AN ECONOMIC ANALYSIS OF THE LAND USE CHANGES ASSOCIATED WITH WATER RESOURCE DEVELOPMENT: PINE CREEK LAKE, OKLAHOMA

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CHAPTER I

INTRODUCTION

Considerable land use change has occurred with the growth and development of the United States. During the early period of growth, the dominant land use policy was designed for the transfer of the public domain to private ownership. During this period land policy issues were related to claiming and settling the interior of the continent. As land in one area was settled new lands were opened up on the frontier. Most of the land use changes were from idle land uses such as pasture and forest to cultivated land uses. The relatively abundant land supply in the early periods of economic growth minimized the economic and social consequences of land use changes and hence reduced the need for extensive land use planning.

With the closing of the frontier further demands for land required that land be converted from one use to another. As population and incomes increased in the United States more land was required for nonagricultural uses. The increasing population required more land for residences, shopping facilities, job sites and recreation facilities. Also the higher income level encouraged Americans to participate more fully in activities requiring land. Parks, recreation areas, high capacity transportation routes, suburban homes with large lots and second homes are a few of these higher-income related land using facilities. As urban areas developed pressure was placed on adjacent agricultural land encouraging its conversion to urban uses.

In more recent periods, the economic and social consequences of land use changes have increased as the limitations of fixed land supplies have become more apparent. Land use changes may to some extent influence structural factors such as land values, population distributions and densities and industry composition. These consequences have led to a greater interest in measuring and explaining the land use change that occurs.

The implications of land use changes in many regions of the country have resulted in extensive land use planning on the local, state and national levels. It has been important for land use planners to identify the stimuli for land use change and to specify the factors that influence the land use change which occurs from a given stimulus. Researchers and land use planners have identified, at least generally, the stimuli for land use change. The stimuli for land use change include such factors as population growth and urban and industrial expansion. Also, through the years many activities have been implemented by various levels of government which affect land use patterns [22]. One such activity has been water resource development projects.

The Problem

Construction of a water resource development project [WRDP] leads to changes in the opportunity costs of the land adjacent to the lake and the surrounding areas. The changes in opportunity costs provide a stimulus for changes in land use beyond those that would have occurred without the project.

Other studies have reported that the land use impacts of water resource development projects are most significant at the local level. Prebble found that as the distance from the reservoir increases the land use impact diffuses rapidly [16]. The land use impact occurring closest to the reservoir is primarily an increase in residential land use which occurs as individuals take advantage of the amenities of the lake [12]. Vandeveer [22] also found that the most significant land use impact is on increases in residential land use. Other studies have indicated that there are increases in commercial and other nonagricultural land uses which complement the recreational and residential land uses developing in the project area [12, 16].

Some previous studies have estimated the land use impact of a WRDP but within a framework in which the factors that influence land use changes are assumed constant. A major limitation of these studies has been a failure to incorporate explanatory factors. In studies that have focused on identifying causal factors a principal weakness has been a lack of forecasting ability.

Both limitations are serious constraints for evaluating the land use impact of a reservoir project. The development of a more adequate model is needed to measure land use change and to provide a basis for explaining and predicting the land use change associated with the project. A model encompassing both predictive and explanatory factors would be of considerable value in the formulation of land use policies for reservoir development projects.

The purpose of this study is to evaluate the general nature of the land use impacts resulting from a WRDP. The results of this study may be used to identify the factors that cause land use change in the project area and to describe the nature of the land use impact resulting from a WRDP. This information will enhance and improve the resource planning process.

Objectives

The general objective of this study is to evaluate the land use impact of a WRDP. The specific objectives of this study are to:

a) measure land use changes in the Pine Creek (Oklahoma) reservoir area.

b) estimate and project the differential land use changes directly related to the Pine Creek Reservoir Project.

c) estimate the relationship between selected economic and locational factors and land use changes in the study area.

d) compare the land use impacts resulting from the Pine Creek and Keystone (Oklahoma) reservoir projects.

Description of the Study Area

The Pine Creek Dam and Lake were authorized under the Flood Control Act of 1958 to control and develop water resources in the Little River Basin and to reduce flood flows on the Red River. The Pine Creek Project was the third of a seven reservoir system to be completed. Design and construction of the project were carried out by the Tulsa District, Corps of Engineers. On site construction began in February, 1963 and ended in 1969. The Pine Creek Reservoir is located in Southeast, Oklahoma on the Little River and lies approximately five miles north of Wright City. Parts of the lake extend into Pushmataha and Choctaw Counties but the greatest area of the lake lies in McCurtain County. The surface area of the lake is 3,800 acres at 438 feet above mean sea level and has a shoreline of 74 miles. The flood control pool covers 17,200 acres at 480 feet above mean sea level.

The Pine Creek Lake is surrounded by the Kiamichi Mountains. The hilly, mountainous country is mostly covered with timber and provides an unusually attractive setting for outdoor recreation activities.

The Pine Creek reservoir project was selected for analysis because of its isolated location from urban areas or major transportation routes and the availability of land use data for periods before and after reservoir construction. The implication of the remoteness of the reservoir project from other exogeneous forces which may stimulate land use change is that the reservoir project is the major factor contributing to the changing land use patterns in the project area.

The land use impact of the Pine Creek Reservoir project may be compared with the Keystone Reservoir Project. The Pine Creek and Keystone Reservoir Projects differ in several key aspects. The basic differences in the two areas provide the basis for broader generalizations concerning the land use impacts of other water resource development projects. Fortunately, both projects were constructed near the same time and so macroeconomic factors should not affect the land use impacts in the two reservoir areas. A map of the Pine Creek Study Area may be found in Appendix A. A map and description of the Keystone area may be found in the study by Vandeveer [23]. A brief description of the Keystone area is provided in Chapter V.

Land Use Data

The land use data for the Pine Creek study were obtained by aerial photographs obtained from the Tulsa District, Corps of Engineers and the Agricultural Stabilization and Conservation Service. The land use was identified by the varieties of tones, patterns and spatial organizations depicted in the aerial photographs. The availability of aerial photographs for several time periods made it possible to compare and analyze land use trends in the area.

With the use of aerial photographs and a topographic map the land uses in the Pine Creek Area were codified. A system of parallel north-south and east-west intersecting lines were drawn on the topographic map to form approximately 3,400 sample observations. A single observation covers 20 acres. Each line was assigned a specific coordinate which allowed each observation to be uniquely located. The entire study area covers approximately 37,000 acres.

The sampling procedures followed generally accepted procedures. Each sample observation was located on the aerial photographs. A dot grid was superimposed over the observation in a random manner with approximately 20 dots per sample observation. For each sample observation, the dots falling on each land use were counted and recorded on a code sheet. Land uses were classified into nine categories: (1) cultivated land and feedlots, (2) pasture land and range land, (3) forested and woodlands, (4) residential and farmsteads, (5) roads, highways and parking lots, (6) railroads, electric transmissions and other utilities, (7) all others, commercial and institutional, (8) impoundments and (9) lake or stream water. A copy of the code sheet can be found in Appendix B.

Data were collected for seven years: 1955, 1960, 1961, 1963, 1965, 1970 and 1974. The number of observations for each year is respectively: 2805, 365, 555, 2500, 2322, 3412 and 3205. The data for 1960 and 1961 were not used in this study since the sample size for each of these years is very small and covers a limited area of the Pine Creek study area.

Organization of the Study

In the following chapter the theoretical background needed for evaluating the land use impacts of a reservoir project is presented. This chapter consists of three main sections. In the first section special emphasis is given to the concepts of land use, land value, opportunity costs in the context of land use and the interdependent relationship among land uses. In the next section the literature review is presented. The literature review is used to develop a conceptual framework of analysis. The last section of this chapter is a discussion of the method of analysis which includes a conceptual model for evaluating the land use impacts of a reservoir project.

A descriptive analysis of land use change in the Pine Creek area before and after the reservoir project is provided in Chapter III. A conceptual model of the association between several selected variables and land use change is presented in this chapter. Multiple regression analysis is used to test empirically the importance of each variable hypothesized to influence land use change which occurred in the Pine Creek area.

The conceptual framework for differential land use models developed by Vandeveer [22] to estimate the land use impact resulting from the Keystone Reservoir Project is presented in Chapter IV. The theoretical concepts of the Markov process which are used to estimate the land use impact model are also presented and analyzed.

Chapter V is a comparison of differential land use change estimates in the Pine Creek and Keystone area. The comparison helps identify land use patterns that may typically follow a reservoir project.

A summary of estimation procedures, the major findings based on the integrated analysis of the two sets of models and the need for further research is presented in Chapter VI.

CHAPTER II

THEORETICAL BACKGROUND

An important objective of this chapter is to provide a conceptual framework for analyzing land use changes in the study area. First the concepts of land use and land value are defined to point out the distinction between the two terms. The following sections are used to define opportunity cost in the context of land use and to discuss the interdependence among land uses. The literature review is also presented in this chapter along with a discussion of the method of analysis used in this study.

Definition of Land Use

Land use may be defined as the service or purpose of the land to the individual owner or society. Clawson [5] defines land use as the activity for which the land is used. A few examples of widely accepted land use classifications are agriculture, residential, manufacturing, recreational and forestry. This study is directly concerned with land use only.

Definition of Land Value

In general, the value of land is derived from the use of the land and is influenced by the efficiency and capacity of the land in that use [6]. The relative demand and supply of land in a particular use generates within the economy a market value of the land [2]. Land value will not be a concern in this study.

Definition of Opportunity Cost of Alternative Land Uses

Chisholm (4) discusses opportunity cost in the context of firm location and suggests the usefulness of the concept in explaining land use change. The opportunity cost of land in one use is measured by the alternative uses to which that same land may be put. Essentially, each alternative use is in competition with other land uses. How effectively each land use competes for the use of a single parcel of land varies broadly on the basis of its comparative advantage or more specifically on the basis of (1) physical properties of the land, (2) accessibility to desired locations, and (3) market determined factors which account for the relative demand or supply of land in alternative uses. Conceptually, these factors define for the individual land owner or the potential user of the land the opportunity cost of the land in each use. To make a decision among alternative uses, opportunity costs of land in each use must be translated into land value or net returns gained from land being in a particular use relative to some other use. As the competitive interaction among land uses is resolved, land is allocated to alternative uses, and hence the land use pattern for an area is determined.

Changes in opportunity costs of land in one use will alter the relative opportunity costs of other land uses. Consequently this initiates a new round of competition among alternative land uses. The competition among land uses causes the basic process of land use change.

The Interdependence Among Alternative Land Uses

The competition among alternative land uses for the use of a single parcel of land may be distinguished from the competition among alternative land uses from an area point of view. The competition among land uses within an area reflects the structure of interdependence among the land uses. Alternative land uses may be complementary or in direct conflict with one another.

A complementary relationship exists among land uses when land in one use attracts to the area land in another use. Accordingly, an increase in land in one use in the area results in an increase in land in another use. Clawson [6] describes complementary land uses as giving value to another use. An example of complementary land uses within a given area is the relationship between recreational and commercial uses.

From an area viewpoint, land uses may also be competitive. Conflicting or substitute land uses are defined as land uses where the presence of one discourages the presence of the other. Two land uses are conflicting when an increase in land in one use results in the decrease of land in the other use. An example of conflicting land use may be the relation of residential land use and commercial land use. Where land development has been sporatic and unplanned, it is not uncommon for residential and commercial to compete for the use of the neighboring land area.

Which land uses are complementary and which are conflicting within an area varies from one situation to another. If any single land use increases sufficiently, then it will conflict with other land uses in the area.

Construction of a reservoir project will encourage the use of land which is complementary to the impacts of the project. For instance, one major purpose of the reservoir project is recreation. The land uses in the project area after the reservoir was constructed should reflect the land use patterns complementary to the major impacts of the lake.

The direction in which land use shifts is also indicated by the interdependence among land uses. The competitive ability of some land uses to outbid other uses based on the strength of demand suggests what land uses to expect in the next period [19]. The direction of land use change will largely depend on the amount of capital which has been invested in the land. To a great extent, the more capital intensive the present land use, the greater the likelihood that in the next time period, the land use will be more capital intensive. Similarly, if the capital investment has been small or absent, in the next time period the land use has a greater possibility of reverting to a less capital intensive land use.

Literature Review

The review of literature is used to develop the conceptual framework of analysis and therefore serves two purposes in this study. One purpose of the literature review is to help formulate hypotheses about economic and locational factors and land use changes resulting from the reservoir project. The other purpose of the literature review is to help select a model which can be used to evaluate the land use changes associated with the project. A review of literature regarding land use change reveals that the process of allocating land among alternative uses (land use change) has typically been explained in the context of varying land values.

Land Value Studies

David Ricardo [18] and J. H. Von Thunen [23] helped develop the general approach of explaining land value on the basis of productivity and spatial or locational factors. Ricardo saw the variation in soil fertility as an explanation for the differences in economic rent of land. Von Thunen's exposition of the economic rent emphasized the importance of location and transportation factors relative to a market center.

Much of the research concerning land value has focused on the variation in land prices within a given land use category. The general aim of these studies has been to determine how one parcel of land is differentiated from another to account for the variation in land prices. Indirectly these studies have contributed information concerning land use since a considerable amount of the dollar value of land is derived from its use value. In this sense many of the land studies are useful in determining those factors which may also be related to changes in land use.

More recent studies have built on these concepts and have tried to test empirically the importance of other factors in directly determining land values and in directly evaluating the factors associated with alternative land use patterns. In a recent study, Ray Jennings [9] analyzed those factors which affect the agricultural land markets in North Central Oklahoma. Jennings used multiple regression analysis to estimate the relative importance of several variables in explaining agricultural land values. He estimated land values on the basis of proximity, productivity, population factors and the proportion of mineral rights attached to the land. He also included a time variable to adjust for the secular trend in land values. Jennings found the proximity variables and the time adjustment factor to be most useful in explaining the variation in agricultural land values.

A land study by Jack L. Knetsch [12] was confined to estimating the impact of reservoirs on surrounding land values. Knetsch concentrated entirely on locational characteristics in an effort to determine the source of land value increases around reservoirs. Knetsch concluded that increases in land values near the reservoir were derived from the value of land as a recreational or amenity resource. The implication is that the presence of a reservoir improves in some manner the usefulness of the land for alternative purposes which leads to increases in the competitive bids for the land nearest the lake.

In a study by the Corps of Engineers [21] the authors used the comparison method as a way to factor out land value change caused by a navigation project. The authors compared land values at two sites (one with a port and one without a port). Over time, the port site location may be expected to receive additional impetus for land value changes from the increased navigational activities. The differences between the land values at the two sites is a measure of the net impact of the navigation project. The comparison approach was used to identify the characteristics and attributes which appear important in explaining differences in land values in the two areas. One limitation of this approach is establishing that changes in land values are caused entirely because of the navigation project rather than from factors unrelated to the project.

In summary, the findings of the land value studies suggest that the following factors may influence land use changes:

1) time and trend factors,

2) physical properties of the land,

3) economic and social characteristics of the immediate environment, and

4) locational and proximity factors.

Land Use Impact Studies

Some studies have concentrated on measuring the specific impact of a given stimuli on land use patterns. These studies are useful for providing alternative approaches for assessing the impact of a major economic investment on land use changes in the surrounding area.

Chapin and Weiss [3], in a study on urban development patterns, began with the assumption that certain "priming actions" such as a lake or highway may trigger other actions that eventually lead to the existing land use patterns. They employed multiple regression techniques to identify the factors most likely to influence land development patterns in a metropolitan area. They concluded that the important factors are marginal land not in urban use, accessibility to work areas, proximity factors and residential amenities.

They used the relative importance attached to each variable to compile probabilistic information in a land development forecast model. The model is designed such that at each stage of land development, a new stimulus may be added to generate additional land use changes in the next period. The authors do not set apart the net land use change associated with a single stimulus, but instead they try to predict the land use trends which should follow from the accumulation of various stimuli in the area.

B. R. Prebble [16] attempted to measure the impact of a reservoir on spatial land use patterns to assess the specific impact of a reservoir. Prebble selected study sites that are relatively isolated from major urban areas or transportation facilities. By doing this, he was able to reduce the possibility that factors other than the reservoir influenced spatial land use patterns in the reservoir area. He used multiple regression analysis to test his hypothesis that spatial land use patterns in the reservoir area are related to proximity to the lake, good access roads, and aesthetic attributes of the reservoir. Prebble's study found that each of these factors influenced the rate and pattern of land use changes in the immediate area of the reservoir.

A study by L. Vandeveer [22] took a completely different approach and used a stationary, finite Markov chain procedure to estimate differential land use change due solely to the reservoir project. Vandeveer developed a differential land use impact model which compares (1) actual land use patterns after the reservoir is built with (2) projected land use patterns. The projected land use patterns are based on land use trends before the reservoir is built. The difference between the two is an estimate of the net land use impact of the reservoir project. Long run land use impacts may be predicted using a similar procedure. Land use patterns are projected to some future period based on land use trends prior to reservoir construction. Similar projections are based on land use trends after the reservoir is constructed. The difference in the projected land use estimates gives the projected net land use impact of the reservoir project.

The results of the study indicate substantial nonagricultural land use increases associated with the Keystone Reservoir project. The immediate differential land use impact of the reservoir was primarily due to infrastructure or facilative development in the reservoir area. In the long run the infrastructure related land use impact declined but the residential land impact increased quite rapidly.

Method of Analysis

The objective of this section of the study is to discuss a method of analysis for measuring, explaining and predicting the land use impact of a WRDP. The review of literature indicates that several approaches have been taken to estimate the net land use impact of a reservoir project. The major approaches taken include multiple regression analysis, comparative analysis and Markov chain procedures. The discussion which follows will concentrate on the Markov chain procedures and multiple regression analysis since they hold the most promise of accurate measurement of the land use change caused by a WRDP.

The Markov chain procedure is appropriate for measuring the net land use change of a water resource development project. This procedure also may be used to predict the land use patterns for the study area based on land use trends before and after the reservoir is built. The difference between the two projections gives the net land use impact of the reservoir project.

Generally, the major strength of the Markov chain procedure is its ability to predict land use patterns in an internally consistent manner. In the context of land use, the procedure forces the number of acres observed in one period to be equal to the acres projected in the future. One of the major limitations of the Markov chain procedure is that the rate of land use change is assumed constant throughout the projection period. Another limitation is that it does not provide a causation framework. The rate of change in factors which may cause land use change, are implicitly assumed to be constant.

An evaluation of the land use impact of WRDP using a Markov chain process is dependent upon unique levels of key variables such as population, economic activity, and rate of land use change during the base period of the projections. If the values of the key variables change from the base period then these changes should be explicitly incorporated into the model.

The coefficients of key variables or factors hypothesized to influence land use patterns may be estimated with the use of multiple regression analysis. The results of a model which uses multiple regression analysis may be used to determine the relationship between variation in the number of acres in a given land use and variation in the hypothesized factors, ceteris paribus.

Multiple regression procedures are more appropriate for explaining land use change than for projecting land use changes caused by the reservoir project. First, with this procedure there is difficulty maintaining estimates of total acreage for the study area that is consistent with the observed total acreage. Secondly, it is difficult to account for land use change caused by all the factors unrelated to the project so that only net land use change is estimated. Consequently the land use impact attributable to a reservoir project based on the mutliple regression procedures may be grossly inaccurate.

Ideally, the evaluation of the land use impact of a WRDP requires a model with two important properties: (1) the ability to explain the land use change; and, (2) the ability to estimate actual and long run land use changes due to the reservoir project. Conceptually such a model should simultaneously estimate the impact of the dynamic forces that lead to land use adjustment and estimate current and future land use patterns resulting from the reservoir project. In such a model, the projected land use patterns would reflect changes in exogenous variables and therefore improve the estimates of land use change beyond those available from a Markov process analysis.

Neither multiple regression analyses nor stationary Markov chain procedures embody both the properties of the ideal model which are needed to evaluate land use impact of a WRDP. However, both properties of the ideal model would be satisfied with a non-stationary Markov chain model. Within a nonstationary Markov chain model the transition probabilities on which the projections are based vary for each projection period based on changes in exogenous variables. The actual implementation of a dynamic or nonstationary Markov chain model is hampered by: (1) the lack of knowledge of the relationship between economic, social, and other exogeneous variables, and land use change and (2) the problems of maintaining the structural balance needed within a system of transition probabilities. The approach of this study is to use each procedure independently as an approximation to and predecessor of a more comprehensive model. Multiple regression procedures will be used to explain the net land use change resulting from a water resource development project, and a stationary Markov process model will be used to project future land use impacts.

CHAPTER III

OBSERVED LAND USE PATTERNS AND IDENTIFICATION OF FACTORS INFLUENCING LAND USE CHANGE IN THE PINE CREEK RESERVOIR AREA

In this chapter, a conceptual land use change model is developed to determine the importance of several variables which may influence land use change in the Pine Creek Reservoir area. The conceptual land use change model is then estimated with the use of multiple regression analysis. The regression results for the land use change models are also presented. First, the observed land use patterns in the Pine Creek Reservoir area both before and after the reservoir was built are discussed to indicate what land use changes occurred.

Observed Land Use Patterns in the Pine Creek Reservoir Area

Land use patterns in reservoir area are expected to change following construction of a reservoir project. The trend in land use after the reservoir was constructed is one measure of the total impact of the reservoir. The on-site construction began in 1963, however the construction of the dam did not begin until June, 1969 and was completed at the end of the year. After 1969, changes in the land use patterns may be assumed to be partially dependent on the presence of the reservoir project. The land use patterns before and after the reservoir was built are presented in Table I.

Prior to reservoir construction, the predominant land use was forests which represented 73 percent and 77 percent of the total land area in 1955 and 1963 respectively. Pasture land use was the second largest land use in the Pine Creek area, and represented 20 percent and 18 percent of the total land area in 1955 and 1963 respectively. Cultivated land use decreased from 1,432 acres in 1955 to 460 acres in 1965, representing a 68 percent decline. Residential land use fluctuated very noticeably between 1955 and 1965 although the percentage share is still very small each year. All other land use remained fairly stable both before and after the reservoir was constructed.

After 1970, the predominant land use shifted to pasture. In 1970, pasture land use represented 73 percent while forests represented only 20 percent of the land area. This shift may reflect the necessary clearing of forest land which was required for reservoir construction and preparing the land for use as a wildlife sanctuary. Cultivated land use increased after the reservoir was built. Increases in cultivated land use may account for the increased availability of cultivated land which typically experienced flood damage before the construction of the reservoir.

The changes in the average land use per observation from 1955 to 1974 is illustrated graphically in Figure 1. Examination of the average acres in land use per observation characterizes the general impact of the Pine Creek Reservoir project. Pasture and forest changed dramatically between 1963 and 1970, the reservoir construction period. Overall, the residential and all other land uses

TABLE I

ACRES IN EACH LAND USE AND ACRES AS A PERCENTAGE OF TOTAL LAND AREA, PINE CREEK, OKLAHOMA, 1955-1974

	1955		1963		1965		1970		1974	
Land Use	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
Cultivated	1,432	3.97	808	2.23	460	1.28	1,117	3.41	866	2.65
Pasture	7,353	20.36	6,633	18.30	7,498	20.85	23,767	72.61	20,023	61.28
Forest	26,025	72.08	27,748	76.56	26,565	73.86	6,659	20.34	10,534	32.24
Residential	248	.69	110	.30	277	.77	100	.31	145	.44
All Other	1,050	2.91	943	2.60	1,168	3.25	1,088	3.32	1,105	3.38
Subtotal	36,108	100.00	36,242	100.00	35,968	100.01	32,731	100.00	32,673	100.00
Lake and Streams	602		468		742		3,980		4,037	
Total[a]	36,710		36,710		36,710		36,710		36,710	

[a] Columns may not add to column totals due to rounding errors.

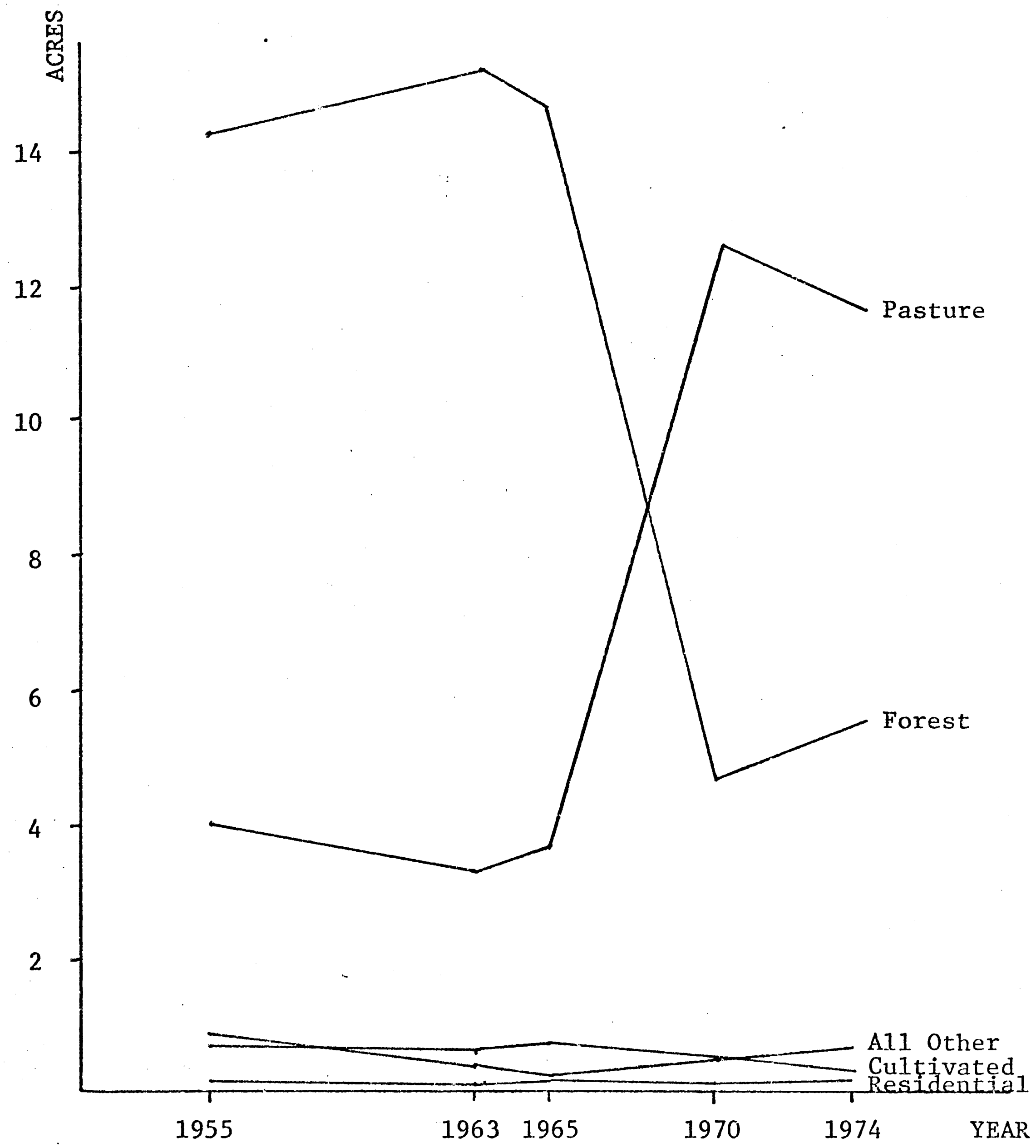

Figure 1. Average Acres per Land Use Observation, 1955-1974

remained fairly stable, showing a slight decrease after reservoir construction.

Conceptual Model: Land Use Change

One major impact of a reservoir project is to initiate land use change in the surrounding area. In other words, the amount of land in a given use before the project is constructed deviates from the amount of land in that use after the reservoir is constructed. The impact of the project on all alternative land uses is not expected to be the same. Previous studies have found that residential and commercial land uses are affected positively and far more substantially than other land use categories. The land use change which actually occurs can easily be measured by examining the number of acres in a given use before and after the reservoir is completed. However, why land use changes is not easily discernible.

As shown earlier, factors which influence land use may be summarized as:

1) time and trend factors;

2) physical properties of the land;

3) locational and proximity factors; and,

4) economic and social characteristics of the immediate environment.

Conceptual Model

A land use model may be developed for the purpose of identifying and analyzing the effect of several factors hypothesized to influence the land use change which occurs in the Pine Creek Reservoir area.

Several variables may be used as measures for these factors and represent the effect of these factors on land use change in the study area.

For this study a model to determine the association between these factors and land use change in the Pine Creek area may be expressed as:

$$\text{LANDUSE} = f(\text{FLDPOOL}, \text{DISTLAKE}, \text{DISTROAD}, \text{DISTTOWN}, \text{YR}, \text{POP}, \text{EMPLOY}, \text{WAGE}) \quad (1)$$

A brief description of the variables may be found in Table II.

The discussion which follows describes the variables selected to explain land use change, the hypotheses which indicate how each variable may influence land use change and how each variable is measured for use in empirical land use change models for the Pine Creek area.

Description of the Explanatory Variables

Time Factors. Land use, as well as many of the factors which influence land use, will change over time. In particular, the single exogenous event of the Pine Creek Reservoir Project may disrupt the land use trend in the Pine Creek area, at least in the short run. It is important to observe land use over a sufficiently long period of time so that the land use trend can be identified and so that trend factors can be separated from changes associated with the reservoir project. YR63, YR65, YR70 are included in the empirical land use models as dummy variables to account for each year of observations: 1963, 1965, 1970 and 1974. The 1974 dummy variable is

TABLE II

LIST OF VARIABLES IN LAND USE CHANGE MODEL

Variable	Description
LANDUSE	The number of acres in the land use category.
FLDPOOL	Location within the flood pool area versus within the nonflood pool area.
DISTLAKE	The shortest distance between the observation and the lake water.
DISTTOWN	The shortest distance between the observation and any one of the five towns in the study area.
DISTROAD	The shortest distance between the observation and the road which provides direct access to the lake.
POP	Average population for the study area.
EMPLOY	Average annual employment for the study area.
WAGE	Average annual wage for the study area.
YR55	Deviation of the average acres in the land use in 1955 from the average acres in that use in 1974.
YR63	Deviation of the average acres in the land use in 1963 from the average acres in that use in 1974.
YR70	Deviation of the average acres in the land in 1970 from the average acres in that use in 1974.

included in the intercept term in the estimating equations. The coefficient for each time variable acts as an intercept shifter and represents the deviation in land use from the average acres in that land use in 1974.

Physical Properties of the Land. One way to identify the physical properties of land which may influence land use is to select those unique properties which stand out excessively as an attribute or disadvantage for alternative land uses. One important variable which differentiates the physical properties of land in the Pine Creek area is location within the flood control pool area. Location in the flood pool (FLDPOOL) is a critical physical factor in this study because of the restriction on alternative land uses if the land is in the flood pool area.

For the Pine Creek Reservoir, the flood pool area is owned and administered by the U.S. Army Corps of Engineers and Oklahoma Department of Wildlife Conservation. The flood pool area represents approximately 44 percent of the study area. Because the land use in the flood pool area is determined within an institutional framework instead of a free-market framework, the land use alternatives are limited to those permitted by the Army Corps of Engineers and Oklahoma Department of Wildlife Conservation. According to other studies, the major land use impact is expected in the immediate peripheral area of the project (16). This area corresponds closely to the area covered by the flood pool. To account for the effect of land being in the flood pool a dummy variable, FLDPOOL, is included in the land use model.

Other unique properties are the presence of the lake, towns and roads. These properties are unique because they are limited to a few select locations in the study area.

Locational and Proximity Factors. The physical properties such as the presence of the lake, towns or roads gain importance only if they are available to potential users. The availability to potential users can be measured as the distance travelled to reach the lake, a town or a road.

Distance travelled to the lake (DISTLAKE) is included in the land use model and shows the accessibility of the amenities of the lake such as recreation, electric power, water supply, etc. Closer and closer to the lake, the more land is expected to be in those uses complementary to the purposes of the project. The land use changes which occur after the Pine Creek Reservoir was constructed are expected to be concentrated near the lake.

DISTLAKE is measured in units of .17677 mile. The unit measurement is equivalent to the side of a square which is 20 acres. This variable is computed by counting the number of observations which must be passed in order to reach an observation which includes lake water. For each observation, the distance to the lake was measured along two perpendicular lines drawn through the observation being considered. This gives four possible directions to travel in order to reach the lake. The shortest distance is the value for DISTLAKE. A positive sign on the coefficient indicates that the further one moves away from the lake, the greater the land found in that use. A negative relationship is expected for DISTLAKE and residential and all other use categories; and, a positive relationship is expected for pasture, forest and cultivated.

Distance travelled to a road (DISTROAD) is included in the land use model to indicate the general accessibility of the lake as well as other activities in the vicinity. Infrastructure development, such as roads, enhance the land for purposes such as residential, commercial and recreational.

DISTROAD is computed in a manner similar to DISTLAKE. Roads which provide direct access to the lake are designated as road observations. DISTROAD is computed for those roads only. Land in residential, cultivated and all other uses are expected to have negative coefficients for DISTROAD. Positive relationships are expected for DISTROAD and pasture and forest land uses.

Distance travelled to a town (DISTTOWN) is included in the land use model to determine if the relative availability of goods and services provided in a town encourage more extensive utilization for some land uses in the study area. Particularly, land uses which most directly benefit from the availability of goods, services and market centers, such as residential, all other and cultivated are expected to increase closer and closer to the town.

DISTTOWN is measured as a "crow flies" for five towns in the study area: Rufe, Slim, Plainview, Moundgrove and Ringold. (A map of these towns is provided in Appendix D.) The presence of a town is not considered significant beyond two miles.

DISTTOWN is computed as the shortest possible distance between two points. The location of the individual observation within the two mile boundary is the starting point, and the central point of the nearest town is the point of destination. The reciprocal value of DISTTOWN is used in the land use model to minimize the discontinuity between the observation on the two mile border of the town and the observation beyond the two mile border. A positive sign on the coefficient for DISTTOWN therefore, means that closer and closer to the town, the land use is also increasing. Residential, all other and cultivated land uses are expected to be positively associated with DISTTOWN while pasture and forest land uses are expected to correspond negatively with DISTTOWN.

Economic and Social Factors. Population, employment and wage averages are also included in the land use model because it is felt that these factors exert influence on the relative availability of land for alternative uses. These factors represent area wide or macro effects.

Population (POP) trends as exemplified in many urban centers may exert pressures which lead to substantial land use change. Generally, Oklahoma has experienced increasing population trends in the metropolitan areas and declining trends in rural or agricultural regions. Even so, the three rural counties in the study area have experienced increasing population trends since 1960 (14). The changes in population are expected to correspond positively with changes in residential and all other land uses, as more land resources are utilized to meet the demands of the growing population.

POP is measured in thousands of population for McCurtain, Pushmataha, and Choctaw counties. An average is taken to assign a population average for the Pine Creek study area.

The average annual employment (EMPLOY) is used as an indicator of the economic activity and economic well being in the study area.

EMPLOY is expected to correspond positively with changes in residential and all other land uses and negatively with changes in cultivated, pasture and forest land uses. EMPLOY is measured as the average annual employment which is averaged for the three counties to represent employment in the Pine Creek area.

The average annual wage (WAGE) is used as one indicator of economic activity and economic well-being in the study area. WAGE is expected to relate positively with residential and all other land use changes. A negative relationship is expected for cultivated pasture and forest land uses.

Empirical Results and Analysis of the Land Use Change Models

The relationship between the selected explanatory variables and land use change in the above model are estimated with the use of multiple regression analysis. The least squares procedures used to estimate the multiple regression equation allow the parameters for each explanatory variable to be estimated and the importance of each explanatory variable in explaining the variation in the dependent variable to be measured.

A linear relationship is assumed to exist between the dependent variable, land use and the independent or explanatory variables. The dependent variable is measured as the number of acres in the land use category specified in a specific location in the study area, ij.

Land use models are developed for five land use categories: cultivated, pasture, forest, residential and all other. Individual land use observations are measured according to the procedure outlined in Chapter I and are employed as the sample data for the estimated land use models. The sample data represent both time-series and cross-sectional land use data for the Pine Creek area.

Two regression equations are used to estimate the land use change model and can be expressed as:

$$\text{MODEL 1:}\quad \text{LANDUSE}_{ij} = b_0\text{YR74} + b_1\text{LANDUSE}_{ij(t-n)} + b_2\text{DISTLAKE}_{ij} + b_3\text{DISTROAD}_{ij} + b_4\text{DISTTOWN}_{ij} + b_5\text{YR63} + b_6\text{YR65} + b_7\text{YR70} + b_{11}\text{FLDPOOL}_{ij} \qquad (2)$$

$$\text{MODEL 2:}\quad \text{LANDUSE}_{ij} = b_0 + b_1\text{LANDUSE}_{ij(t-n)} + b_2\text{DISTLAKE}_{ij} + b_3\text{DISTROAD}_{ij} + b_4\text{DISTTOWN}_{ij} + b_8\text{POP}_t + b_9\text{EMPLOY}_t + b_{10}\text{WAGE}_t + b_{11}\text{FLDPOOL}_{ij}. \qquad (3)$$

The results of the estimation equations are presented in Table III. The estimated parameters and the computed t-values for each explanatory variable are given along with the R^2 value for each land use model.

Performance of Land Use Change Models

The R^2 value indicates the proportion of total variation in the amount of land in a particular land use which is explained by the variation in the explanatory variables. R^2 is very low for all land use models with the exception of forest land use. A low R^2 does not necessarily discount the importance of the individual explanatory

TABLE III

ESTIMATED PARAMETERS OF LAND USE MODELS FOR THE PINE CREEK AREA, OKLAHOMA

Explanatory Variables	Cultivated Land Use Model 1	Cultivated Land Use Model 2	Pasture Land Use Model 1	Pasture Land Use Model 2	Forest Land Use Model 1	Forest Land Use Model 2	Residential Land Use Model 1	Residential Land Use Model 2	All Other Land Use Model 1	All Other Land Use Model 2
$Y_{(t-n)}$	.07	.07	.35	.35	.55	.55	-.07	-.07	.01	.01
	(2.53)	(2.53)	(32.43)	(32.43)	(67.01)	(67.01)	(2.88)	(2.88)	(1.03)	(1.03)
$DISTLAKE_{ij}$	.03	.03	-.02	-.02	.01	.01	-.002	-.002	.002	.002
	(1.63)	(1.63)	(2.80)	(2.80)	(2.27)	(2.27)	(.40)	(.40)	(.71)	(.71)
$DISTROAD_{ij}$	-.08	-.08	.06	.06	-.003	-.003	-.03	-.03	-.06	-.06
	(1.69)	(1.69)	(3.30)	(3.30)	(.02)	(.02)	(2.20)	(2.20)	(9.06)	(9.06)
$DISTTOWN_{ij}$	.16	.16	1.10	1.10	-.89	-.89	.39	.39	.11	.11
	(.44)	(.44)	(7.45)	(7.45)	(8.05)	(8.05)	(3.84)	(3.84)	(1.75)	(1.75)
YR63	-1.10	-	-3.65	-	3.96	-	-.30	-	-.09	-
	(4.01)		(20.92)		(28.07)		(2.96)		(1.44)	
YR65	-.92	-	-2.14	-	2.83	-	.55	-	.05	-
	(2.61)		(11.00)		(18.24)		(5.13)		(.75)	
YR70	1.25	-	4.86	-	-7.76	-	.36	-	-.14	-
	(3.71)		(27.71)		(52.14)		(3.41)		(2.24)	
POP_t	-	.0004	-	.004	-	-.003	-	.003	-	.0004
		(.43)		(7.15)		(7.99)		(8.36)		(1.92)
$EMPLOY_t$	-	-.005	-	-.03	-	.03	-	-.009	-	-.001
		(1.77)		(11.72)		(18.51)		(7.65)		(1.60)
$WAGE_t$	-	.003	-	.01	-	-.02	-	.003	-	.0004
		(1.97)		(16.17)		(28.05)		(7.05)		(1.40)
$FLDPOOL_t$	-.82	-.82	-1.47	1.47	.18	.18	-.24	-.24	-.12	-.12
	(3.33)	(3.33)	(11.58)	(11.58)	(1.82)	(1.82)	(3.03)	(3.03)	(2.16)	(2.16)
INTERCEPT	3.45		7.24		3.61		1.04		1.74	
R^2 =	.056		.350		.658		.160		.026	
N =	1,427		7,996		9,550		859		3,762	

variables, but does suggest some error in specifying the model for explaining variation in the dependent variable (8). The variation in the explanatory variables explained 66 percent of the variation in forest land use while for the remaining land use categories the R^2 ranged from 3 percent to 35 percent.

Performance of the Explanatory Variables

Time Variables

The coefficient for each time dummy variable (YR63, YR65, YR70) can be interpreted as the deviation in expected value for the land use from the 1974 expected value. The expected value for each year may be derived by adding the coefficient for the dummy variable representing the year of observation to the intercept value in the land use model. For instance, the expected value for pasture in 1963 is equal to the intercept (3.45) plus the coefficient for the 1963 dummy variable (-1.10).

The two most important years of observation for the Pine Creek Reservoir Project are 1963, the time period prior to reservoir construction and 1970, the time period immediately after reservoir construction. The change in the expected value for land use from 1963 to 1974 is illustrated in Figure 2. The two major land use categories, pasture and forest, experience the most substantial land use change between 1963 and 1970. The other land uses show a similar trend, however the absolute change is not as dramatic.

$\text{LANDUSE}_{(t-n)}$ is included in the land use model to adjust for the effect of land that remains in a given use during a particular

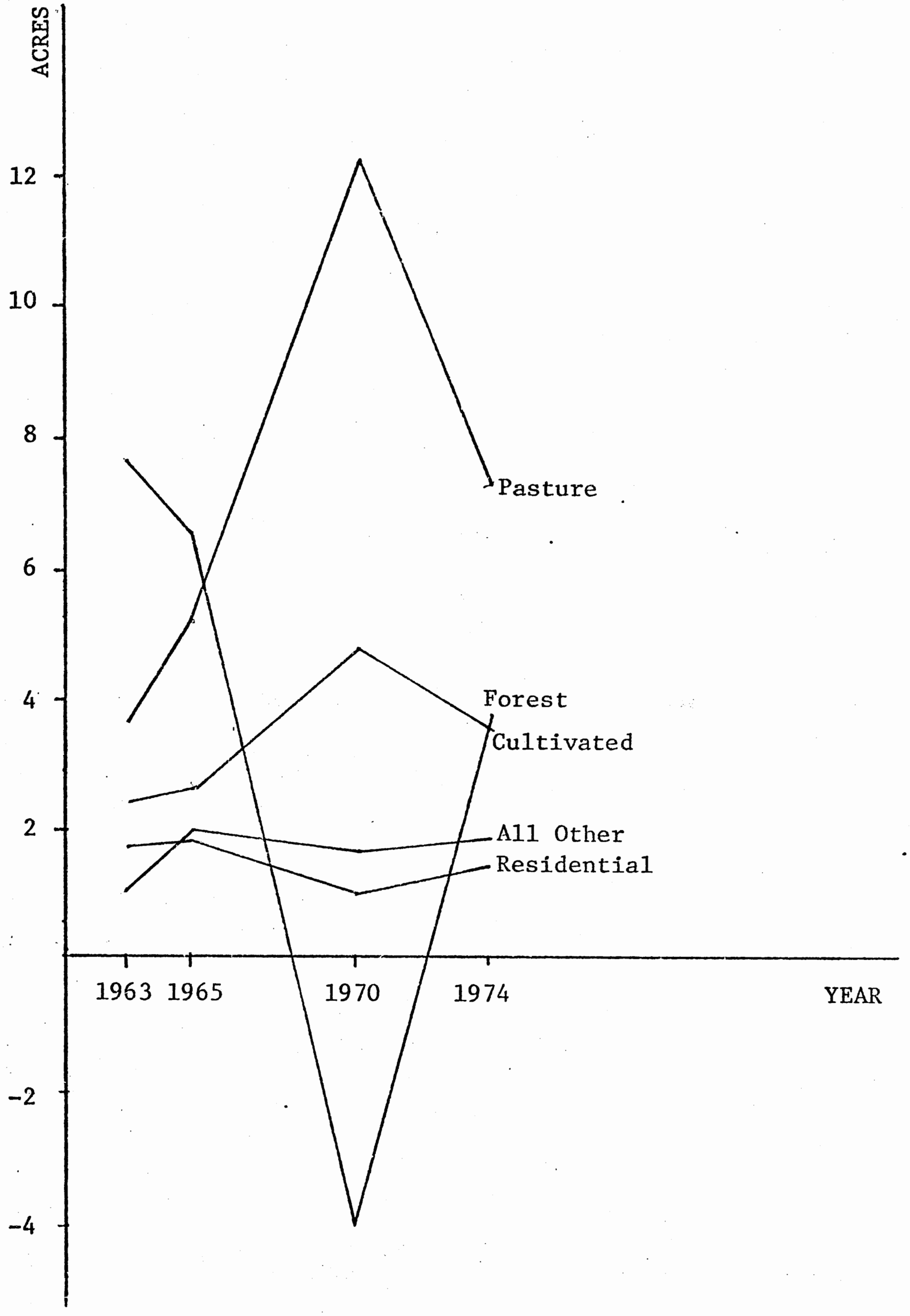

Figure 2. Expected Value of Each Land Use, 1963-1974

time period.[1] LANDUSE$_{(t-n)}$ is statistically significant in every land use model except for the all other land use model.

Distance Variables

The association between DISTLAKE and pasture and forest land uses are statistically significant. The amount of land in pasture use increases by .02 acre for every additional unit travelled closer to the lake. DISTLAKE has nearly the opposite effect in the forest land use model. The amount of forest land increases by .01 acre for every additional unit travelled further away from the lake. The findings of past research seem to indicate that residential development will occur near the lake, however, in the residential land use models, DISTLAKE is statistically insignificant. The results of the cultivated and all other land use models indicates that no relationship exists between DISTLAKE and the amount of land in the cultivated and all other classes.

The accessibility of different activities within the study area is expected to depend upon the relative proximity of roads. DISTROAD, which measures the accessibility of the activities, is significant in all land use models with the exception of forest. The only positive relation is found in the pasture land use model and implies that at distances further and further from a road, the amount of land

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[1] This variable may at first appear to be similar to a Nerlove lag variable. The conceptual model in this study is not the same as that in the Nerlove model. In addition the strong assumptions of the Nerlove model are not made.

in pasture increases, ceteris paribus. Cultivated, residential and all other land uses indicate a negative association with DISTROAD which is consistent with previous hypotheses.

The results for DISTTOWN indicate that pasture, residential and all other land uses are likely to be found closer to the town rather than at very far distances. The interpretation of DISTTOWN is different from the other distance variables because it is measured as a reciprocal value. The outlying distances have the smallest values and the closest distances have the highest values. Therefore, a positive sign indicates that as DISTTOWN increases (coming closer and closer to the town) the amount of land in that use also increases. A negative sign on the coefficient as given in the forest land use models indicates that as DISTTOWN decreases (going further and further away from the town), the land in forests increases. Cultivated land is expected to be associated with nearness to a town, however, the coefficients for DISTTOWN are statistically insignificant in the cultivated land use model.

Physical Properties of the Land

The coefficient for FLDPOOL indicates the effect of being located in the flood pool area. FLDPOOL is statistically significant in every land use model, especially pasture. Cultivated, pasture, residential and all others tend to be lower in the flood pool than outside, ceteris paribus. Forest is the only land use which is greater in the flood pool area.

The signs on the coefficients in the land use models for pasture and forest suggest that pasture land use increases at the expense of forest land use. The flood pool and distance variables help to locate the concentration of forest and pasture land use impacts in the study area. The distance variables indicate that forest land use increases closer and closer to the lake and further from the nearest town. Pasture land use increases at distances closer to the nearest town and closer to the lake.

Since pasture land use increases in the nonflood pool area and as the distance to the lake increases, most of the increase in pasture land use occurs in the nonflood pool area but very near the flood pool boundaries. On the other hand, forest land use increases in the flood pool and at distances closer and closer to the lake. This implies that forest land is most concentrated inside the flood pool area and therefore the decrease in forest land use occurs in the nonflood pool area.

In several land use models, the results for WAGE and EMPLOY are statistically significant but do not correspond with the expected relationship. The high degree of correlation between the WAGE and EMPLOY variables suggests that the inconsistent results may be the consequence of multicollinearity.

POP is included in the land use model to represent the population in the Pine Creek area. As expected, nonagricultural land use increases as POP increases. The results indicate the association between POP and residential land use is highly significant.

EMPLOY represents the economic activity and well-being in the Pine Creek area. As the number of persons employed increases, the nonagricultural land uses are also expected to increase, however, the all other land use category is not statistically significant at the 10 percent probability level. Residential land use is statistically significant but contradicts the hypothesized relationship. Again, the inconsistent results may be the consequence of multicollinearity. EMPLOY proved to be significant and consistent with previous expectations in the forest land use model. An increase in the average annual employment by 100 persons increases forest land use by three acres. The positive relation between EMPLOY and forest land use may be attributed to the importance of commercial forest in the Southeastern region of the state.

WAGE earnings are included to represent the same factors as EMPLOY and are expected to have a similar effect on land use change in the Pine Creek area. As the wage earnings increase, residential, pasture and the all other land uses increase and cultivated land use decreases. The relationship between WAGE and residential and all other uses is consistent with previous expectations.

CHAPTER IV

MARKOV CHAIN PROCEDURES AND RESULTS OF THE DIFFERENTIAL LAND USE CHANGE MODEL

One objective of this study is to measure the net land use change resulting from the Pine Creek Reservoir project. This chapter includes a summary of the theoretical concepts of Markov chain procedures and the differential land use change model which may be used to measure the land use impact resulting from the reservoir project. The actual and projected differential land use change estimates derived from the model are presented and analyzed.

Theoretical Concepts of the Markov Chain Procedure

The basic concepts of the Markov chain process were first introduced in 1907 by A. A. Markov. Markov chain analysis is only applicable to processes which are assumed to have stochastic behavior. In recent years, economists have adapted the Markov chain procedures to reveal how economic processes changed through time and what paths they are likely to take in the future (10). In one of the most recent studies a finite, stationary Markov chain model was constructed which estimates and projects the land use change resulting from a reservoir project (22). The procedures used in that study are used to estimate the differential land use change resulting from the Pine Creek Reservoir project.

An essential assumption for a Markov chain process is that the possible outcomes can be classified as a number of mutually exclusive states or groups. Secondly, the movement between states must be regarded as a stochastic process. The finite Markov chain process, a special case of the Markov chain process requires that the possible outcomes from the stochastic process be finite. To develop a Markovian model requires a flow matrix which is then used to estimate a transition probability matrix.

In this study a finite Markov chain model is developed to measure the net land use change due to the project. Land use change is the stochastic process. The land use categories are defined as the states (S_1, S_2, ..., S_n). The movement between the alternative land use categories is summarized by a land use flow matrix. The land use flow matrix is used to depict the movement of land between the land use categories during a specified time period.

The next step is to develop the land use transition probability matrix. The probability of moving from one land use category to another land use category is computed as:

$$P_{ij} = \frac{S_{ij}}{\Sigma_i S_{ij}}$$

P_{ij} is the proportion of land starting in land use S_i in period t and shifting to land use S_j in the following period. The transition probability matrix, P, may be expressed as:

$$P = \begin{array}{cc} & \begin{array}{cccc} S_1 & S_2 & \cdots\cdots & S_n \end{array} \\ \begin{array}{c} S_1 \\ S_2 \\ \vdots \\ \\ S_n \end{array} & \begin{bmatrix} P_{11} & P_{12} & & P_{1n} \\ P_{21} & P_{22} & & P_{2n} \\ & & & \\ & & & \\ P_{n1} & P_{n2} & & P_{nn} \end{bmatrix} \end{array}$$

If the p_{ij} elements in each row are positive and sum to unity, the Markov chain process is considered to be regular. The implication of a regular Markov chain process in measuring land use change is that land will not be created or destroyed during the land use transition process.

By assuming the probabilities in the transition probability matrix are constant over time, the Markov chain process is stationary. When measuring land use change, this means the factors influencing land use change are also assumed constant over time.

With a regular and stationary Markov chain process land use patterns can be estimated on the basis of past trends for future periods up to infinity. If Q_0 denotes a vector of the initial land use and P is the transition probability matrix, then land use patterns may be projected for the next period Q_1 as follows:

$$Q_1 = Q_0 P$$

or

$$Q_1 = Q_0 P^1$$

and

$$Q_2 = Q_1 P = (Q_0 P) P = Q_0 P^2.$$

Thus,

$$Q_n = Q_0 P^n.$$

If the Markov chain process is regular then as the transition probability matrix P is raised to successively higher powers P will eventually reach an equilibrium state in which each row converges to a unique row vector which represents a stable organization of land uses. The net movement from one land use to another will be offset by another. The equilibrium transition matrix and the initial land use vector may be used to compute long-run projections.

Actual Differential Land Use Change Model

Vandeveer (22) constructed a differential land use model (referred to as DLUM) to estimate the net impact of the Keystone Reservoir on land use change. The DLUM is more appropriate than the usual before and after approach since the Markovian framework permits land use patterns to be projected as if the reservoir had not been built. This predicted land use pattern is then compared with the actual observed land use pattern in the time period (a) to give the actual differential land use change.

In order to estimate the predicted land use pattern assume that Q_a is a vector indicating the initial land use in the study area, Q_b is the land use at the end of the time period, and ${}_{ab}P$ is the transition probability matrix over the same period. Then, according to Markov chain procedures:

$$Q_b = Q_a[{}_bP]. \tag{1}$$

This concept can be generalized to predict land use patterns in a future period n (where $n \geq b$, $n = 0$ in a). The general form is:

$$_{ab}Q_n = Q_a\ [_{ab}P]^n \tag{2}$$

where $_{ab}Q_n$ is an estimated land use vector in time period n which is based on a transition probability matrix constructed over time period a,b. If time period a,b represents the pre-investment time period for the Pine Creek Reservoir, $_{ab}Q_n$ is equivalent to predicting land use patterns assuming the dam has not been built. Given the actual land use pattern (Q_n), then the net impact can be estimated by comparing Q_n with $_{ab}Q_n$.

If the reservoir had a net impact on land use change in the study area, the actual or observed land use pattern should differ from the projected land use change (had the reservoir not been built). Accordingly, the actual differential land use change (D_n) can be computed as:

$$D_n = Q_n - {}_{ab}Q_n = Q_n - Q_a\ [_{ab}P]^n. \tag{3}$$

Projected Differential Land Use Change Model

By comparing projected land use estimates for time period n based on the land use trends before the reservoir had been built and land use trends after the reservoir had been built, the projected differential land use impact may be estimated. If the reservoir project influences the land use change in the area, then the transition probability matrix for the period following reservoir construction will be different from the transition probability matrix before reservoir construction. Let c denote the beginning of the time period immediately after the reservoir is built and let d denote the end of that time period. Then Q_c represents the initial land use vector following reservoir construction and Q_d represents the land use vector at the end of the time period. The projected land use estimates for time period n (where $n \geq d$) based on land use trends before the reservoir had been constructed can be expressed as:

$$ {}_{cd}Q_n = Q_c \; [{}_{cd}P]^{n-c}. \tag{4} $$

The projected differential land use impact (D_n') is the difference between projected land use patterns based on pre-investment land use flows and projected land use patterns based on post-investment land use flows.

$$ D_n' = {}_{cd}Q_n - {}_{ab}Q_n. \tag{5} $$

Empirical Land Use Change Results

Differential land use impact models were developed for the Pine Creek Reservoir area. The land use flow matrices for the nonflood pool area during the pre- and post-investment periods are found in Tables IV and V. Land use flow matrices for the flood pool area during the pre- and post-investment periods are provided in Tables VI and VII.

The land use flow matrix indicates the number of acres shifting to one land use category from another land use category. The off-diagonal elements indicate the flow of land from use i at the beginning

TABLE IV

PRE-INVESTMENT LAND USE FLOW MATRIX IN THE NONFLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use in 1955	Land Use in 1963					
	Cultivated	Pasture	Forest	Residential	All Other	Total
			- acres -			
Cultivated	247.1	270.3	198.9	1.7	21.1	739.1
Pasture	154.2	2,546.2	879.7	8.4	91.1	3,679.6
Forest	30.9	308.9	11,709.5	7.5	118.1	12,174.9
Residential	3.8	21.9	45.5	43.5	16.0	130.7
All Other	21.9	41.6	186.9	9.9	229.5	489.8
Total	457.9	3,188.9	13,020.5	71.0	475.8	17,214.1

TABLE V

POST-INVESTMENT LAND USE FLOW MATRIX IN THE NONFLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use in 1970	Land Use in 1974					
	Cultivated	Pasture	Forest	Residential	All Other	Total
			- acres -			
Cultivated	216.2	187.9	126.8	8.3	20.8	560.0
Pasture	471.3	9,608.5	2,260.4	36.4	223.4	12,600.0
Forest	38.5	735.1	2,533.9	14.3	64.3	3,386.1
Residential	.5	5.1	17.7	46.3	16.9	86.1
All Other	11.4	109.9	114.0	22.2	323.8	581.3
Total	737.5	10,646.5	5,052.8	127.5	649.2	17,213.5

TABLE VI

PRE-INVESTMENT LAND USE FLOW MATRIX IN THE FLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use in 1955	Land Use in 1963					
	Cultivated	Pasture	Forest	Residential	All Other	Total
			- acres -			
Cultivated	161.8	186.4	159.6	2.3	18.4	528.5
Pasture	77.4	1,981.3	669.6	6.0	51.7	2,785.9
Forest	16.9	272.8	9,365.7	7.0	81.7	9,744.1
Residential	4.5	20.0	40.0	15.5	7.6	87.6
All Other	6.2	58.3	155.1	1.2	194.7	415.5
Total	266.8	2,518.7	10,390.1	32.1	354.0	13,561.6

TABLE VII

POST-INVESTMENT LAND USE FLOW MATRIX IN THE FLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use in 1970	Land Use in 1974					
	Cultivated	Pasture	Forest	Residential	All Other	Total
			- acres -			
Cultivated	46.0	327.5	123.9	1.8	15.4	514.6
Pasture	68.5	7,170.6	2,342.9	7.2	125.8	9,715.1
Forest	6.9	642.3	2,195.4	1.2	46.3	2,892.1
Residential	.6	4.8	.7	6.7	1.1	13.9
All Other	3.5	98.7	107.1	1.4	215.3	426.0
Total	125.5	8,243.9	4,770.0	18.3	403.9	13,561.7

of the time period to use j at the end of the time period. The diagonal elements indicate the number of acres remaining in the same land use category throughout the time period. The sum of each row is the number of acres in that use at the beginning of the time period. The sum of each column indicates the actual number of acres in that use at the end of the time period.

The land use flow matrices were estimated using the sample observations which give the land use pattern at the beginning and end of the time period and a set of assumptions regarding land use flows among alternative uses during two points in time. Only sample observations with land use observations for both years were included. Sample observations which were eventually inundated are excluded from the flow matrices. The algorithm used to estimate land use flows in the flood pool and nonflood pool areas is discussed in Appendix C.

Results of Differential Land Use Change Models for the Pine Creek Nonflood Pool Area

Observed Land Use Patterns. Land use patterns observed in the nonflood pool area are summarized in Table VIII. During the pre-investment period land is concentrated mostly in forest land use. From 1963 to 1970 the major land use shifts from forest to pasture. Residential land use declines during the pre-investment period, but increases in 1970 and 1974. This increase is contrary to the residential land use trend in the flood pool area. In the nonfloood pool area there are no institutional restraints on residential land

TABLE VIII

OBSERVED LAND USE PATTERNS IN THE NONFLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA, 1955-1974

Land Use	Actual Land Use			
	1955	1963	1970	1974
Cultivated	739	458	560	737
Pasture	3,679	3,189	12,600	10,646
Forest	12,175	13,020	3,386	5,053
Residential	131	71	86	127
All Other	490	476	581	649
Total[a]	17,214	17,214	17,213	17,212

[a] Totals may differ due to rounding errors.

use. Any increases in residential land use are considered a result of market-determined factors stimulated by the presence of the lake.

Actual Differential Land Use Change. The actual differential land use change is the difference between actual land uses and projected land uses had the reservoir not been built. Projected land use patterns for 1970 and 1974 based on preinvestment land use trends and observed land uses are presented in Table IX.

Differential increases are found in all land uses as a result of the reservoir project with the exception of the offsetting decrease in forest land uses. The most substantial and most immediate impact of the project is in forest and pasture land uses. The differential land use changes for residential, all other and cultivated are larger in 1974 than in the period immediately following completion of the reservoir project.

Projected Differential Land Use Change. Projected differential land use change estimates are derived for 1977, 1985, 2000, and time period infinity and are provided in Tables X and XI. The differential land use change estimates project a net decline in forest land use from 1977 through time period infinity. The remaining land use categories show a net increase due to the reservoir project. The land use impacts in the long run are very similar to the land use impacts immediately following reservoir construction. The land use impact continues to increase for residential, all other and cultivated land uses while the impact on forest and pasture steadily declines.

TABLE IX

ACTUAL PROJECTED AND ACTUAL DIFFERENTIAL LAND USE IN THE NONFLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use Category	Actual Land Use (Q_n)		Projected Land Use Based on 1955-1963 Transition Probability Matrix ($_{ab}Q_n$)		Actual Differential Land Use (D_n)	
	1970	1974	1970	1974	1970	1974
Cultivated	560.0	737.4	355.6	320.5	204.3	416.9
Pasture	12,600.0	10,646.5	2,807.3	2,627.2	9,792.8	8,019.2
Forest	3,386.0	5,052.8	13,539.0	13,770.7	-10,153.1	-8,717.9
Residential	86.1	127.5	51.8	46.1	34.31	81.4
All Other	581.4	649.5	453.0	441.2	128.3	208.1
Total[a]	17,213.5	17,213.5	17,206.7	17,205.7		

[a] Totals may differ due to rounding errors.

TABLE X

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE IMPACT IN THE NONFLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA, 1977, 1985

Land Use Category	Projected Land Use Based on 1955-1963 Transition Probability Matrix (${}_{ab}Q_n$)		Projected Land Use Based on 1970-1974 Transition Probability Matrix (${}_{cd}Q_n$)		Projected Differential Land Use (D_n)	
	1977	1985	1977	1985	1977	1985
Cultivated	299.5	261.0	749.2	714.3	449.7	453.3
Pasture	2,503.9	2,240.2	9.846.4	8,772.2	7,342.6	6,531.9
Forest	13,928.5	14,257.3	5,756.1	6,792.0	-8,172.4	-7,465.3
Residential	43.0	38.0	148.6	183.8	105.7	145.9
All Other	419.2	413.7	686.5	748.5	267.3	334.7
Total[a]	17,194.0	17,210.2	17,186.8	17,210.8		

[a] Totals differ due to rounding and extrapolation errors.

TABLE XI

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE IN THE NONFLOOD POOL AREA IN PINE CREEK LAKE, OKLAHOMA, 2000, INFINITY

Land Use Category	Projected Land Use Based on 1955-1963 Transition Probability Matrix ($_{ab}Q_n$)		Projected Land Use Based on 1970-1974 Transition Probability Matrix ($_{cd}Q_n$)		Projected Differential Land Use (D_n)	
	2000	Infinity	2000	Infinity	2000	Infinity
Cultivated	222.5	182.3	671.8	664.2	449.3	481.9
Pasture	192.8	1,574.5	8,335.2	8,274.7	6,407.3	6,700.2
Forest	14,636.9	15,060.8	7,221.4	7,279.5	-7,415.5	-7.781.3
Residential	34.1	30.9	201.8	205.0	167.6	174.1
All Other	390.9	365.2	783.1	790.0	392.2	424.8
Total[a]	17,213.4	17,213.7	17,213.3	17,213.4		

[a] Totals differ due to rounding and extrapolation errors.

Results of Differential Land Use Change Models for the Pine Creek Flood Pool Area

Observed Land Use Patterns. The observed land use patterns in the flood pool area are presented in Table XII. Land in the flood pool area constitutes 44 percent of the land in the Pine Creek study area.

Before reservoir construction, the predominant land use was forest. After construction, however, the major land use was pasture. Residential land use increased steadily from 1963 to 1970. After 1970 residential land use declined substantially. The principal reason for this decline is land in the flood pool area is under the control of the Army Corps of Engineers and the Oklahoma Department of Wildlife Conservation instead of private ownership. As a consequence, private and residential development is prohibited. Generally, the all other land use acreage remained fairly stable throughout the entire study period.

Actual Differential Land Use Change. Estimates of the actual differential land use change in the flood pool area are presented in Table XIII. The results for 1970 show that the reservoir project stimulated additional use of cultivated, pasture and all other land uses in the project area. Forest and residential uses were not positively affected by the reservoir project. Comparison of actual and projected land uses for the flood pool area in 1974 indicates the reservoir project initiated net increases only in pasture and all other land uses. Land in cultivated use declined along with forest and residential land uses. The impact of the reservoir declined considerably after 1970, especially for cultivated land use.

TABLE XII

ACTUAL LAND USE PATTERN IN THE FLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA, 1955-1974

Land Use	Actual (Observed) Land Use Pattern			
	1955	1963	1970	1974
Cultivated	528	267	515	126
Pasture	2,786	2,519	9,715	8,244
Forest	9,744	10,390	2,892	4,770
Residential	88	32	13	18
All Other	415	354	425	404
Total[a]	13,561	13,562	13,560	13,562

[a] Totals differ due to rounding errors.

TABLE XIII

ACTUAL PROJECTED AND ACTUAL DIFFERENTIAL LAND USE IN THE FLOOD POOL, PINE CREEK LAKE, OKLAHOMA

Land Use Category	Actual Land Use (Q_n)		Projected Land Use Based on 1955-1963 Transition Probability Matrix ($_{ab}Q_n$)		Actual Differential Land Use (D_n)	
	1970	1974	1970	1974	1970	1974
Cultivated	514.6	125.5	185.9	162.1	328.7	-36.6
Pasture	9,715.1	8,243.9	2,267.0	2,143.4	7,448.1	6,100.5
Forest	2,892.2	4,770.0	10,764.8	10,929.4	-7,872.6	-6,159.4
Residential	14.0	18.4	22.0	19.7	-8.0	-1.3
All Other	426.0	404.0	316.8	301.9	109.2	102.1
Total[a]	13,561.7	13,561.8	13,556.5	13,556.5		

[a] Totals differ due to rounding errors.

Projected Differential Land Use Change. Projected differential land use change estimates presented in Tables XIV and XV reveal the trend of net declines in cultivated, forest and residential and net increases in pasture and all other land uses through 1977. However, from 1985 to infinity, residential land use shows small net increases. The long-run land use impacts in the flood pool are considerably less than in the nonflood pool area.

Comparison of Land Use Change Estimates in the Flood Pool and Nonflood Pool Areas

Comparison of the differential land use change in the flood pool and nonflood pool areas, generally indicates the largest absolute land use impact is in the nonflood pool area. Forest and pasture land uses are affected much the same way in both areas. Cultivated land use change is positive and large in the nonflood pool area while in the flood pool area cultivated land use impact is negative and very small.

The differential land use estimates for nonagricultural land use in the flood pool and nonflood pool areas may also be compared to highlight the differences in the impact of the reservoir in the two areas. The marked differences in trends inside and outside the flood pool area can be seen in Figure 3. For example, in 1977, the differential impact on nonagricultural land uses in the flood pool area is 100 acres, while in the nonflood pool areas the differential impact is more than 373 acres.

A graphical view of the differential impact for residential land use only, inside and outside the flood pool is presented in

TABLE XIV

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE IN THE FLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA

Land Use Category	Projected Land Use Based on 1955-1963 Transition Probability Matrix ($_{ab}Q_n$)		Projected Land Use Based on 1970-1974 Transition Probability Matrix ($_{cd}Q_n$)		Projected Differential Land Use (D_n)	
	1977	1985	1977	1985	1977	1985
Cultivated	148.8	127.3	93.5	75.0	-55.2	-52.3
Pasture	2,057.3	1,870.4	4,543.8	6,638.7	5,486.6	4,768.3
Forest	11,040.5	11,270.1	5,481.6	6,439.2	-5,558.9	-4,830.9
Residential	18.64	17.2	18.62	18.2	-.02	.96
All Other	292.4	274.6	395.4	389.0	103.0	114.4
Total[a]	13,557.6	13,559.6	13,533.0	13,560.1		

[a] Total acres are not equal due to rounding and extrapolation errors.

TABLE XV

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE IN THE FLOOD POOL AREA, PINE CREEK LAKE, OKLAHOMA, 2000, INFINITY

Land Use Category	Projected Land Use Based on 1955-1963 Transition Probability Matrix ($_{ab}Q_n$)		Projected Land Use Based on 1970-1974 Transition Probability Matrix ($_{cd}Q_n$)		Projected Differential Land Use (D_n)	
	2000	Infinity	2000	Infinity	2000	Infinity
Cultivated	108.9	91.5	71.3	70.3	-37.6	-20.5
Pasture	1,645.6	1,388.0	6,326.0	6,296.0	4,680.4	4,908.0
Forest	11,532.4	11,823.4	6,756.0	6,785.7	-4,776.4	-5,037.7
Residential	16.2	15.4	17.5	17.4	1.3	2.1
All Other	257.8	243.5	390.9	391.7	133.1	148.2
Total[a]	13,560.9	13,561.8	13,561.7	13,561.1		

[a] Total acres are not equal due to rounding and extrapolation errors.

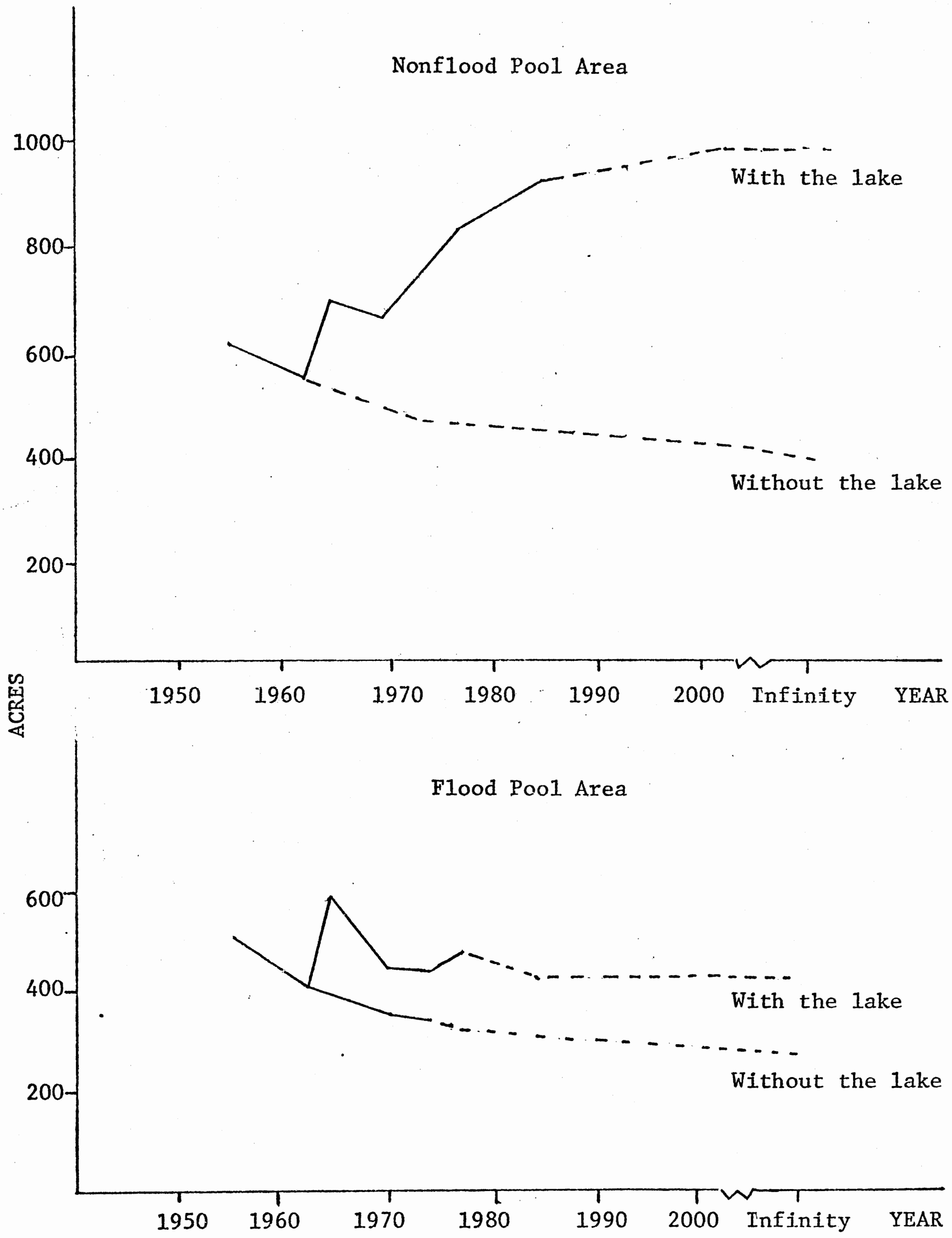

Figure 3. Actual and Projected Nonagricultural Land Uses With and Without the Lake in the Flood Pool and Nonflood Pool Areas

Figure 4. The difference in residential land use impact depicts clearly the land use patterns in the flood pool which are in close proximity to the reservoir and those outside the flood pool in the outlying area. After reservoir construction residential land use typically increases in the immediate vicinity of the lake where the lake may be viewed but due to the extensive flood pool area, it is very difficult to locate in the immediate access area of the Pine Creek Lake. As a result the private and residential land development near the lake does not occur.

Generally, the land use impact of the reservoir project diminishes at distances further and further away from the lake. Consequently, the residential land use change that does occur in the more outlying areas is less than the land use change which might have occurred in the flood pool area. The overall implication is that the total land use impact of the reservoir project is somewhat reduced because of the large flood pool area of the Pine Creek Reservoir project.

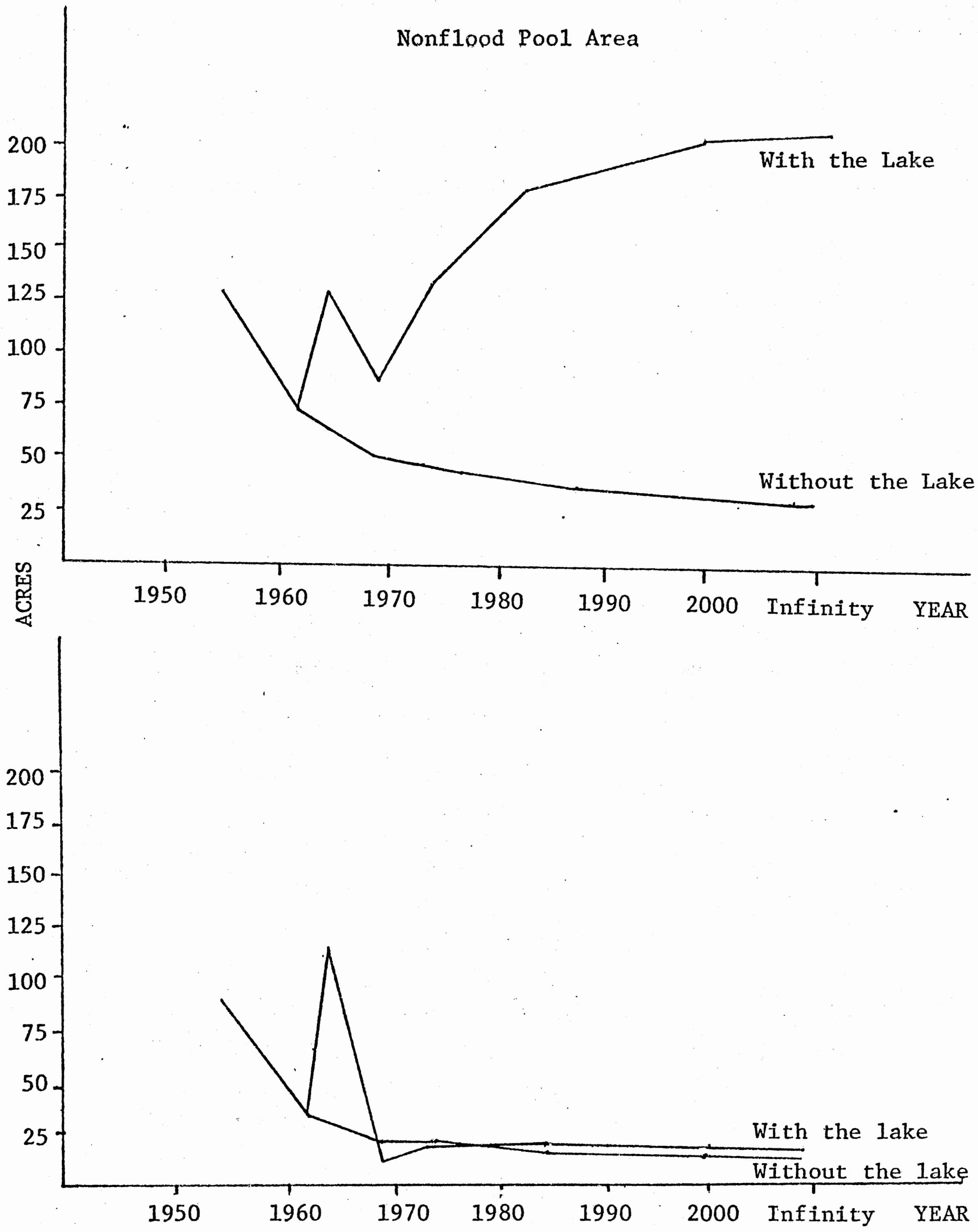

Figure 4. Actual and Projected Residential Land Use With and Without the Lake in the Flood Pool and Nonflood Pool Areas

CHAPTER V

COMPARISON OF LAND USE IMPACTS IN THE PINE CREEK AND KEYSTONE AREAS

In Chapter IV a differential land use impact model was developed as a measure for isolating the land use change resulting from the Pine Creek Reservoir project. In this chapter the aim is to identify the land use impact due to reservoir projects in general.

The Keystone and Pine Creek areas both received substantial investment for water resource development projects. The projects were authorized around the same time so the macroeconomic environments affecting land uses at each may be assumed to be similar. Both projects have similar primary purposes. In addition, both project provide opportunities for many land-based and water-based recreational activities. Generally, the distribution of land among alternative uses prior to reservoir construction are alike. In spite of these similarities there are differences in the land use impacts resulting from each of the projects.

The land use impacts in the Pine Creek area may be compared with the land use impacts in the Keystone area. The two areas have several fundamental differences. These differences are assumed to account for the differences in land use impacts resulting from the projects. Further, consideration of these differences may provide the basis for broader generalizations concerning the land use impacts of other water resource development projects.

Background Information on Selected Study Areas

The Keystone Lake and Dam are a part of the Arkansas River Basin project. Construction of the Keystone Reservoir begain in January, 1957 and was completed in 1965. The primary purpose of the project was flood control, navigation and hydro-electric power. Other purposes of the project include ample storage capacity for control and retention of upstream sediment, recreation and wildlife enhancement. The lake is located in Osage, Tulsa and Creek Counties approximately 20 miles west of Tulsa, Oklahoma. The land around the Keystone Lake varies from rocky, wooded hills to rolling, grassy pastures and provides an aesthetic attraction for visitors. More detailed information concerning the Keystone project may be obtained in the land use study by Vandeveer.

Identification of Similarities and Differences in the Selected Study Areas

The purpose of this section is to outline the differences in the Keystone and Pine Creek areas and to discuss how they may account for the differences in land use impacts. The differences in land use impacts in the Pine Creek and Keystone areas may be attributable to differences in population, economic activities, transportation systems and the size of the lake and flood pool areas.

Size of the Lake and Flood Pool Area

Keystone Lake is approximately seven times larger than Pine Creek Lake. Keystone Lake covers 26,300 acres and has a shoreline of 240 miles. The surface area of Pine Creek Lake is only 3,800 acres and has a shoreline of 74 miles. In terms of area observed for land use changes, the Keystone study area covers a total of 91,670 acres not including the lake area. The area observed for land use change in the Pine Creek Lake area is 30,773 acres, excluding the 3,800 acres covered by the lake.

The shoreline along the Keystone Lake is usually very steep, such that the flood pool occupies very little additional area. By comparison, in the Pine Creek area the physical area of the flood pool is very large. That is, the flood pool extends quite a distance from the shoreline. The size of the flood pool is a decisive factor in the Pine Creek area and indicates the accessibility of land near the lake for private development. In the Pine Creek area due to the extensive area of the flood pool much of the residential and commercial land development is discouraged since it is very difficult to locate near the shoreline.

Location

Analysis of the location of the two projects shows major differences in the population, economics and transportation systems in the Pine Creek and Keystone areas.

Keystone Lake is located approximately 20 miles from Tulsa, a major metropolitan area. Tulsa has a population of approximately

331,000 persons (14). The Tulsa economy is the mixture of many industrial, commercial and retail enterprises. Petroleum is only one of several major industries in the area. Several major highways provide good access from Tulsa to Keystone Lake and the surrounding area.

In contrast, the region surrounding Pine Creek Lake is mostly rural. Wright City is the nearest city to the lake and has a population of nearly 1,100 persons. Ardmore is the nearest city with a population greater than 25,000, and is more than 120 miles away from the lake. The economic activity in the Pine Creek area is closely linked with agriculture and commercial forest industry. The transportation network leading to the lake is mostly farm-to-market roads. Direct access to the lake from places outside the study area is limited to two highways.

The locational differences implicitly indicate the level of competition among alternative land uses in the area. Generally, Pine Creek is an area of low population density and hardly any industrial development. As such, the local demand for alternative land use seems very modest. On the other hand, the Keystone project is relatively close to a major metropolitan area. The scarcity of land for alternative uses is more likely in the Keystone area. Indirectly this suggests more diversified needs and demands for land resources.

Pre-investment Land Use Trends

The land use patterns in the Pine Creek and Keystone areas during their respective pre-investment periods are given in Table XVI.

TABLE XVI

TOTAL ACRES AND PERCENTAGE OF TOTAL ACRES WITHIN EACH LAND USE CATEGORY DURING THE PRE-INVESTMENT PERIODS, PINE CREEK AND KEYSTONE AREAS

	Keystone[a]			
Land Use	Total Acres in 1948	Percentage of Total Acres	Total Acres in 1958	Percentage of Total Acres
Cultivated	6,108	6.7	6,485	7.1
Pasture	29,983	32.7	34,404	37.5
Forest	52,610	55.7	47,389	51.7
Residential	828	.9	899	1.0
All Other	2,142	2.3	2,494	2.7
Total	91,670		91,670	

	Pine Creek			
Land Use	Total Acres in 1955	Percentage of Total Acres	Total Acres in 1963	Percentage of Total Acres
Cultivated	1,267	4.1	724	2.4
Pasture	6,465	21.0	5,707	18.5
Forest	21,918	71.2	23,410	76.1
Residential	218	.7	103	.3
All Other	905	2.9	830	2.7
Total	30,775		30,775	

[a] Source: L. R. Vandeveer, An Economic Analysis of Differential Land Use Changes Associated with Water Resource Development: Keystone Lake, Oklahoma, 1976.

The two areas differ in absolute acreage in each use, however, the percentage shares of land in each use are quite similar.

Examination of the rate of change of each land use during the pre-investment period is shown in Table XVII. The land use trends prior to reservoir construction are completely different in the two areas. All land uses in the Keystone area increase with the exception of forest, while in the Pine Creek area all land uses decline except for forest. These initial differences in land use trends prior to reservoir construction most likely stem from the differences in economic stimuli for land use change in the two areas. Apparently, in the Pine Creek area the economic incentives were not sufficient to encourage alternative land uses besides forest.

The very rapid declines in cultivated and residential land uses in the Pine Creek area possibly arise as one of the very first land use impacts resulting from the reservoir project. The authorization of the project in 1958 merely hastened the abandonment of improved farm land and residential land. Those persons who had to move responded immediately following authorization rather than just prior to reservoir construction.

Post-Investment Land Use Trends

The land use patterns observed in Pine Creek and Keystone areas after reservoir construction are provided in Table XVIII. The results in Table XVIII show that the percentage shares maintained in the Keystone area are very much the same as those during the pre-investment period. However, in the Pine Creek area the major land use shifts

TABLE XVII

PERCENTAGE CHANGE IN EACH LAND USE DURING THE PRE-INVESTMENT PERIODS, KEYSTONE AND PINE CREEK AREAS

Land Use	Keystone[a] Percentage Change from 1948-1955	Pine Creek Percentage Change from 1955-1963
Cultivated	6.1	-42.9
Pasture	14.8	-11.7
Forest	-9.9	6.8
Residential	8.6	-52.8
All Other	16.4	-8.3

[a] Source: L. R. Vandeveer, An Economic Analysis of Differential Land Use Changes Associated with Water Resource Development: Keystone Lake, Oklahoma, 1976.

TABLE XVIII

TOTAL ACRES AND PERCENTAGE OF TOTAL ACRES WITHIN EACH LAND USE CATEGORY DURING THE POST-INVESTMENT PERIODS, PINE CREEK AND KEYSTONE AREAS

	Keystone[a]			
Land Use	Total Acres in 1964	Percentage of Total Acres	Total Acres in 1970	Percentage of Total Acres
Cultivated	3,493	3.8	2,883	3.14
Pasture	33,154	36.2	32,847	35.8
Forest	50,577	55.0	51,282	55.9
Residential	1,246	1.4	1,454	1.6
All Other	3,206	3.5	3,204	3.5
Total	91,670		91,670	

	Pine Creek			
Land Use	Total Acres in 1970	Percentage of Total Acres	Total Acres in 1974	Percentage of Total Acres
Cultivated	1,075	3.5	863	2.8
Pasture	22,314	72.5	18,890	61.4
Forest	6,277	20.4	9,822	31.9
Residential	100	.3	146	.5
All Other	1,007	3.3	1,053	3.4
Total	30,775		30,775	

[a] Source: L. R. Vandeveer, An Economic Analysis of Differential Land Use Changes Associated with Water Resource Development: Keystone Lake, Oklahoma, 1976.

from forest in the pre-investment period to pasture in the post-investment period.

The land use impacts observed in the two areas in 1970 are given in Table XIX. The land use impact estimates are given as a proportion of actual land use to show the relative impact of the project on each land use. Despite the differences, comparison of the land use impacts shows that both reservoir projects stimulated additional nonagricultural land use.

In both instances, the nonagricultural land use impact stems from demands for alternative land uses such as commercial and residential which are associated with recreational activities and amenities of the lakes. However, in the Keystone area, these land use demands are intensified by the nearness to a metropolitan area. The relatively smaller impact on nonagricultural land use in the Pine Creek area generally indicates (1) less demand for these uses relative to the Keystone area, and (2) the adverse effect of the extensive flood pool area.

The differences in agricultural land use impacts may also be accounted for by the recreational activities which accompany the two projects. Vandeveer (22) suggests that the increases in forest land use are associated with improving the environment for newly-created recreational and leisure opportunities of Keystone Lake. The decrease in forested land in the Pine Creek area is associated with improving the environment for wildlife and hunting activities provided by the Oklahoma Department of Wildlife Conservation.

Nearness to major metropolitan areas may be the overriding factor accounting for differences in pasture and cultivated land

TABLE XIX

ACTUAL DIFFERENTIAL LAND USE IMPACT IN 1970, KEYSTONE AND PINE CREEK AREAS

Land Use	Keystone[a] Estimated Actual Differential Land Use (D_n)	Keystone[a] Estimated Actual Differential Land Use Impact as a Percentage of Actual Land Use
Cultivated	-4,000	-138.7
Pasture	-4,660	-14.2
Forest	7,716	15.1
Residential	464	46.9
All Other	480	17.62

Land Use	Pine Creek Estimated Actual Differential Land Use (D_n)	Pine Creek Estimated Actual Differential Land Use Impact as a Percentage of Actual Land Use
Cultivated	534	49.7
Pasture	17,240	77.3
Forest	-18,023	-287.2
Residential	28	28.0
All Other	237	23.5

[a] Source: L. R. Vandeveer, An Economic Analysis of Differential Land Use Changes Associated with Water Resource Development: Keystone Lake, Oklahoma, 1976.

uses in the two areas. The declines in pasture and cultivated land uses in the Keystone area are the counter effects of increases in demand for nonagricultural land uses. Agricultural land use changes were the predominant land use changes resulting from the Pine Creek project and may indicate the importance of agriculture to the area economy.

An alternative interpretation of the contradictory land use impacts on pasture and cultivated land may be that in the Pine Creek area there is enough idle land (mostly forest) to meet the demands for agricultural and nonagricultural land uses. On the other hand, the negative agricultural land use impact in the Keystone area may indicate that the demand for land resources is so great that nonagricultural land may increase only at the expense of actively used agricultural land.

Long-Run Land Use Impacts in the Pine Creek and Keystone Areas

The long-run land use impacts of the Pine Creek and Keystone reservoir projects are indicated by the projected differential land use impact estimates provided in Tables XX and XXI. No major difference exists between the initial land use impacts discussed in the previous section and the long-run land use impacts. However, over time the magnitude of the land use impacts of the projects change in both areas.

The agricultural land use impact of the Pine Creek project declines over time while the negative agricultural land use impact resulting from the Keystone project becomes even larger over time.

TABLE XX

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE CHANGE, PINE CREEK AREA, OKLAHOMA, 1985, 2000, INFINITY

Land Use	Projected Land Use Based on 1955-1963 Transition Probability Matrix $({}_{ab}Q_n)$			Projected Land Use Based on 1970-1974 Transition Probability Matrix $({}_{cd}Q_n)$			Projected Differential Land Use Change (D_n)		
	1985	2000	Infinity	1985	2000	Inifinity	1985	2000	Infinity
Cultivated	387	330	273	674	634	630	287	304	357
Pasture	4,110	3,573	2,962	15,542	14,799	14,710	11,431	11,226	11,748
Forest	25,530	26,172	26,885	13,238	13,988	14,074	-12,292	-12,184	-12,811
Residential	53	49	45	192	204	405	139	155	160
All Other	689	649	609	1,124	1,149	1,154	435	450	545
Total[a]	30,773	30,773	30,773	30,773	30,773	30,773			

[a] Columns may not sum to total due to rounding errors.

TABLE XXI

PROJECTED AND PROJECTED DIFFERENTIAL LAND USE CHANGE, KEYSTONE AREA, OKLAHOMA, 1985, 2000, INFINITY

Land Use	Projected Land Use Based on 1955-1963 Transition Probability Matrix (${}_{ab}Q_n$)			Projected Land Use Based on 1970-1974 Transition Probability Matrix (${}_{cd}Q_n$)			Projected Differential Land Use Change (D_n)		
	1985[a]	2000	Inifinity	1985[a]	2000	Infinity	1985[a]	2000	Infinity
Cultivated	7,169	7,394	7,585	2,562	2,441	2,301	-4,607	-4,953	-5,185
Pasture	39,349	40,795	41,927	31,945	31,187	30,462	-7,404	-9,608	-11,465
Forest	41,141	39,353	37,737	52,132	52,709	52,799	10,991	13,356	15,465
Residential	1,081	1,168	1,337	1,812	2,146	2,804	731	978	1,467
All Other	2,857	2,959	3,082	3,193	3,186	3,223	336	227	141
Total	91,670	91,670	91,670	91,670	91,670	91,670			

[a] Values for 1985 were extrapolated.

The source of the differences in long-run agricultural land use impact is more likely associated with proximity to a metropolitan area than any other single factor.

The results in Table XXII indicate more clearly the long-run impacts on nonagricultural land uses. The long-run trends in the Keystone area suggest that the demand for nonagricultural land will continue to increase. In the Pine Creek area the demand for additional nonagricultural land levels off shortly after the project is completed. Despite local differences it appears the long-run residential land use impact increases over time in both areas. The magnitude of the residential land use impact corresponds with the intensity of land use demand generated by the presence of the lake and the nearness to metropolitan areas.

In addition, the results in Table XXII show that in the Keystone area most infrastructure development which falls under the all other land use category occurred immediately after the reservoir was constructed. By comparison, the Pine Creek project stimulated long-term infrastructure development. The rate of infrastructure development in the Keystone area may be related to the intense land use demand in Tulsa and the rapid land use adjustment which is expected there.

Conclusion

The most evident implication for other water resource development projects is that the project will most likely enhance residential development in the area. Secondly, failure to consider other economic

TABLE XXII

INCIDENCE OF ACTUAL AND PROJECTED NONAGRICULTURAL DIFFERENTIAL LAND USE CHANGE, KEYSTONE AND PINE CREEK AREAS

Land Use	Percent of Total Land Use Differential Within Selected Land Uses[a]				
	Percent of Actual Differential Land Use		Percent of Projected Differential Land Use		
			Keystone[b]		
	1964	1970	1985	2000	Infinity
Residential	37	52	69	78	87
All Other	63	48	31	22	13
Total	100	100	100	100	100
			Pine Creek		
	1970	1974	1985	2000	Infinity
Residential	11	20	24	26	23
All Other	89	79	76	74	77
Total	100	100	100	100	100

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

[b] Source: L. R. Vandeveer, An Economic Analysis of Differential Land Use Change Associated with Water Reservoir Development: Keystone Lake, Oklahoma, 1976.

or social stimuli for land use change may tend to overstate or understate the impact of the water resource project.

The single most important factor accounting for the magnitude of land use change in the selected study areas appears to be density of population. It seems that density of population indicates potential frequency of use of the lake and surrounding land area and as such, indicates the need for additional land resources to provide goods and services for these users.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The primary objective of this study has been to evaluate the land use impact of water resource development projects. To accomplish this objective, two independent models were developed: an explanatory land use change model and a predictive differential land use change model. The results generated by each model were presented in Chapters III and IV. This chapter of the study is used to summarize the major findings. In the final section of this chapter, suggestions for future research are discussed.

Summary of Estimation Procedures

In order to estimate the net land use change which is attributable to the Pine Creek Reservoir project a differential land use change model was developed based on Markov chain procedures. The Markov model was used to estimate current and predict long-run net land use changes resulting from the reservoir project. In addition, the estimates of land use change resulting from the Pine Creek Reservoir project were compared to the estimates of land use change resulting from the Keystone Reservoir project. The comparison of the net land use changes in the two areas provides a basis for anticipating the land use changes which may result from other water resource development projects.

Land use change models were developed for selected land use categories to identify those factors influencing land use change in the Pine Creek Reservoir area. In the land use change models the number of acres in a particular use is assumed to be functionally related to several explanatory variables which represent economic and locational factors in the study area. A least squares regression procedure was used to estimate the parameters for the explanatory variables and to determine the importance of each variable in explaining land use changes in the Pine Creek area.

Major Findings

The results of the differential land use change models indicate that substantial land use change occurred as a result of the construction of the reservoir project. The primary land use impact was a conversion of forests into pasture land. There were also noticeable changes in cultivated, residential and all other land use categories caused by the project.

In general, locational and economic factors were functionally related to the pattern of land use following reservoir construction. More specifically, land use changes which occurred in the Pine Creek Reservoir area are a function of the location of the land, its accessibility to the reservoir, its nearness to major roads and towns, its previous land use and whether it is located within the flood pool. The local economy also had a significant effect on the land use change occurring in the project area. In general, the results of the land use change model may be used to explain or support the results of the differential land use change model.

However, in some cases, the coefficients of the explanatory variables provided contradictory results and therefore were not useful for explanatory purposes.

The most substantial land use impact both absolutely and relatively occurred in the agricultural land use categories. The results of the differential land use change models indicates pasture land use had the largest net increase and forest land use had the largest net decrease. For the two periods prior to reservoir construction, forest land use averaged 74 percent of the total land area while pasture land use averaged 19 percent of the total land area. Pasture land use averaged 67 percent and forest lands averaged 27 percent of the total land area for the two periods after the project was completed.

Most of the increase in pasture land use following reservoir construction was primarily at the expense of forest land use. Since the total land in the study area is fixed, any increase in pasture land use must be accompanied by a decrease in some other land use categories. Cultivated, residential and all other land uses held fairly consistent shares of the total land area before and after reservoir construction. Thus, the large decrease in forest land use must have offset the increase in pasture land use.

The coefficients in the forest and pasture land use models confirms this finding. For instance, a decrease in the distance to the lake by one unit led to an increase of .02 acre in pasture and to a decrease of .01 acre in forest land. The examination of the distance and flood pool coefficients shows that increases in pasture land use occurred in the nonflood pool area near the flood pool boundaries at the expense of forest land use. The major reason accounting for the decrease in forest and the increase in pasture is an improvement in the environment for recreational uses and the development of a wildlife refuge.

The reservoir project also had an effect on nonagricultural land uses. Most of the land use impact for nonagricultural was caused by structural development. The expected residential and commercial land use development did not occur, at least not on the scale reported in other studies of the economic impact of WRDPs (16, 22). The size of the flood pool was a decisive factor accounting for the reduced residential and commercial land use impact. Comparison of land use impacts in the Pine Creek and Keystone Reservoir areas indicates that residential land use is generally enhanced by WRDP. Further, the comparison points out that the size of the population and nearness to a major urban area are important determinants of the scale of nonagricultural land use impacts of the WRDP.

The land use changes in the flood pool area differ from the land use changes occurring in the nonflood pool area because of restrictions on private land use in the flood pool area by the U.S. Army Corps of Engineers and the Oklahoma Wildlife Commission. Due to this restriction, differential land use change models were developed for the flood pool and nonflood pool areas. Comparison of the differential land use impact in the flood pool and nonflood pool areas indicates that the largest absolute land use impact was in the nonflood pool area.

The agricultural land use impact was fairly evenly distributed in the flood pool and nonflood pool areas. For example, in the nonflood pool area, the actual differential land use impact for pasture was 9,793 acres in 1970 and 8,019 in 1974. In the flood pool area, these estimates for the same two periods were 7,448 acres and 6,101 acres, respectively. The forest land use impact was about evenly distributed between the flood pool and nonflood pool areas.

The cultivated land use was evenly distributed in 1970, but much less so in 1974. In 1974, the cultivated land use impact was much higher in the nonflood areas. The results of the differential land use impact model indicate that cultivated land use increased in the nonflood pool area and decreased in the flood pool area. The increase in cultivated land use in the nonflood pool area may account for the increased availability of cultivated land which typically experienced flood damage before the construction of the reservoir. The decrease of cultivated land in the flood pool may be due to the restrictions placed on private land use in the flood pool area.

The impact of the reservoir project on nonagricultural land uses is substantially higher in the nonflood pool area especially for residential land use. The difference in the residential land use impact shows clearly that the land use impact in the flood pool area is much smaller than in the nonflood pool area. The usual private and residential land development near the lake did not occur because of the extensive flood pool area.

Overall, the total land use impact of the reservoir project is probably less than what might have been expected if the flood pool area had been smaller. The results of the land use model allow the same qualitative conclusion. An examination of the flood pool coefficients indicate that location within the flood pool led to decreases in cultivated, pasture, residential and all other land uses.

Generally, the land use impact is largest in the areas closest to the lake and diminishes rapidly as the distance from the lake increases. Consequently, the extensive flood pool caused the major land use impacts to be shifted to the nonflood pool area, quite a distance from the lake. Since the land use impacts in the nonflood pool area are smaller than the land use impacts that would have occurred near the lake, the total land use impact of the project is significantly decreased by the large flood pool area.

The long-term land use impacts of the reservoir project were estimated for periods from 1977 to infinity. The land use impact over time continued to be largest for the agricultural land uses although these land use impacts do decline in the long run. Most of the long-run land use impact for nonagricultural land uses represents long-term infrastructure development. The results indicate that the residential land use impact will continue to be small but will show a steady increase over time.

Need for Further Research

In this study a Markov chain model is used in conjunction with multiple regression analyses to explain and predict land use change.

The Markov chain model is used independently to predict the net land use change resulting from a reservoir project while the multiple regression model is used independently to identify those factors associated with land use change in the reservoir area.

The two transition probability matrices on which the Markov chain model is based reflect the pre- and post-land use change trends. The transition probabilities during future time periods are assumed to be the same as those for the base period over which the transition probability matrices were estimated. In the analysis of land use change, this assumption implies that the rate of change in factors influencing land use does not change over time. Estimates based on this assumption may be less accurate than if the transition probabilities were allowed to change in each projected period to reflect more probable land use trends.

The transition probabilities at any future point in time are likely to be a function of secular factors, social and economic variables, and other exogenous variables. As the Markov chain model is presently defined, these variables are not taken into account. Inclusion of these variables within a functional system of transition probabilities could improve estimates of land use change associated with reservoir construction and give more accurate projections of future land use changes. First, the estimated parameters for each of the variables can be used to provide information on the magnitude and direction of land use change of each land use category in response to an exogenous event. Secondly, after careful analysis of these estimates, a multiple regression procedure may be used to estimate the transition probabilities directly for each time period.

Estimating the transition probabilities directly for each time period will give a nonstationary Markov chain model. The major advantage of the nonstationary model is that changes in exogenous variables from one time period to the next are taken into account in predicting land use change. The use of the nonstationary model may improve estimates of land use change associated with reservoir projects as well as land use change projections. The results of such a model would simultaneously provide explanations for the scale of land use change caused by the project and the current and long-term land use patterns. Future research should attempt to estimate directly transition probabilities which reflect changes in important exogeneous variables.

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APPENDIX A

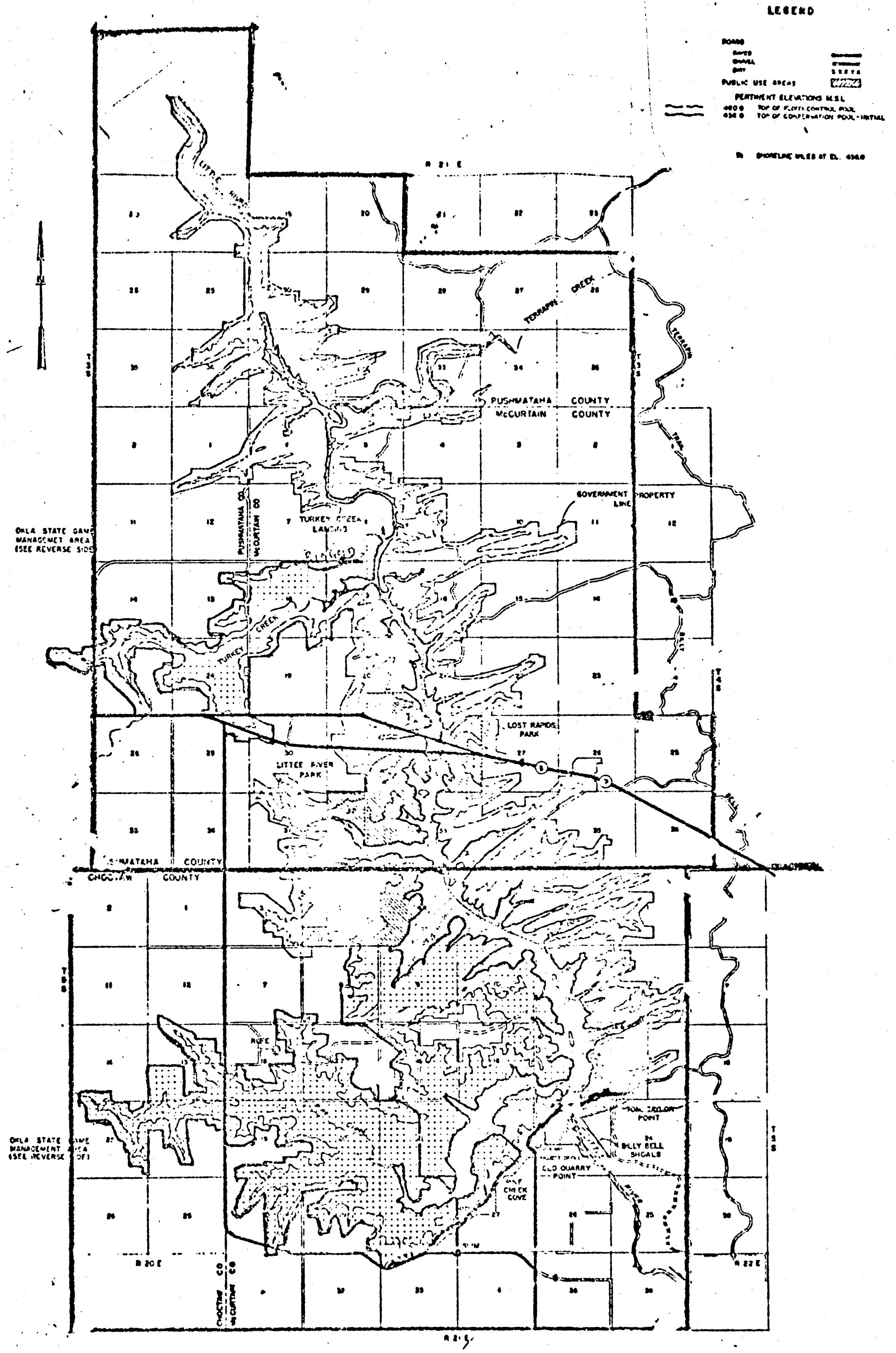


Figure 5. Pine Creek Study Area

APPENDIX B

Land Use Coding Sheet

Coordinates of the southern-most point:

Southwest to northeast diagonal ______(1-3)

Southeast to northwest diagonal ______(4-6)

Land Use Code	Dot Count	1st Count
1.	Cultivated land, feedlots, etc.	______(7-8)
2.	Pastureland, rangeland	______(11-12)
3.	Forested, woodland	______(15-16)
4.	Residential and farmsteads	______(19-20)
5.	Roads, highways, parking lots	______(23-24)
6.	Railroads, electric transmission or other utilities	______(27-28)
7.	All others: commercial, institutional, etc.	______(31-32)
8.	Impoundments	______(35-36)
9.	Lake or stream water	______(39-40)

Land use codes at northern-most point ______(43)

Year of photo ______(44-45)

Size of observation (one if not full size) ______(46)

APPENDIX C

PROCEDURE FOR ESTIMATING LAND USE FLOWS IN A SAMPLE OBSERVATION

The purpose of this appendix is to describe the procedure used to estimate a sample observation pre-investment and post-investment land use flow matrix. The Markov chain procedure discussed in Chapter IV requires a land use flow matrix in order to estimate land use patterns in future time periods. The development of a land use flow matrix requires that land use flows be estimated between two points in time. The land use data derived from the aerial photographs only provide the amount of land in a given use at the beginning or end of the time period. It is not known what portion of the acreage decline in one land use that goes to other land use categories since the land use flows are not measured directly. In this study, the flow of land among the alternative uses is estimated by using a land use flow algorithm.

The Algorithm

The land use flow algorithm provides a set of assumptions which is used to compute the off-diagonal elements in the land use flow matrix. Land use flow matrices are estimated for the pre-investment period (1955-1963) and the post-investment period (1970-1974). The land use flow matrices are developed separately for the flood pool and nonflood pool areas for each investment period.

Algorithm for Land Use Observations in the Nonflood Pool Area

The procedure used to estimate the off-diagonal elements of the land use flow matrix for the nonflood pool area is based on the assumption that increases in land use come from decreasing land uses in the same observation in that time period. If any agricultural land use increases in the nonflood pool area, then the acreage increase is assumed to come first from any decreasing agricultural land uses. Should the decreases in agricultural land use acreages be too small, then the remaining acreage increase is assumed to come proportionately from the nonagricultural land uses with acreage decreases. Similarly, increases in nonagricultural land uses are assumed to come proportionately from other nonagricultural land uses and all the remaining land use categories with acreage decreases.

Algorithm for Land Use Observations in the Flood Pool Area

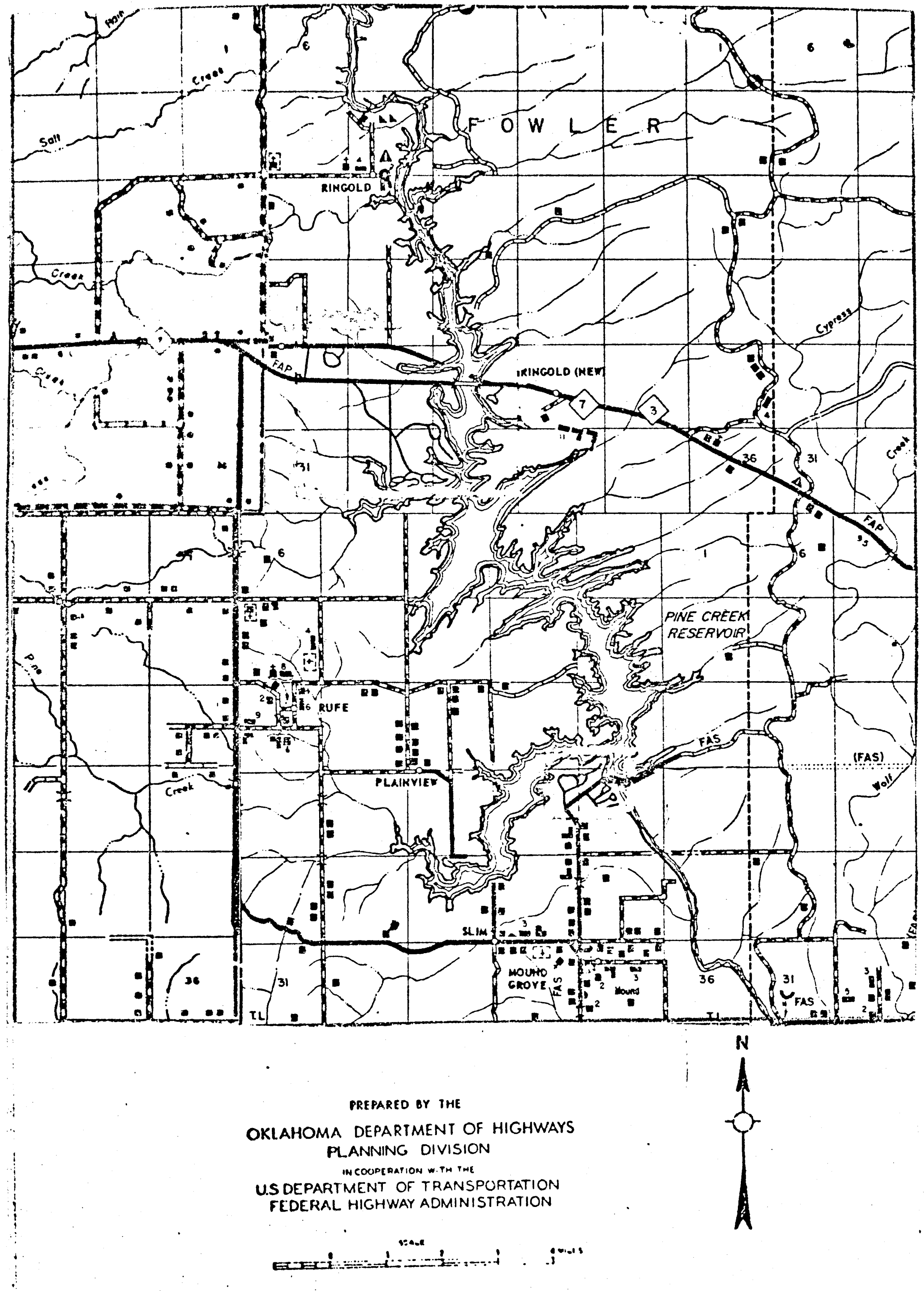
A slightly different set of assumptions is used to estimate the off-diagonal elements of the land use flow matrix for the flood pool area. If the acres in any agricultural land use increase then the increase in acreage is assumed to come proportionately from decreases in other agricultural land uses and nonagricultural land uses. However, the decreases in nonagricultural land uses is allocated first to the all other land use category. If any amount of the decrease in nonagricultural land uses still remains, then it is allocated proportionately to pasture and forest land uses. The decreases in nonagricultural land uses are assumed to shift only to pasture and forest land uses since cultivated land is prohibited in the flood pool area after the reservoir is constructed.

Summary

The land use flow algorithm is a set of assumptions which is used to allocate the decrease in land uses among increasing land uses. To compute the land use flows, the sample observation must be available for the two points in time for the pre-investment and post-investment periods. The total acreage decline during the given time period must equal the total acreage increase during the same period. In this way, the total acreage at the beginning of the time period is equal to the total acreage at the end of the time period.

The elements on the principal diagonal of a land use flow matrix represent the land use acreage that remains in that use throughout the time period in which the matrix is estimated. The off-diagonal elements represent the land use flows between alternative uses over time. The sum of the row or column totals in the land use flow matrix equal the total acreage for the study area. The elements in the pre-investment land use flow matrix represent the sum of the land use flows for the sample observations during the pre-investment period. Similarly, the post-investment land use flow matrix represents the sum of the land use flows for the sample observations during the post-investment period.

APPENDIX D



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OKLAHOMA DEPARTMENT OF HIGHWAYS
PLANNING DIVISION
IN COOPERATION WITH THE
U.S DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Figure 6. Selected Towns Near the Pine Creek Lake

VITA 2

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