a] Column totals may not equal column sums because of rounding error.

TABLE X

PROJECTED LAND USE IN 1976 AND 2000, KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

Land Use	1976		2000	
	Based on 1948-58 Transition Matrix	Based on 1964-70 Transition Matrix	Based on 1948-58 Transition Matrix	Based on 1964-70 Transition Matrix
Commercial	95.8	185.2	102.4	188.3
Extractive	433.5	367.7	494.2	398.7
Transportation	1,349.7	1,505.0	1,419.7	1,548.3
Utilities	481.9	667.7	472.7	616.6
Institutional	53.5	65.7	55.5	62.5
Impoundments	384.6	407.7	414.5	372.0
Residential	1,032.5	1,637.4	1,168.5	2,146.5
Cropland	7,036.8	2,637.9	7,393.6	2,440.9
Pastureland	38,550.7	32,408.4	40,795.4	31,187.3
Woodland	42,251.8	51,788.2	39,353.4	52,708.8
Total[a/]	91,670.0	91,670.0	91,670.0	91,670.0

[a/] Column totals may not equal column sums because of rounding error.

TABLE XI

LAND USE PROJECTIONS FOR TIME INFINITY,
KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

Land Use	Based on 1948-58 Transition Matrix	Based on 1964-70 Transition Matrix
Commercial	104.7	201.1
Extractive	513.4	412.4
Transportation	1,516.5	1,624.7
Utilities	465.0	575.5
Institutional	56.8	59.5
Impoundments	426.8	351.2
Residential	1,337.2	2,804.3
Cropland	7,586.1	2,400.8
Pastureland	41,927.4	30,462.3
Woodland	37,736.7	52,779.0
Total[a/]	91,670.0	91,670.0

[a/]Column totals may not equal column sums because of rounding error.

Actual Differential Land Use Change

Actual and projected land uses given in the previous section are used to calculate differential land use change resulting from reservoir construction. In order to facilitate the analysis, the ten land use categories are sub-divided into two broad land use divisions, agricultural and non-agricultural land uses.

The estimated differential land use change resulting from the construction of Keystone Lake for years 1964 and 1970 is shown at the right of Table XII. In Table XII, the estimated non-agricultural differential land use change associated with reservoir construction for 1970 (column 8, D_n) is 891 acres. This value is the difference between the actual non-agricultural land use in 1970 (column 4, Q_n) and the land uses that are projected to exist had the reservoir not been constructed (column 6, ${}_{ab}Q_n$).

Non-Agricultural Land Uses

Reservoir construction substantially increased non-agricultural uses of land with the exception of extractive land uses. The decrease in extractive land uses such as oil drilling probably reflects the impact of increased easement costs for drilling rights associated with the shift to non-agricultural uses in the area. Increases in transportation and utilities land uses reflect the necessary rerouting of roads, highways, power lines, and railroads within the reservoir area. There were large increases in residential land uses. In fact in 1970, residential uses accounted for more than half of the increase in non-agricultural use. As might be expected, commercial and institutional land

TABLE XII

ACTUAL AND PROJECTED LAND USE AND DIFFERENTIAL LAND USE CHANGE, KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

	Actual Land Use (Q_n)				Projected Land Use Based on 1948-58 Transition Matrix ($_{ab}Q_n$)		Estimated Actual Differential Land Use Change (D_n)	
Land Use	1948	1958	1964	1970	1964	1970	1964[a]	1970[b]
Non-agricultural Uses								
Commercial	48	76	197	189	85	92	112	97
Extractive	78	280	313	347	345	399	- 32	- 52
Transportation	1,232	1,277	1,475	1,491	1,302	1,327	173	164
Utilities	507	495	714	689	490	485	224	204
Institutional	40	48	66	66	50	52	16	14
Residential	828	899	1,240	1,454	945	990	295	464
Sub-Total[c]	2,733	3,075	4,005	4,236	3,217	3,345	788	891
Agricultural Uses								
Impoundments	237	318	441	422	346	369	95	53
Cultivated	6,108	6,485	3,493	2,883	6,693	6,883	-3,200	-4,000
Pasture	29,983	34,404	33,154	32,847	36,057	37,505	-2,903	-4,660
Woodland	52,610	47,389	50,577	51,282	45,358	43,566	5,219	7,716
Sub-Total	88,938	88,596	87,665	87,434	88,454	88,325	- 788	- 891
Total[d]	91,670	91,670	91,670	91,670	91,670	91,670		

[a] Third column of data minus the fifth.

[b] Fourth column of data minus the sixth.

[c] Column sub-totals may not equal column sub-total sums because of rounding error.

[d] Column totals may not equal column sums because of rounding error.

uses increased in the area as the result of increased recreational and residential activities.

Some of the data in Table XII are summarized graphically in Figure 4. Actual non-agricultural land use from year 1948 to 1970 follows line ABCD. Line segment BC reflects the sharp increase in non-agricultural uses of land that occurred during the construction phase of the reservoir. Estimated non-agricultural land use -- assuming that reservoir construction had not occurred -- is represented by line ABEF. The distance between these two lines (CE in 1964 and DF in 1970) is the differential change in non-agricultural land uses as a consequence of reservoir construction.

Agricultural Land Uses

Agricultural land use decreases necessarily correspond to non-agricultural land increases. The actual DLUM estimates for 1970 indicate that total agricultural uses of land decreased by 891 acres. Within the agricultural land use categories, cultivated and pasture lands decreased while woodland acreage increased. This phenomenon suggests that following reservoir construction additional emphasis is placed on the esthetic attributes of the area as a complement to the newly recreational and leisure opportunities. Because of these newly created opportunities, the total impact of reservoir construction on food and fiber producing land exceeds the quantity of land merely inundated.

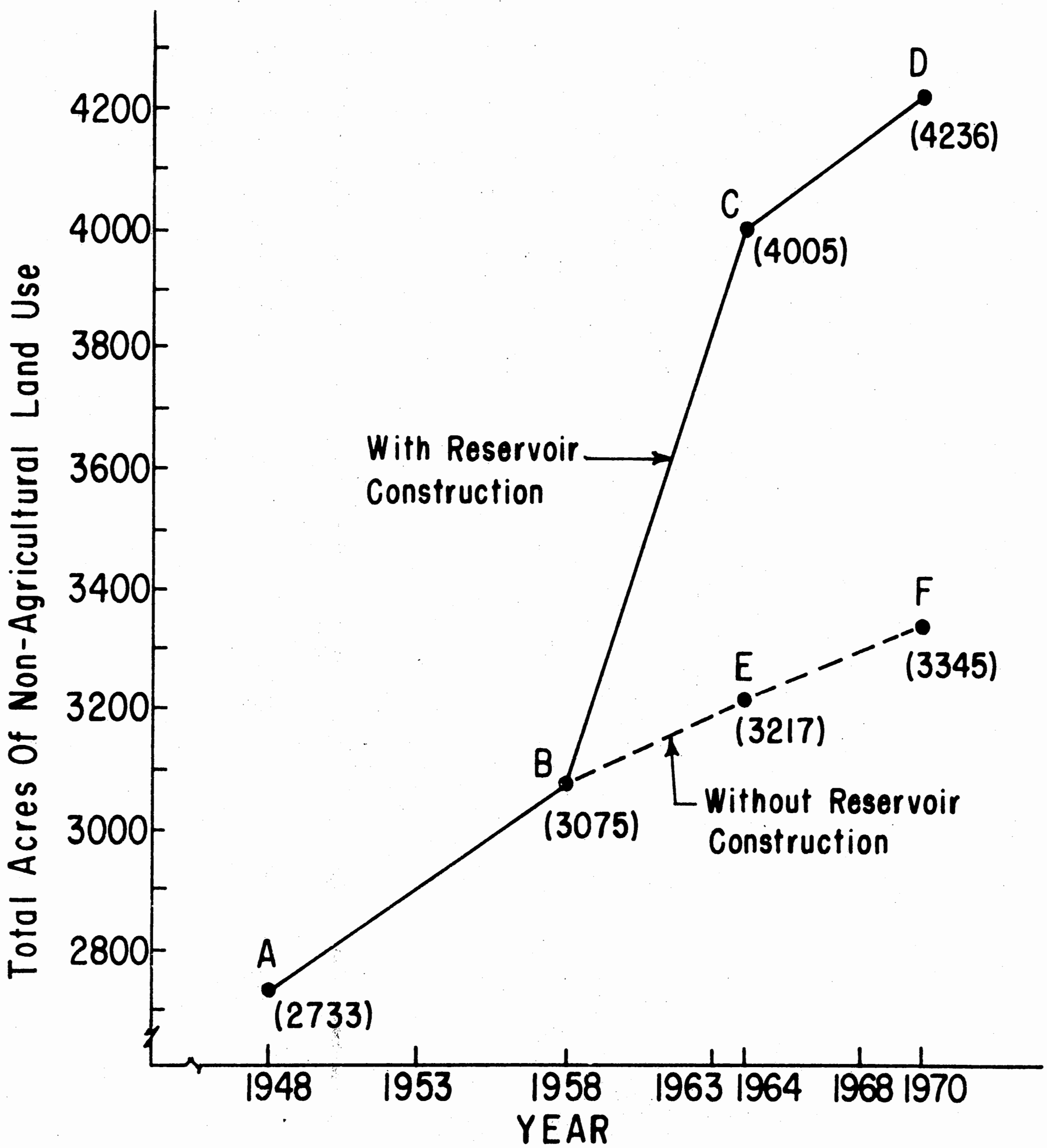

Figure 4. Total Acres of Non-Agricultural Land Use With and Without Construction of Keystone Lake for Years 1948 to 1970

Projected Differential Land Use Change

The over-all, long-term differential land use changes associated with reservoir construction are shown in the last two columns of Table XIII. Each entry in these columns is the difference between the estimated land uses for the appropriate years projected by the pre-investment and post-investment transition matrices which are shown in the first four columns of Table XIII.

The estimated differential land use results of Table XIII are generally similar to those of Table XII; however, there is one interesting difference. The differential land use changes in Table XIII indicate that during the first few years following lake construction, the non-agricultural uses are characterized by balanced growth of both the residential and infrastructure land uses. Most of the significant non-agricultural change after 2000 occurs in the residential category while the other non-agricultural land uses remain relatively constant.

This result is particularly apparent in Table XIV which shows the percentage distribution of the total non-agricultural differential land use impact in selected years. The results in Table XIV indicate that the early differential impact on non-agricultural, non-residential land uses is relatively important, but that over time the projected differential change of these land use categories steadily declines. What this suggests is that the reservoir construction immediately stimulates infrastructure or facilitative investments associated with land uses such as transportation and utilities. These land uses increase at a rate far in excess of the pre-investment rate causing a relatively large, relatively early differential impact illustrated by line segment

TABLE XIII

PROJECTED LAND USE AND PROJECTED DIFFERENTIAL LAND USE CHANGE, KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

	Projected Land Use					
	Based on 1948-58 Transition Matrix ($_{ab}Q_n$)		Based on 1964-70 Transition Matrix ($_{cd}Q_n$)		Projected Differential Land Use Change ($\hat{D}_n$)	
Land Use	2000	Infinity	2000	Infinity	2000[a]	Infinity[b]
Non-Agricultural Uses						
Commercial	102	104	188	201	86	97
Extractive	494	513	399	412	-95	-101
Transportation	1,420	1,516	1,548	1,624	128	108
Utilities	473	465	617	575	144	110
Institutional	56	57	62	60	6	3
Residential	1,168	1,337	2,146	2,804	978	1,467
Sub-Total	3,713	3,992	4,960	5,676	1,247	1,684
Agricultural Uses						
Impoundments	414	427	372	351	-42	-76
Cultivated	7,394	7,585	2,441	2,301	-4,953	-5,185
Pasture	40,795	41,927	31,187	30,462	-9,608	-11,465
Woodland	39,353	37,737	52,709	52,799	13,356	15,042
Sub-Total	87,956	87,677	86,709	85,993	-1,247	-1,684
Total[a]	91,670	91,670	91,670	91,670		

[a] Third column of data minus the first.

[b] Fourth column of data minus the second

[c] Column totals may not equal column sums because of rounding error.

TABLE XIV

INCIDENCE OF ACTUAL AND PROJECTED NON-AGRICULTURAL DIFFERENTIAL LAND USE CHANGE, KEYSTONE LAKE, OKLAHOMA

	Percent of Total Land Use Differential Within Selected Land Uses[a/]			
Land Use	Percent of Actual Differential Land Use		Percent of Projected Differential Land Use	
	1964	1970	2000	Infinity
Commercial	14.21	10.89	6.90	5.76
Extractive	-4.06	-5.84	-7.62	-6.00
Transportation	21.95	18.41	10.26	6.41
Utilities	28.43	22.90	11.55	6.53
Institutional	2.03	1.57	.48	.18
Residential	37.44	52.08	78.43	87.11
Total	100.00	100.00	100.00	100.00

[a/] Each entry shows the proportion of the estimated total differential increase in non-agricultural land use resulting from the construction of the lake for each land use category.

BC in Figure 5. Line segment CD in Figure 5 shows that after the construction of the reservoir is completed, there is little additional land use conversion to these uses. In later time periods, the infrastructure pattern that would have existed if the reservoir had not been constructed gradually catches up with the post-investment land use pattern as shown by line segment EF. Over time this catch-up process reduces the differential impact for non-agricultural, non-residential uses.

Projected patterns of residential land use change are shown in Figure 6. Lines ABCD and ABEF represent residential land use with and without reservoir construction, respectively. Line ABCD shows that an immediate increase in residential activity accompanies reservoir construction and continues into the indefinite future. This secular increase in residential activity over time suggests that the construction of a reservoir significantly influences the esthetic qualities of the area, thereby increasing the desirability of the area for surburban and/or second homesite construction.

Land Use Rate of Change Analysis

The bar graph analysis in Figure 7 traced the pattern of differential non-agricultural land use change with and without reservoir construction. Without reservoir construction, the additional non-agricultural land use from 1964 to 1970 was 128 acres compared to 279 additional acres that would have been added after the year 2000. However with reservoir construction, the change in non-agricultural land uses is estimated to be much larger for both time periods. This suggests that reservoir construction does significantly increase the rate

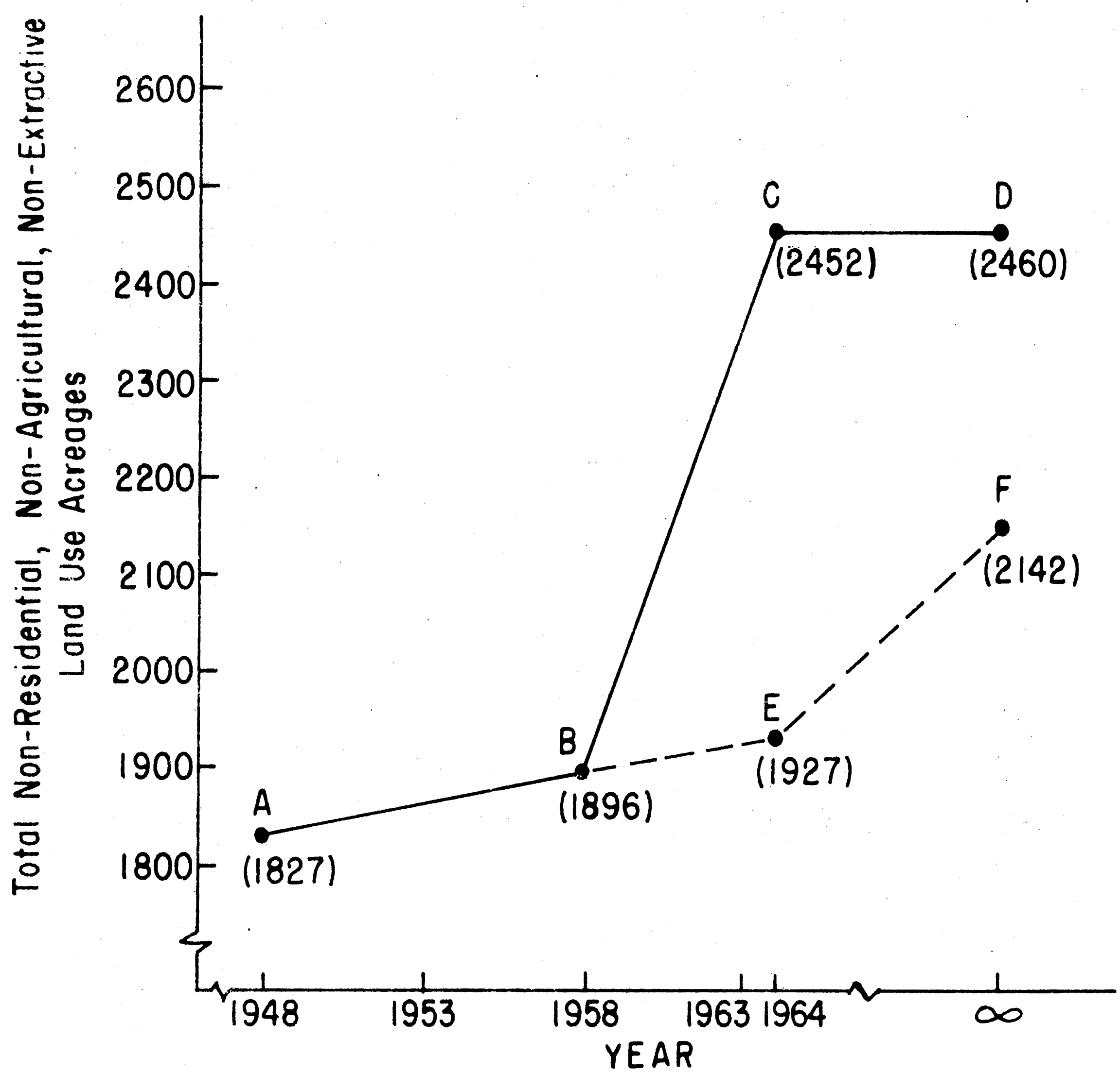

Figure 5. Total Acres of Non-Residential, Non-Agricultural, Non-Extractive Land Use With and Without Construction of Keystone Lake for Years 1948 to Infinity

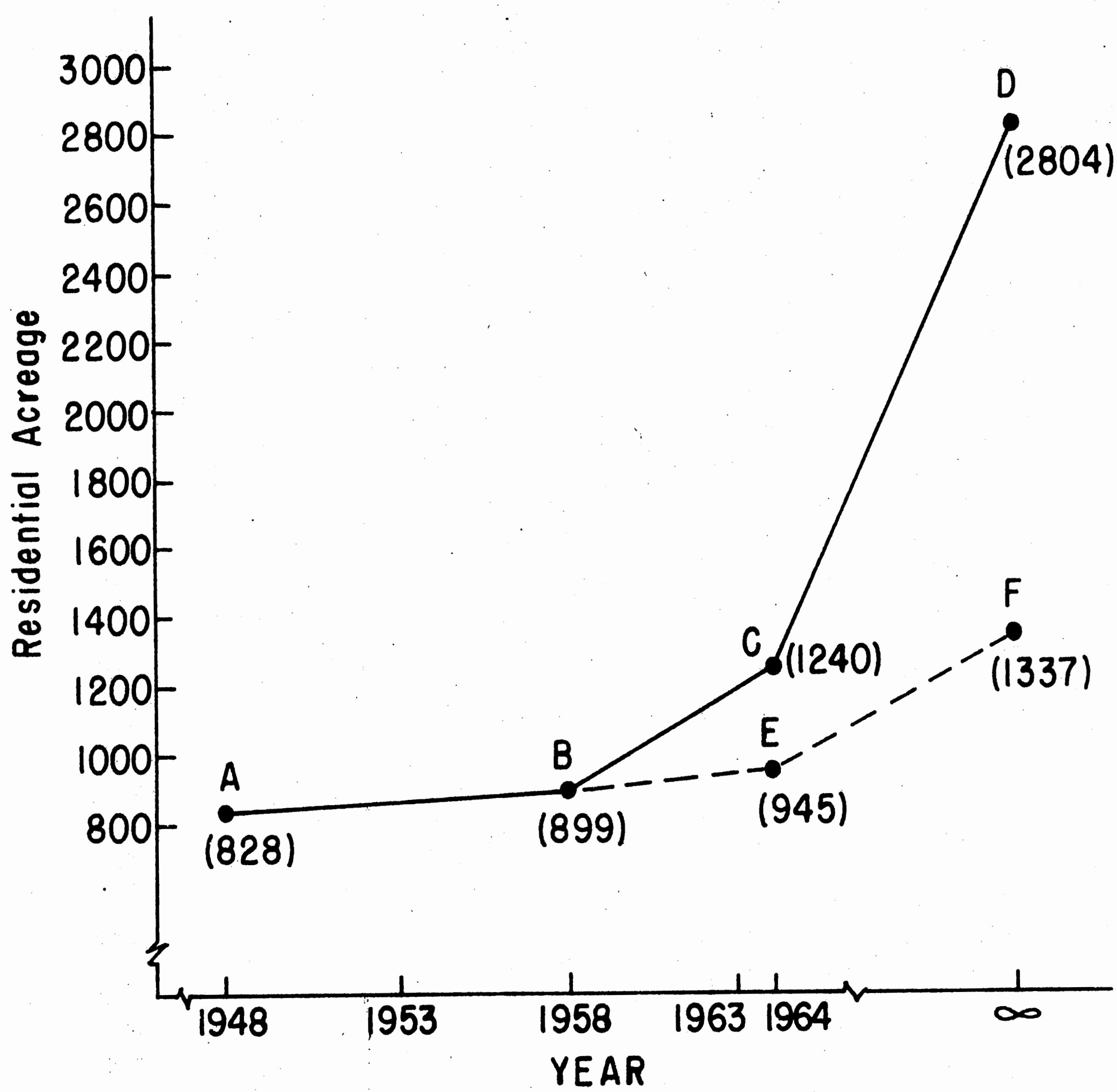

Figure 6. Total Acres of Residential Land Use With and Without the Construction of Keystone Lake for Years 1948 to Infinity

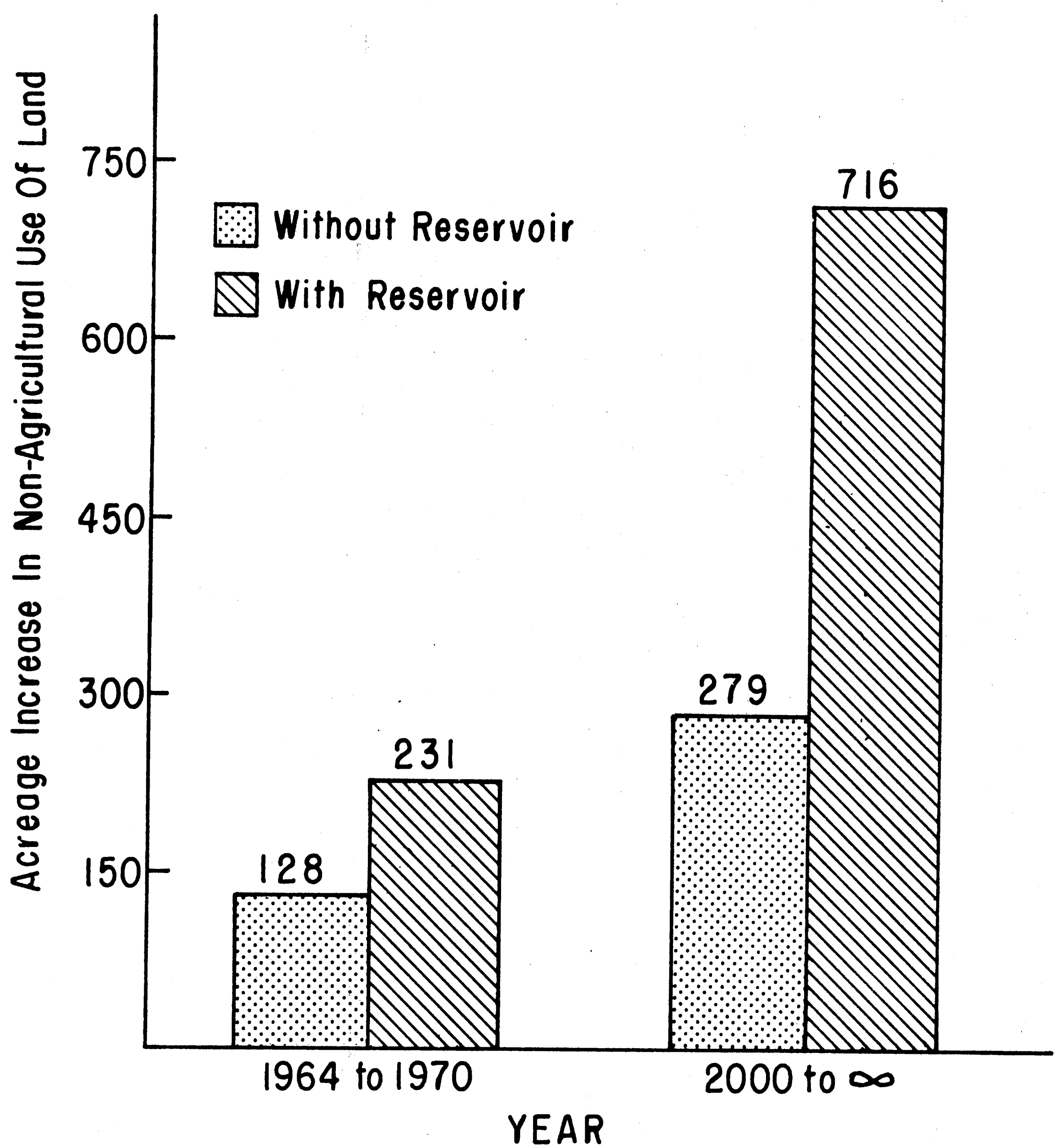

Figure 7. Change in Total Acres of Non-Agricultural Land Use With and Without Construction of Keystone Lake During Two Time Periods

of change from agricultural to non-agricultural land uses. Moreover, the rate of increase with reservoir construction is relatively greater in the after 2000 period indicating that the total differential impact will be realized over an extended time period.

CHAPTER V

IMPACT OF LAND USE CHANGE ON PRIVATE PROPERTY WEALTH

The purpose of this chapter is to estimate the change in property wealth in the study area associated with land use changes resulting from the construction of Keystone Lake. In the previous chapter actual and projected differential land use changes associated with lake development were estimated for the study area. The results indicate that substantial land use changes followed the completion of the reservoir. In particular, agricultural uses decreased while-non-agricultural land uses increased. With these land use changes an increase in property wealth may result because of a) increases in land and improvements prices due to the proximity of the reservoir, and b) land use pattern adjustments in the reservoir area.

Assumptions

The model described in Chapter II was used to estimate the property wealth impact of Keystone Lake. The estimates are based on three assumptions:

1. Only privately held property is included in this analysis. Thus the analysis is limited to residential, commercial, and agricultural land use categories.
2. Land and improvement prices are held constant in this analysis for the purpose of estimating those effects which are due only to land use pattern adjustments in the reservoir area.

3. Only change in private property wealth in the non-inundated portion of the study area is considered in this analysis. The loss of property wealth due to inundation is not computed.

Estimated Land Use Quantities

Estimated actual and projected private land use in 1970 and infinity are given in Table XV. These land use quantities were estimated in Chapter IV and are presented here with residential land use subdivided into rural and city residential land uses. This was necessary because land and improvements associated with city residential land uses are valued differently from those of rural residential land uses. For a detailed account of the technique used in estimating rural and city residential land uses, see Appendix D.

With the exception of city residential, all land use quantities in Table XV are measured in acres. For city residential land use quantities, the unit of measurement is 0.795 acre lots.[1]

Estimated Land and Improvement Values

Estimates of land market values (V_n) and improvement market values (I_n) were obtained from responses to a questionnaire sent to members of the Oklahoma Society of Farm Managers and Rural Appraisers. Each professional appraiser was requested to give his best estimate of average

[1]The size of the residential lot is large because it includes residential acreage per residential unit. The explanation of the procedure used to estimate the size of a city residential lot is given in Appendix B.

TABLE XV

ACTUAL AND PROJECTED PRIVATE LAND USE,
KEYSTONE LAKE, OKLAHOMA

Land Use	Unit	Actual Land Use Quantities (Q_n) 1970	Projected Land Uses Without Reservoir Construction $({}_{ab}Q_n)$ 1970	Projected Land Uses With Reservoir Construction $({}_{cd}Q_n)$ Infinity	Projected Land Uses Without Reservoir Construction $({}_{ab}Q_n)$ Infinity
Rural Residential	Acre	408.5	239.7	787.2	323.7
City Residential	Lot	1,316.3	943.2	2,536.8	1,274.5
Commercial	Acre	188.6	91.6	201.1	104.1
Cultivated Land	Acre	2,882.7	6,883.0	2,400.8	7,586.1
Pastureland	Acre	32,847.2	37,506.7	30,462.3	41,927.4
Woodland	Acre	51,282.4	43.566.5	52,779.0	37,736.7

per unit market value of land and improvements for the specified land uses in this analysis. A copy of the questionnaire is given in Appendix E. The estimated land and improvement per unit market values from the questionnaires are given in Table XVI. Land and improvement per unit values were deflated to 1961 dollars so that the differential change in private property wealth could be compared to the total construction cost of the reservoir.[2]

Actual Differential Change in Private Property Wealth

Estimates of actual differential change in private property wealth in the Keystone Lake area are given in Table XVII. These estimates are in 1961 dollars. Actual private property wealth in 1970 (W_n) is given in the first column of Table XVII while the projected private property wealth in the area had the reservoir not been constructed ($_{ab}W_n$) is given in the second column of this table. Actual differential change in private property wealth (P_n) is estimated by [13] and given in the last column of Table XVII.

The 1970 differential private property wealth results in Table XVII indicate that an increase of approximately seven million dollars in private property wealth resulted from the differential change in land use caused by the construction of Keystone Lake. Assuming constant per unit land and improvement prices, this value indicates that private property wealth in the reservoir area increased by approximately 33

[2]The original cost estimates for reservoir construction are assumed to be given in average 1961 dollars, the mid-point of the construction period.

TABLE XVI

LAND AND IMPROVEMENT VALUES FOR PRIVATE LAND USES,
KEYSTONE LAKE AREA, OKLAHOMA, 1975

Land	Unit	Value in 1961 Dollars[a/] Land	Improvements	Value in 1961 Dollars Land	Improvements
Rural Residential	Acre	1,460.42	19,836.84	776.33[b/]	10,544.85[b/]
City Residential	Lot	2,789.47	19,684.21	1,487.02[b/]	10,493.31[c/]
Commercial	Acre	5,668.75	19,868.75	2,513.65[d/]	8,810.26[d/]
Cropland	Acre	406.25		125.63[e/]	
Pastureland	Acre	254.29		78.64[e/]	
Woodland	Acre	193.42		59.81[e/]	

a/Source: Appendix E.

b/1975 value deflated by implicit price deflator for residential farm structures (22).

c/1975 value deflated by implicit price deflator for residential non-farm structures (22).

d/1975 value deflated by implicit price deflator for non-residential structures (22).

e/1975 value deflated by farm real estate index of average value per acre (23 24).

TABLE XVII

ESTIMATED PRIVATE PROPERTY WEALTH IN 1970 AND DIFFERENTIAL CHANGE IN PRIVATE PROPERTY WEALTH IN 1970, KEYSTONE LAKE, OKLAHOMA

(Thousands of 1961 Dollars)

Land Use	Private Property Wealth in The Reservoir Area	Projected Private Property Wealth Without Reservoir Construction	Differential Change In Private Property Wealth
Improvement Values			
Rural Residential	4,307	2,527	1,780
City Residential	13,812	9,897	3,915
Commercial	1,661	807	854
Sub-Total	19,780	13,231	6,549
Land Values			
Rural Residential	317	186	131
City Residential	1,957	1,403	554
Commercial	474	230	244
Cultivated Land	362	865	-503
Pastureland	2,583	2,950	-367
Woodland	3,067	2,606	461
Sub-Total	8,760	8,240	520
Total	28,540	21,471	7,069

percent. Most of this increase is the result of residential and commercial improvement construction. The net differential change in private property wealth for land is small because decreases in agricultural land wealth offset the major portion of increases in non-agricultural land wealth.

Projected Differential Change in Private Property Wealth

The projected differential change in private property wealth ($\hat{P}_n$) in the area as time approaches infinity is estimated by [15]. These results are given in Table XVIII. The projected differential change in private property wealth associated with land use pattern adjustments in the reservoir area is estimated to be approximately twenty-one million dollars. This change indicates that after all land use pattern adjustments are completed, private property wealth in the reservoir area will have increased by 78 percent over the value had the reservoir not been constructed.[3] As before, most of the differential change in private property wealth occurs as the result of increased commercial and residential construction in the reservoir area.

Secondary Impacts of Lake Construction

Keystone Lake was constructed at a total, direct cost of $123,840,000 to the Federal Government (8). However, this value does not fully represent the total amount of new investment in the study area. Reservoir construction causes land use changes nearby which in

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[3]Measured in constant 1961 dollars.

TABLE XVIII

PROJECTED PRIVATE PROPERTY WEALTH IN INFINITY AND DIFFERENTIAL CHANGE IN PRIVATE PROPERTY WEALTH IN INFINITY, KEYSTONE LAKE, OKLAHOMA

(Thousands of 1961 Dollars)

Land Use	Projected Private Property Wealth With Reservoir Construction	Projected Private Property Wealth Without Reservoir Construction	Projected Change In Private Property Wealth
Improvement Values			
Rural Residential	8,301	3,415	4,886
City Residential	26,619	13,373	13,246
Commercial	1,772	917	855
Sub-Total	36,692	17,705	18,987
Land Values			
Rural Residential	611	251	360
City Residential	3,772	1,895	1,877
Commercial	506	262	244
Cultivated Land	302	953	-651
Pastureland	2,396	3,297	-901
Woodland	3,157	2,257	900
Sub-Total	10,744	8,915	1,829
Total	47,436	26,620	20,816

turn stimulate private improvement investment in the area. Therefore, the total amount of new investment associated with the construction of the reservoir is the value of government investment plus the investment in new improvements in the private sector.

The amount of new investment in the private sector in the form of new improvements in the reservoir area associated with the original government investment is estimated in Table XVIII to be $20,816,000. This indicates that investment in the private sector increases by approximately 17 cents for every dollar of government investment in the construction of the reservoir. The extended effect of a dollar increase in government investment on reservoir construction is to increase total investment in the reservoir area by $1.17. This extended effect is probably a low estimate because price effects due to the proximity of the reservoir were not considered.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The primary objective of this study is to estimate actual and projected differential land use change associated with the construction of Keystone Lake, Oklahoma. A second purpose is to estimate the differential change in private property wealth in the reservoir area associated with land use pattern adjustments. The first of these objectives was accomplished through: (1) quantification of land use in the reservoir area, (2) projection of land uses in the reservoir area, and (3) estimation of projected land uses in the area had the reservoir not been constructed. The second objective was accomplished through: (1) the estimation of private property wealth in the reservoir area, (2) projection of private property wealth in the reservoir area, and (3) estimation of projected private property wealth in the area had the reservoir not been constructed. In either case land use changes both with and without the lake are estimated. The difference between the changes is the differential land use change.

Differential Land Use Change Analysis

Estimation Procedures

Keystone Lake in north central Oklahoma was chosen as the study area. The study time period is 1948 to 1970 with two sub-periods. The two sub-periods are the pre-investment (1948-1958, a time period prior to reservoir construction) and post-investment (1964-1970, a time period following reservoir construction).

A stationary, finite Markov chain process was used to project land uses in the study area. The projection technique consists of a land use flow matrix and a transition matrix. The land use flow matrix summarized the quantity of land moving from each land use into all other land uses during a definite time period. The transition or flow of land from one category to another is regarded as a stochastic process with a known probability of occurence. The matrix of these probabilities is the transition matrix. The transition matrix along with a vector of starting state land uses constitute the necessary data for a Markov process to project future land use patterns.

Primary land use data were collected in the study area at the beginning and end of each sub-period using aerial photographs. These primary land use data were converted to acreage values and used to estimate pre-investment and post-investment land use flow matrices. Land use projections based on the pre-investment land use flow matrix are estimates of the land use pattern that would have existed in the area had the reservoir not been constructed. Estimates of future land use patterns in the reservoir area accounting for the presence of the reservoir are projected using the post-investment land use flow matrix.

A differential land use model using land use projections obtained from the Markov process is developed to estimate that portion of the total land use change which may be attributed to reservoir construction. Actual differential land use change is the difference between projected land uses had the reservoir not been constructed and actual land uses following reservoir construction. Projected differential land use change in future time periods which is attributable to reservoir construction is estimated using the same approach. In this case, the post-investment time period is used to project future land use patterns existing after reservoir construction. The difference between estimates of future land use patterns based on pre-investment and post-investment transition matrices is a measure of the future differential impact of the public investment on land use patterns.

Empirical Results

The analyses in this study demonstrate that there are substantial land use changes associated with reservoir construction. Estimates of actual and projected differential land use change are given in Table XIX. With the exception of extractive land uses, all non-agricultural land uses increased as a result of reservoir construction. As might be expected for a lake development project near a major metropolitan area, there are large increases in residential land uses. By 1970, residential uses had accounted for more than half of the increase in non-agricultural land uses. Within the agricultural land use categories, cultivated and pasture land uses decreased while woodland acreage increased. This phenomenon suggests that following reservoir construction more emphasis is placed on the esthetic attributes of the area as a complement to the newly created recreational and leisure opportunities.

The projected differential land use results in Table XIX are generally similar to the actual differential land use results; however, there is one interesting difference. During the first few years following lake construction the non-agricultural uses are characterized

TABLE XIX

ESTIMATES OF ACTUAL AND PROJECTED DIFFERENTIAL LAND USE CHANGE ASSOCIATED WITH THE THE CONSTRUCTION OF KEYSTONE LAKE, OKLAHOMA

(Units in Acres)

Land	Estimated Actual Differential Land Use Change		Estimated Projected Differential Land Use Change	
	1964	1970	2000	Infinity
Non-Agricultural Uses				
Commercial	112	97	86	97
Extractive	-32	-52	-95	-101
Transportation	173	164	128	108
Utilities	224	204	144	110
Institutional	16	14	6	3
Residential	295	464	978	1,467
Sub-Total	788	891	1,247	1,684
Agricultural				
Impoundments	95	53	-42	-76
Cultivated	-3,200	-4,000	-4,953	-5,185
Pasture	-2,903	-4,660	-9,608	-11,465
Woodland	5,219	7,716	13,356	15,042
Sub-Total	-788	-891	-1,247	-1,684

by balanced growth of both the residential and infrastructure land uses. Most of the significant non-agricultural land use change after 2000 occurs in the residential category while other non-agricultural land uses remain relatively constant. This result indicates that reservoir construction immediately stimulates infrastructure or facilitative investments in the reservoir area and that these land uses increase at a rate far in excess of the pre-investment rate causing a relatively large, relatively early differential impact. In later time periods, the facilitative land use pattern that would have existed if the reservoir had not been constructed catches up with the post-investment land use patterns. Over time this catch up process reduces the differential impact of non-agricultural, non-residential land uses.

Differential Property Wealth Change Analysis

Estimation Procedure

The differential land use change analyses indicate substantial land use adjustments associated with reservoir construction. Actual and projected differential changes in private property wealth associated with these land use adjustments were estimated for the reservoir area assuming constant per unit land and improvement market values. Differential change in private property wealth at any point in time is the difference between estimated private property wealth in the reservoir area and the estimated private property wealth in the same area had the reservoir not been constructed. Since property values are assumed constant, this procedure estimates only the wealth impact resulting from land use pattern adjustments.

Empirical Results

Estimates of property wealth held privately in the forms of land and improvements indicate a substantial change in total private property wealth associated with land use pattern adjustments in the reservoir area. Most of the differential change in private property wealth occurs as the result of increased commercial and residential construction in the area. The net differential change in private property wealth in the form of land is small because decreases in agricultural land wealth offset the major portion of increases in non-agricultural land wealth.[1] The findings indicate that after all land use pattern adjustments are completed, private property wealth in the reservoir area will have increased by 78 percent (in constant dollars) over the total private property wealth in the area had the reservoir not been constructed and by 108 percent over the private property wealth prior to initiating construction of the lake.

Other Conclusions

Estimates generated by the differential land use change models predict substantial land use pattern adjustments associated with the construction of Keystone Lake. These results provide valuable insights into the exogenous or differential long-term land use changes resulting from reservoir construction. The pattern of these results provides professional planners with an improved conceptual understanding of the land use change impacts associated with reservoir construction.

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[1] If before and after land price differentials had been included in the analysis, a greater impact probably would have been observed.

This study demonstrates a technique for producing improved estimates of reservoir impacted land use change. The technique (differential land use model) is superior to other approaches because it projects existing land use trends before reservoir construction into and beyond the construction period. This facilitates the accurate measurement of differential land use change attributable to reservoir development. Such a technique should provide professional planners with a land use change estimation tool which has obvious applications in benefit-cost analyses of project feasibility. Furthermore, the differential land use model is equally appropriate for estimating the land use impact of public investments other than water.

In this study, land use data were collected by a unique method. This data collection process proved to be effective in quantifying land uses consistent with the data requirements of the Markov chain process. The method also proved to be less tedious and involved less time and cost than alternative methods.

Limitations of the Study and Need for Further Research

Additional research estimating differential land use changes associated with reservoir construction might include several modifications. In this study, the size of sample observations within the study area was arbitrarily selected. Further research could develop a system of sample observations which conforms more nearly to the contour of the reservoir. This would produce more accurate estimates of differential land use change associated with reservoir construction. This method would also permit the measurement of the change in land use intensities by proximity to the reservoir.

Further research should include the collection of more detailed primary land use data. For instance, in addition to the coding of land use presence, the number of structures associated with each land use variable could be included in the land use coding process. Rural and city residential land uses could be differentiated as they are coded from aerial photographs.

The estimation of land use flow matrices in this study requires the formulation of assumptions regarding land use flows between alternative uses over time. Land use flows were inferred from the land use data rather than measured directly. Future studies should attempt to directly measure land use flows between time periods rather than merely recording land use presence in each time period.

The differential land use model in this study assumed that transition probabilities remain constant through time. This means that existing trends in land use change in each of the sub-periods are assumed to continue into the future. Further research should include an investigation of how transition probabilities change over time to allow for the development of a system of non-stationary transition probabilities which would compensate for changing economic conditions.

The differential land use change estimated in this study is solely attributed to the construction of Keystone Lake. Other exogenous factors influencing land use change are assumed to remain constant or to be non-existent. The study does not specifically consider the unique land use changes associated with the necessary relocation of the city of Mannford and other minor urban areas. Similarly, the study does not attempt to explicitly account for the land use change associated with the opening of Keystone Expressway and the establishment of rural water districts in the study area.

The private property wealth analysis in this study assumes constant per unit land and improvement values. With this assumption, the differential change in private property wealth associated with reservoir construction is probably under-estimated. Further research should include the estimation of differential change in private property wealth associated with increasing land and improvement values due to the proximity of the property to the reservoir.

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APPENDIXES

APPENDIX A

COLLECTION OF PRIMARY LAND USE DATA

The land use coding sheet consists of 13 land use variables, two variables identifying the location of the sample, one structure count variable, and the year the sample was taken. The land use coding sheet is given in Figure 8. Land uses at each of the approximately 3,000 sample observations, each measuring one-half kilometer square (61.78 acres) are recorded on land use coding sheets. Land uses existing in a sample observation are coded for the beginning and ending years of the pre-investment (1948-58) and the post-investment (1964-1970) sub-periods.

Each sample observation is identified by variables 1 and 2 in the land use coding sheet. Variable 1 gives the east-west location of the sample observation while variable 2 locates its north-south location. The location of the sample observation is identified by the intersection of the coordinates in the southwest corner.

Coding of Non-Agricultural Land Uses

Non-agricultural land uses are variables 3 through 9 in the land use coding sheet. Utilities consist of railroads, powerlines, pipelines while institutional land uses consist of schools, churches, cemetaries, parks and hospitals. In the land use coding process, non-agricultural land uses are coded 1 if the particular land use is

Variable Number			
1	(1-3)	________	X coordinates (East-West)
2	(4-7)	________	Y coordinates (North-South) of SW corner
3	(8)	________	Residential (1 if present)
4	(9)	________	Commercial (1 if present)
5	(10)	________	Manufacturing (1 if present)
6	(11)	________	Extractive (1 if present)
7	(12)	________	Highway Transportation of Parking (1 if present)
8	(13)	________	Railroads or Other Utilities (1 if present)
9	(14)	________	Institutional (1 if present)
10	(15)	________	Cultivated Land, Orchards, Horticulture, Feedlots 0 = 0 - 10%
11	(16)	________	Pasture, Rangeland, Grassland 1 = 11 - 50%
12	(17)	________	Woodland 2 = 50 -100%
13	(18)	________	Lake Water 0 = None 1 = Conservation 2 = Flood (854') 3 = Both
14	(19)	________	Other Impoundments, Ponds (1 if present)
15	(20-1)	________	Count of Structures present. All man-made structures.
16	(23-4)	________	Year (last two digits)
17	(25-6)	________	Coder Initials

Figure 8. Land Use Coding Sheet

present within the sample observation and 0 if not present in the sample observation. For example, if a highway is visible in a sample observation from an aerial photograph, then highway transportation is coded 1.

Coding of Agricultural Land Uses

Agricultural land uses are variables 10 through 12 in the land use coding sheet. These land uses are coded according to the percent of the total sample observation area occupied by each in terms of the total area being coded. More specifically, each agricultural land use is coded: 0 if the agricultural land use occupies 0 to 10 percent of the sample observation; 1 if the agricultural land use occupies 11 to 50 percent of sample observation; and, 2 if the agricultural land use occupies 50 to 100 percent of the sample observation. For example, if it is estimated that cultivated land occupies 5 percent, pastureland occupies 20 percent, and woodland occupies 60 percent of the sample observation, then agricultural variables 10 through 12 are coded, 0 1 2.

Other impoundments, variable 14, includes agricultural land used for ponds. This variable is coded in the same way that non-agricultural land uses are coded.

Coding of the Lake Water Variable

The variable lake water (variable 13) consists of land used for the conservation pool and land used for flood control purposes. The conservation pool is the actual water in the lake while the flood pool is the land in the flood control area surrounding the reservoir. This land is owned and managed by the Army Corps of Engineers. Lake water in each sample observation is coded according to the following: 0 if no lake water is present within the sample observation; 1 if conservation pool is present; 2 if flood pool is present; and 3 if both conservation and flood pools are present in the sample observation.

Structure Count

The structure count variable (variable 15) is a count of all man-made structures within the sample observation. The structure count is made by simply counting the relevant structures within the sample observation. The relevant structures are houses, oil wells, oil and water storage tanks, commercial establishments and institutional facilities. Barns, garages, and other outbuildings commonly associated with a place of residence are not included in this count.

Manufacturing

The manufacturing (variable 5) land use variable is not considered in this study because of the lack of sample observations in which this variable is present. Omitting this variable does not effect the structure of this study because the study area and manufacturing is not a major land use.

APPENDIX B

QUANTIFICATION OF LAND USES FROM PRIMARY LAND USE DATA

The purpose of this appendix is to describe the procedure for quantifying land uses given the primary land use data for each sample observation. As explained in Chapter III, primary land use data are not consistent with the assumptions of a Markov chain process. To meet these data requirements, land uses are quantified for each sample observation by converting primary land use data to land use acreage estimates. These land use acreage estimates are subsequently used to derive land use flow matrices as explained in Chapter III and Appendix C.

Procedure for Estimating Non-Agricultural Average Acreage Values

The acreage value for a non-agricultural land use is estimated by measuring the average number of acres the land use occupies in a large number of sample observations in which the land use is present. This average acreage value estimates the acres occupied by a non-agricultural land use when this land use is present in a sample observation.

There are several methods available for measuring land use acres from aerial photographs; however, the preferred method and the method used in this study is the dot grid method (25). The dot grid measurement technique utilizes a transparent overlay with dots systematically arranged on a grid pattern. The overlay is placed over the aerial photograph and the number of dots tallied for each land use lying within the boundaries of the sample observation being evaluated. These dots are then used to compute the acreage occupied by each land use. The number of dots for a given land use divided by the total number of dots in the sample observation equals the proportion of the total area accounted by that land use.

For each non-agricultural land use, a large sample of aerial photographs were selected in which each particular land use was present. Within a sample, the land use area was measured by randomly placing the dot grid over each aerial photograph and recording the number of dots falling on that land use. The average number of dots per sample was converted to a land use acreage value. These land use average acreage estimates along with respective sample standard deviations are given in Table XX. The standard deviations associated the mean estimates in Table XX are less than one-half of the mean in most cases indicating a high degree of confidence in the sample estimates.

It should be pointed out that primary land use data indicate the existence or non-existence of land uses in a sample observation. If a land use is coded as being present, it is quite possible that more than one of these land uses is present in a single sample observation. With the exception of city residential, all land use average acreage values in Table XX were estimated in a way which captures the total average acreage occupied by a land use when that land use is present in the sample observation. For instance, if the average number of commercial establishments in a sample observation is three when a commercial land use is coded present, then according to our estimates in Table XX these

TABLE XX

NUMBER OF SAMPLE OBSERVATIONS, ESTIMATED AVERAGE ACREAGES, AND STANDARD DEVIATIONS BY NON-AGRICULTURAL LAND USE CATEGORIES WHEN PRESENT IN A SAMPLE OBSERVATION, KEYSTONE LAKE, OKLAHOMA, 1964

Land Use	Number of Sample Observations	Average Acreage Estimates (Mean)	Standard Deviation
Rural Residential	80	1.1703667	.6439
City Residential	20	.7951325	.2651
Commercial	64	4.0118262	4.5941
Extractive	80	1.0979713	.6889
Highway Transportation	80	2.2321433	.9493
Railroads and Utilities	80	1.9787625	1.0780
Institutional	80	2.6544386	3.7669
Lake Water			
Conservation	80	23.1057060	
Flood	80	14.2495210	
Both Conservation and Flood	80	37.3552270	
Other Impoundments (Ponds)	80	.7118706	.6689

three establishements would occupy 4.012 acres in the sample observation.

City Residential Land Uses

In Table XX residential land uses were divided into rural and city residential land uses. City residential land uses are defined to include residential land uses located in the following cities in the study area:

Cleveland	New Mannford
Osage	Mannford
New Prue	Prue
Terlton	

City residential land uses are then identified by arbitrarily defining the coordinate boundaries of a city. Residential land uses lying within these coordinate boundaries are defined as city residential land uses. Residential land uses outside of these boundaries are considered as rural residential land uses.

Total Acreage Estimates for City Residential Land Uses

It was estimated above that when present in a sample observation, a city residence occupies 0.795 acres per residence. Thus, this acreage value is not necessarily the total residential acreage existing in a sample observation because there may be several such residences present. The total city residential acreage is computed by multiplying the city residential acreage times the number of residences present in the sample observation. The number of city residences in a sample is obtained from the structure count variable (variable 15, Figure 8, Appendix A). However, the structure count variable includes a count of commercial and institutional structures present in the sample observation. To correct for the presence of these structures in a sample observation, the structure count variable is adjusted downward by three if commercial land uses are coded present and by two if institutional land uses are coded present in the sample observation. These corrections result in the adjusted structure count which is multiplied by the city residential acreage value to obtain the total estimated acreage occupied by city residential land uses existing in a sample observation. The procedure used to compute total city residential acreages will be discussed again in the last section of this appendix when acreage estimates are allocated among all use categories.

Procedure for Estimating Agricultural Percentage Area Values

Agricultural land uses were coded according to the percent of the area being coded. More specifically, each agricultural land use was coded 0 if the agricultural land use occupied 0 to 10 percent of the total sample observation; 1 if the agricultural land use occupied 11 to 50 percent of the total sample observation; and, 2 if the agricultural land use occupied 51 to 100 percent of the total sample observation. It is important to point out that if an agricultural land use is coded 0, this does not necessarily mean that the land use does not exist in the sample observation. Instead it means that 0 to 10 percent of the sample point is occupied by the agricultural land use. Given this coding procedure, there are 23 possible agricultural land use combinations.

As discussed in Chapter III, percentage area values for each agricultural land use combination are necessary for the estimation of agricultural acreages existing in a sample observation. These percentage area values were estimated from a large random sample of aerial photographs. Each agriclutural land use was measured by randomly placing the dot grid on each aerial photograph in the sample and recording the number of dots associated with each agricultural land use. The average dot count for each land use within an agricultural land use combination was computed and expressed as a percent of the sum of averages within a single agricultural land use combination. These estimated percentage area values for each agricultural combination are given in Table III (Chapter III). The percentage area values for each agricultural land use combination sum to 100 percent because they are a percent of agricultural land in each of the three uses which may or may not be 100 percent of the total sample observation area. Percentage area values associated with agricultural land use combination number 6 are interpreted to mean that of the total agricultural land in the sample observation 0.50 percent is cultivated land, 28.14 percent is pastureland and 71.36 percent is woodland.

Quantification of Land Uses in a Sample Observation by Allocating Acreage Values to Primary Land Use Data

Non-agricultural land uses in a sample observation are quantified first by allocating respective acreage values to corresponding primary coded land uses. However, the sum of the allocated land uses cannot exceed the size of the sample observation (61.8 acres). In a rural area it is impossible for the sum of the allocated non-agricultural land use acreage values to exceed the size of the sample observation. This is because in a rural area the sum of all possible non-agricultural acreage values is less than 61.8 acres. In a city sample observation, it is possible for the sum of the allocated non-agricultural acreage values to exceed the size of the sample observation. This is because the computed total city residential acreage between sample observations may vary depending on the number or residences in a city sample observation. If the sum of the allocated non-agricultural land use acreages exceeds 61.8 acres, then the total city residential land use acreage is adjusted downward until the total acreage of the sample observation equals 61.8 acres. For example in Table XXI, the total city residential acreage of 64 acres is computed by multiplying the acreage value city residential (.8) times the adjusted structure count (80). Non-agricultural, non-residential land uses occupy 8.2 acres of the sample observation while the remaining portion is allocated to residential land uses. However in the example, the total city residential acreage exceeds the remaining acreage in the sample observation. Consequently, the total city residential acreage is adjusted downward from 64 to 53.6 acres so that total acreage in the sample observation will not be over allocated.

Agricultural land uses are assumed to occupy all areas which are not allocated to non-agricultural uses. The unallocated portion of the sample observation is distributed among the agricultural uses based on the percentage area values in Table III (Chapter III) corresponding to the coded agricultural land use combination in the sample observation. If non-agricultural land uses occupy the entire sample observation,

TABLE XXI

AN EXAMPLE OF THE PROCEDURE USED TO ADJUST OVER-ALLOCATED NON-AGRICULTURAL ACREAGES IN A SAMPLE OBSERVATION

	Primary Land Use Data	Estimated Average Acreage Value[a]	Quantified Land Uses in A Sample Observation
Commercial	1	4.0	4.0
Highway Transportation	1	2.2	2.2
Utilities	1	2.0	2.0
Institutional	0	0	0
Sub-Total (Non-Residential, Non-Agricultural)	-	8.2	8.2
City Residential	1	.8	-
Adjusted Structure Count	80	80	-
Total City Residential Agreage	-	64	53.6
Total			61.8

[a]Average acreage value estimates are rounded off to the nearest tenth of an acre.

then agricultural land uses are assumed to be not present. An example of agricultural land use allocations for a sample observation is given in Table IV of Chapter III. In this example, the land remaining in the sample observation to be allocated to agricultural uses in 1958 is 54.4 acres and the coded agricultural land uses correspond to agricultural combination number 16 in Table III. Using the percentage area values of agricultural land use combination number 16, 10.7 acres (19.69 percent of 54.4 acres) is allocated to cultivated land, 35.5 acres (65.31 percent of 54.4 acres) is allocated to pastureland, and 8.2 acres (15.00 percent of 54.4 acres) is allocated to woodland.

Land uses in each sample observation were quantified for each of the four years in the study. These data were then used to compute land use flow matrices as described in Appendix C.

APPENDIX C

PROCEDURE FOR ESTIMATING LAND USE FLOWS IN A SAMPLE OBSERVATION

The purpose of this appendix is to describe the procedure used for estimating a sample observation pre-investment and post-investment land use flow matrix. The development of a land use flow matrix for a sample observation requires that land use flows between alternative land uses over time be estimated. As described in Chapter III and Appendix B, land uses were quantified for each sample observation at four points in time. Based on these data, land use flows among alternative land uses between two points in time were estimated using an algorithm developed by the author. Essentially, the algorithm is a series of assumptions regarding the flow of land between land uses which increase over the time period, and those that show a decline. The land use flow algorithm is discussed in the remaining portion of this appendix.

The Algorithm

Land use categories were divided into three groups, each of which is treated differently in the algorithm. These groups are:

Group	Land Use Categories Included in Each Group
1	Commercial, Extractive, Institutional
2	Transportation
3	Utilities, Impoundments, Residential, Cultivated Land, Pastureland, Woodland

As described in Appendix B, each city in the study area is identified by a set of coordinate boundaries. Sample observations within these coordinate boundaries are identified as city sample observations. All sample observations not identified as city are rural sample observations. Slightly different sets of assumptions regarding land use flows were developed for rural and city sample observations.

Algorithm for Rural Sample Observations

As discussed in Chapter III, the principal diagonal of a land use flow matrix represents land use acreages that remain in their respective land use categories throughout the time period in which the matrix is estimated. In describing the procedure for estimating the principal diagonal of the sample observation land use flow matrix, some mathematical notation is necessary. Assume that the beginning land use vector is B_i where i = 1, ...r, and the ending land use vector for the time period is E_i where i = 1, ...r. Then each F_{ii} = minimum (B_i, E_i) where F_{ii} are the diagonal elements of the land use flow matrix.

The off diagonal elements of the land use flow matrix represent land use flows between alternative land uses over time. These elements are computed using appropriate assumptions regarding land use flows between alternative land uses.

In estimating the off diagonal elements of the land use flow matrix, it is assumed that increasing land uses come from decreasing land uses in the sample observation in the time period. More specifically, it is assumed that if the acreage of a land use variable in group one or three increases over the time period, then this increase in acreage comes proportionately from decreasing agricultural land use.[1] However, if there is no decrease in agricultural land use acreages or if the decrease in agricultural land use acreages is not as large as the increase in group one or three acreage, then the remaining acreage increase is assumed to come proportionately from all other land use categories with acreage decreases. Transportation (group 2) acreage increases are assumed to come proportionately from all land use categories with acreage decreases in the sample observation.

Algorithm for City Sample Observation

A procedure similar to the one discussed in the previous section is used to estimate a land use flow matrix for each sample observation that is located in a city. The main diagonal of the land use matrix is developed in the same way; however, the assumptions used to compute the off diagonal elements (land use flows over the time period) of the matrix are modified.

In estimating the off diagonal elements of the land use flow matrix, it is assumed that if the acreage of a land use category in group one increases, then this increase comes porportionately from agricultural

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[1]Agricultural land uses included in this analysis are cultivated land, pastureland and woodland.

categories with acreage decreases. If there is no decrease in agricultural land use acreages or if the decrease in agricultural land use acreages is not as large as the increase in acreage of the group one category, then the increase in acreage of the group one land use category is assumed to come from any decrease in residential acreage. If the acreage decrease in agricultural and residential land use is not large enough to accomodate acreage increases in the group one land use variable, then the remaining increase is assumed to come proportionately from all other land uses with acreage decreases. Assumptions regarding land use flow for land use categories in groups two and three are the same as those for a sample observation which is located in a rural area.

Summary

Each of the above algorithms provides a method for computing land use flows for a sample observation given the before and after land use states. In this algorithm, the total land use acreage increases are equal to total land use acreage decreases for each sample observation. This assures that the total amounts of land in the sample observation at the beginning and at the ending of the estimation period are equal.

Given land use estimates for 1948, 1958, 1964, and 1970, and the algorithm described in this appendix, pre-investment and post-investment land use flow matrices are estimated for each of the 1,484 sample observations in the study area. The pre-investment land use flow matrix (1948-1958) for the entire study area estimated by summing all of the 1,484 pre-investment sample observation land use flow matrices.

Similarly, the post-investment land use flow matrix (1964-1970) for the entire study area is the sum of the 1,484 post-investment sample observation land use flow matrices.

APPENDIX D

ESTIMATION OF RURAL AND CITY RESIDENTIAL LAND USE QUANTITIES

The quantity of land in each of the ten use categories was estimated in Chapter IV. The private property wealth analysis in Chapter V requires the residential land use category to be further divided into city and rural residential uses. In this appendix, rural and city residential land use quantities are estimated using residential land use estimates from Chapter IV and a land use frequency count analysis.

Frequency Count of Sample Observations in Which Each Land Use Is Present

A frequency count was taken in the study area of the number of sample observations in which a particular land use is present. The results are given in Table XXII. Each entry in Table XXII measures the number of sample observations in which respective land uses were present. For instance, in 1958 there were 186 sample observations (out of a total of 1,484) with rural residential land uses present while in the same year there were 22 sample observations with city residential land uses.[1]

[1] The method for identifying rural and city sample observations is given in Appendix B.

TABLE XXII

FREQUENCY COUNT OF SAMPLE OBSERVATIONS IN WHICH A LAND USE IS PRESENT, KEYSTONE LAKE, OKLAHOMA

Land Use	Number			
	1948	1958	1964	1970
Commercial	12	19	49	47
Extractive	71	255	285	316
Transportation	552	572	661	668
Utilities	256	250	361	348
Institutional	15	18	25	25
Impoundments	333	447	620	593
Residential				
Rural	251	186	322	349
City	23	22	42	42

Estimated Number of City Residences

The number of city residences in the study area is computed by dividing the total acreage in city residential sample observations by the size of an average city residential lot.[2] The results are given in Table XXIII. These results indicate a substantial increase in the number of city residences during the period of reservoir construction (1958-1964). In addition to the increase in city residential activity associated with reservoir development, part of this increase is the result of the necessary relocation of cities in the study area.

Procedure for Computing Actual Rural and City Residential Land Use Quantities

Total city and rural residential acreages in the study area for a given year can be computed using average acreage values for each residential land use and the frequency count data from Table XXII.[3] For example, as shown in Table XXIV, there were 186 sample observations in the study area with rural residential land uses present in 1958. The average residence was found to occupy 1.1703667 acres so the total rural residential acreage in 1958 is 217.688 acres. City residential land uses (row six) are estimated to occupy 681.150 acres in the study area in 1958.

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[2]The method for estimating total city residential acreage in a sample observation and the method for estimating the size of an average city residential lot in the study area is described in Appendix B.

[3]Average acreage values for city and rural residential land uses are used repeatedly throughout this analysis. For an explanation of the method used in estimating these values, see Appendix B.

TABLE XXIII

PROCEDURE USED TO ESTIMATE NUMBER OF CITY RESIDENCES, KEYSTONE LAKE, OKLAHOMA

Row		1948	1958	1964	1970
1	Number of Sample Observations With City Residential Land Uses Present[a]	23	22	42	42
2	Total City Residential Acreage[b]	605.39003	681.15025	863.26740	1046.60110
3	Average Acreage Per City Residence (Lot)[c]	.7951325	.7951325	.7951325	.7951325
4	Estimated Number of City Residential Lots[d]	761.37	856.65	1085.69	1316.26

[a] Estimates from Table XXII.

[b] Sum of city residential acreages in the sample observations given in row one.

[c] Acreage estimate from Appendix B.

[d] Row two divided by row three.

TABLE XXIV

COMPUTATION OF ACTUAL RURAL AND CITY RESIDENTIAL LAND USE QUANTITIES, KEYSTONE LAKE, OKLAHOMA

Row		Ending Year of Pre-Investment Sub-Period 1958	Ending Year of Post-Investment Sub-Period 1970
1	Number of Sample Observations With Rural Residential Land Uses[a/]	186	349
2	Average Acreage Per Rural Residence[b/]	1.1703667	1.1703667
3	Rural Residential Total Acreage[c/]	217.688	408.458
4	Total Number of City Residential Lots[d/]	856.65	1316.26
5	Average Acreage Per City Residence[b/]	.7951325	.7951325
6	City Residential Total Acreage[e/]	681.150	1046.601
7	Total Residential Acreage[f/]	898.838	1455.059
8	Rural Residential Total Acreage Expressed As A Percent of Total Residential Acreage	24.21882	28.07157
9	City Residential Total Acreage Expressed As A Percent of Total Residential Acreage	75.78117	71.92842

a/ Estimates from Table XXII.

b/ Acreage estimates from Appendix B.

c/ Product of row one and row two.

d/ Estimates from Table XXIII.

e/ Product of row four and row five.

f/ Sum of row three and row six. These sums are not equal to the estimated residential acreages given in Chapter IV because of rounding error.

As described in Chapter V. the unit of measurement for city residential land uses is a lot. The total number of city residential lots in the study area is computed by dividing the total city residential acreage by the average size of a residential lot. The estimated number of city residential lots in 1970 is 1455.059. The computational procedure is summarized in Table XXIV.

Procedure for Computing Projected City and Rural Residential Land Use Quantities

Projected residential land uses based on pre-investment and post-investment transition matrices were estimated in Chapter IV. Projected rural and city residential land use quantities are computed by assuming that the proportion of city and rural residential land at the ending year of each sub-period (Q_b and Q_d) remains the same through time.

Projected city and rural residential land use quantities for the pre-investment and post-investment sub-periods as well as rural and city proportions of the total residential area are presented in Table XXV. The total estimated rural residential acreage in the study area in 1970 had the reservoir not been constructed (239.678 acres) is computed by multiplying the total estimated residential acreage in the study area times the rural proportion. The total city residential acreage (749.95849 acres) is computed in a similar manner. Using this value, the number of residential lots is computed to be 943.187 in 1970 had the reservoir not been constructed.

This procedure is repeated to estimate city and rural residential land use quantities in the reservoir area as time approaches infinity. These results are shown in the last column of Table XXV.

TABLE XXV

COMPUTATION OF PROJECTED RURAL AND CITY RESIDENTIAL LAND USE QUANTITIES, KEYSTONE LAKE, OKLAHOMA

Row		Estimates Based on the Pre-Investment Time Period		Estimates Based on the Post-Investment Time Period
		1970	Infinity	Infinity
1	Total Residential Acreage[a/]	989.637	1337.230	2804.27
2	Rural Residential Percentage[b/]	24.21882	24.21882	28.07157
3	Total Rural Residential Acreage[c/]	239.678	323.861	787.202
4	City Residential Percentage[b/]	75.78117	75.78117	71.92842
5	Total City Residential Acreage[d/]	749.95849	1013.36850	2017.06710
6	Average Acreage Per City Residence[e/]	.7951325	.7951325	.7951325
7	Number of City Residential Lots[f/]	943.187	1274.464	2536.768

[a/] Residential land use estimates from Chapter IV.

[b/] Percentage estimates are from Table XXIV.

[c/] Product of row one and row two.

[d/] Product of row one and row four.

[e/] Acreage estimate from Appendix B.

[f/] Row five divided by row six.

In this appendix, city and residential land use quantities are estimated in the reservoir area and in the area had the reservoir not been constructed. These land use quantities are used in Chapter V to estimate the differential change in private property wealth associated with land use pattern adjustments in the reservoir area.

APPENDIX E

LAND AND IMPROVEMENT VALUE QUESTIONNAIRE

Listed below are several land uses. Please give your best estimate of the average market value of land and of average improvements. It is hoped that your estimates will reflect the market values present in your community or area of practice.

Residential may be classified as rural or city. City residential is defined as a small town or city consisting of 5,000 or less inhabitants. Rural residential is defined as all other residences not located in a town or city.

	Total Real Estate Value ($)	Land Value ($ or %)	Improvement Value ($ or %)
1a. Rural Residential, a rural residence consisting of a 3 bedroom frame house with 2 outbuildings or barns of average size and quality:	$______ /Acre	______	______
1b. City Residential, consisting of a 3 bedroom frame house of average size and quality:	$______ /Lot	______	______
2. Commercial, average value of land and improvements for retail or sales establishments located on a major thoroughfare:	$______ /Acre	______	______
3. Cropland of average quality without improvements:	$______ /Acre	______	______

4. Native Pastureland of average quality, fenced, without the presence of a pond: $______/Acre ______ __________

5. Native Pastureland of average quality, fenced, with the presence of a pond: $______/Acre ______ __________

6. Woodland with native trees: $______/Acre ______ __________

VITA

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