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Estimating Reservoir Recreational Visits In Indiana

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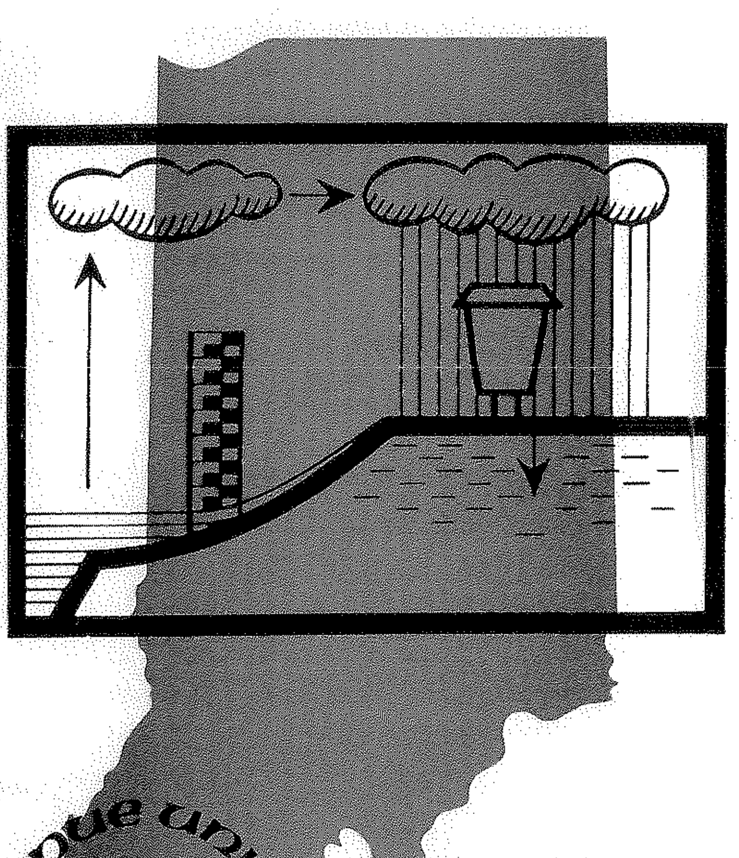
TECHNICAL REPORT NO. 48

ESTIMATING RESERVOIR RECREATIONAL VISITS IN INDIANA



by

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JUNE 1974

PURDUE UNIVERSITY

WATER RESOURCES RESEARCH CENTER

WEST LAFAYETTE, INDIANA

ESTIMATION RESERVOIR RECREATIONAL VISITS IN INDIANA

PROGRESS REPORT ON OWRR-A-026-IND

PREFACE AND ACKNOWLEDGMENTS

This report presents a part of the work on the application of systems analysis methods to surface water management in Indiana sponsored under project OWRR-A-026. The core of this project is a daily simulation model for the 8,000 mi^2 Upper Wabash Basin which includes five potential reservoirs. Three of these have been built and two are authorized but presently subject of public contention. This contention, although couched in environmental arguments, centers on the *type* of recreational use of the reservoir areas with land owners and hikers opposed to what is desired by boating and swimmin enthusiasts.

The ultimate purpose in constructing the simulation model was its possible use for evaluation purposes of benefits from different types of water resource development. The two main project benefits are flood control and recreation. An evaluation of the recreation benefits requires an estimate of the expected future visitation based on Indiana data. This estimation method is the subject of this report. The method is an improvement over existing models in that a network approach was followed. Further work is needed to adjust the model, however. The absence of some constraints for the selection of which data are not yet available, results in several unacceptible prediction results.

We would like to acknowledge the help and encouragement extended by the staff of a number of State and Federal Agencies. In particular we would like to thank Mr. John T. Costello, Acting Deputy Director, Indiana Department of Natural Resources; Mr. Thomas Huck, Asst. Chief, Division of Reservoirs, Indiana Department of Natural Resources; Messrs. Bill Walters, Clay McDermiott, and Tom Huck, Division of Outdoor Recreation, Indiana Department of Natural Resources, Dave Griffith, Division of State Parks, Indiana Dept. of Natural Resources; William H. Allaway, Jr., Economist, Economics and Water Requirements Division, Texas Water Development Board; Mr. John R. Gleidt, Chief, and Mr. Glenn Bayes, Operations Division, Louisville District, Corps of Engineers.

The inputs by Professors D. M. Knudson, W. L. Miller, and H. L. Michael, all members of Mr. K. K. Wolka's graduate committee, and all of Purdue University, are gratefully acknowledged. The text of this report is largely identical to Mr. Wolka's thesis.

The project was administered by the Purdue Water Resources Research Center, Dr. Dan Wiersma, Director; Dr. G. H. Toebes served as principle investigator.

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ABSTRACT

A prediction model was developed to estimate the expected number of recreational visits to federal reservoirs in Indiana. To this end the elementary origin-destination model was amended in several ways. The elementary origin-destination model reads:

$$U_{ij}[\text{visits}] = A_j[\frac{\text{visits}}{\text{people}} * mi^{\alpha}]\ P_i[\text{people}]\ D_{ij}^{-\alpha}[\text{mile}^{-\alpha}] \quad (1)$$

where i = index of population center; j = index for reservoir; A = attractiveness coefficient; P_i = population in center i; D_{ij} = distance from i to the reservoir j.

The Eq. 1 was amended in two stages, using two types of visitation data that were available. The first type of data were essentially V_{ijw}[cars] = number of cars from i, visiting j, on weekend w, where: w = 1, 2, ..., 53 in the 1956-57 summer period; i = 1, 2, ..., 48 (representing the number of counties in Indiana), j = 1, 2, 3. This data was used to estimate α_{jw}. It turned out that the variation in α_{jh} was sufficiently small to adopt an average $\bar{\alpha}$ = 1.67.

The second type of data were annual visitation data without regard to origin, i.e. $\sum_i U_{ijy} = U_{jy}$[visits] where j = 1, 2, ..., 6; y = 1, 2, ..., Y_j; Y_j = number of yearly data; Y_j varied from 3 to 11. In using the data the model of Eq. 1 was modified to read:

$$N[\frac{people}{car}] * 1[\frac{visit}{people}] * V_{ijw}[cars] * DF_j[-] * B[-] = \hat{U}_{jw} =$$

$$= \{Q_j[\frac{visits}{people} * \frac{hrs^{\bar{\alpha}}}{\$}] * \sum_{j=j}^{J} IN_{jy}[\$]\} * \{I_y[-] * P_i[people]\} *$$

$$* T_{ijy}^{-\alpha} \qquad (2)$$

where DF_j = adjustment factor to only count visits from within Indiana; B = multiplier to derive annual data from weekend data; $\hat{U}_{jy}$ = estimated annual visits to reservoir j; Q_j = natural quality coefficient; IN_{jy} = adjusted capital investment for recreational facilities around reservoir j in year y; I_y = buying power multiplier; $T_{ijy}[hr]$ = actual travel time from i to j along various roads in the year y.

It will be recognized that Eq. 2 is formulated to extract all likely causal variation for which data were obtainable.

Using the Eq. 2 after calibration of the empirical Q_j-parameter the model was used to compute for a network of population centra and of reservoirs the estimated distribution of reservoir recreationists. The results have been shown by means of contour plots.

The absolute numerical values for U_{jy} appear too high for small T_{ij} as a result of the basic hyperbolic fitting equation that was selected in Eq. 1. However, selecting a model that is more constrained for small T_{ij} requires additional model parameters. For the calibration of the additional parameter there are insufficient data. The same effort may be achieved with a recreation demand constraint. In the continuation of this study the imposition of a recreation demand constraint will be taken up. Only then will the method become a true network model.

ESTIMATING RESERVOIR RECREATIONAL VISITS IN INDIANA

PROGRESS REPORT ON OWRR-A-026-IND

I. THE DEVELOPMENT OF MODELS FOR ESTIMATING RESERVOIR RECREATION VISITATION

A. Introduction

The emergence of recreation as a significant benefit of multi-purpose reservoirs accompanied the construction of TVA reservoirs in the 1930's. As more persons continued to recreate at reservoirs, it became desirable to estimate the number of visitors using the recreation facilities. Planners and managers of these recreation facilities needed visitation estimates to make knowledgeable decisions concerning their design and operation. Congress desired visitation estimates to help facilitate the evaluation of reservoirs for the authorization of Federal funding. Today, extensive efforts are being made to assign dollar values to recreation visits as a measure of economic benefit.

The methods of estimating reservoir recreation visitation have evolved over the years. Three types of methods can be used to summarize this development: (1) the recreation standards method, (2) the statistical correlation model, and (3) the network, or systems model.

A. The Recreation Standards Method

This first and earliest method of estimating recreation visits incorporates specified recreation visitation rates, or standards. This method uses for a particular recreational activity, an equation for estimating visits, U. The equation usually includes the population of the region, P; the number of recreation facility units for a particular recreation activity around the reservoir, A; and the standard, S. The general form of these equations is:

$$U[\text{visits}] = S[\text{visits/person/facility unit}] * P[\text{persons}] * A[\text{facility units}] \quad (1\text{-}1)$$

The value of the recreation standard is determined by past experience and the expected intensity of use. Methods adopted for the Wabash River Basin Comprehensive Study (1971) and for the North Atlantic Regional Water Resources Study (1972) are of this type.

B. The Statistical Correlation Model

The development of the digital computer caused the statistical correlation model for estimation of recreation visitation to gain popularity with researchers in the early 1960's. The fast computational speed and large memory storage of these computers greatly increased the efficiency associated with calibrating statistical models.

A large number of independent (explanatory) variables could be quickly correlated with the dependent variable (usually visits), resulting in a "best fit" equation.

If one calls the dependent variable Y (representing either visitor days,user days, or activity days, etc.), and the independent variables X's (i.e., X_1 = population, X_2 = facility units, ...), the selected model is either additive and linear:

$$Y = b_o + b_1X_1 + b_2X_2 + \ldots + b_nX_n + E \qquad (1\text{-}2)$$

or purely multiplicative:

$$Y = b_oX_1^{b_1} X_2^{b_2} X_3^{b_3} \ldots X_n^{b_n} \; E \qquad (1\text{-}3)$$

which reduces, after taking logorithms to Equation 1-2. Because Equation 1-2 is a linear model it is possible to use multiple correlation procedures for optimizing the selections for the model parameters $b_0, b_1, \ldots b_n$. The E is a residual term that represents the effect of all independent variables not considered in the model.

Many governmental agencies which manage recreational facilities, as well as recreation researchers, have and are now using statistical correlation models. Examples are the Texas Water Development Board (1968), and the U.S. Army Corps of Engineers (1969).

C. The Network Model

The two previously discussed methods for estimating visitation at reservoirs usually consider each reservoir separately, and neglect the competitive effects of recreational opportunities at nearby reservoirs. As more recreational facilities were being built in the 1950's and 1960's in response to rapidly increasing demands for recreation, these effects, hitherto neglected, became more pronounced.

Systems analysis, which became popular in the middle 1960's, provides techniques by which these neglected interactive effects may be considered, provided that the postulated model is correct and the available data justify the refinement. Two attempts at using the systems concept, i.e. the notion that reservoirs effect each others visitation levels, are those by Ellis (1967, 1969) and by Tadros and Kalter (1971). Ellis constructed a linear electrical network for camping areas in Ontario, Canada. Kalter built a linear programming model of New York State recreational areas.

A more detailed and thorough review of recreation visitation estimation methods can be found in a survey by Kalter (1971).

The objective of this thesis is to construct a recreation visitation model of the systems type and to apply this model to the solution of a particular, real-life estimation problem, namely the estimation of recreation visitation of planned reservoirs, whose realization is being actively opposed by environmental groups.

CHAPTER II

CAUSAL MODEL FOR ESTIMATING RECREATIONAL VISITS

A. Forecasting Models vs. Causal Models

A forecasting model extrapolates, for a selected set of related variables, the behavioral or data patterns observed in the past (deNeufville and Stafford, 1971). The variables affecting behavior may often be identified by statistical correlation procedures. These procedures determine the degree of correlation between variables within the limited time span over which the data were collected. It is commonly assumed that the observed behavioral patterns are part of a long-term trend. The accuracy of forecasts of the future depend on the veracity of this assumption. However, statistical accuracy only measures the degree of relation between variables values (Ostle, 1963); it does not imply causality (Draper and Smith, 1966).

Causal models are based upon previous knowledge of behavioral patterns and variable relationships. Causal models are not statements of absolute truth; they merely try to represent the effects on some variables caused by an heretofore not manifested change in others. In other words, they imply an understanding of how past and present environmental variables have and will affect systems behavior.

(The term systems is used here as a synonym of model.) The consequences of proposed changes may then be predicted (deNeufville and Stafford, 1971), rather than forecasted. Prediction is unique to causal models.

B. Network Model for Reservoir Recreation

A reservoir recreation model will be of the network type. Such a network model is portrayed by the simple graph of Figure II-1. It portrays a network of "visit" flows from sources to sinks. Population centers are the sources of the visits (participation in recreation at a reservoir by one person will be referred to as a visit). Recreational reservoirs are the sinks to which the above visits "flow". (The inevitable return flow is irrelevant to the model; furthermore, visits from reservoir to reservoir will be neglected.) The network links are the highways (travel other than by cars is virtually non-existant).

This network has a boundary. Only the variables of the network inside the boundary are assumed to influence systems behavior. It is also assumed that the network model is closed, i.e., inputs, outputs, and external constraints are either absent or neglected.

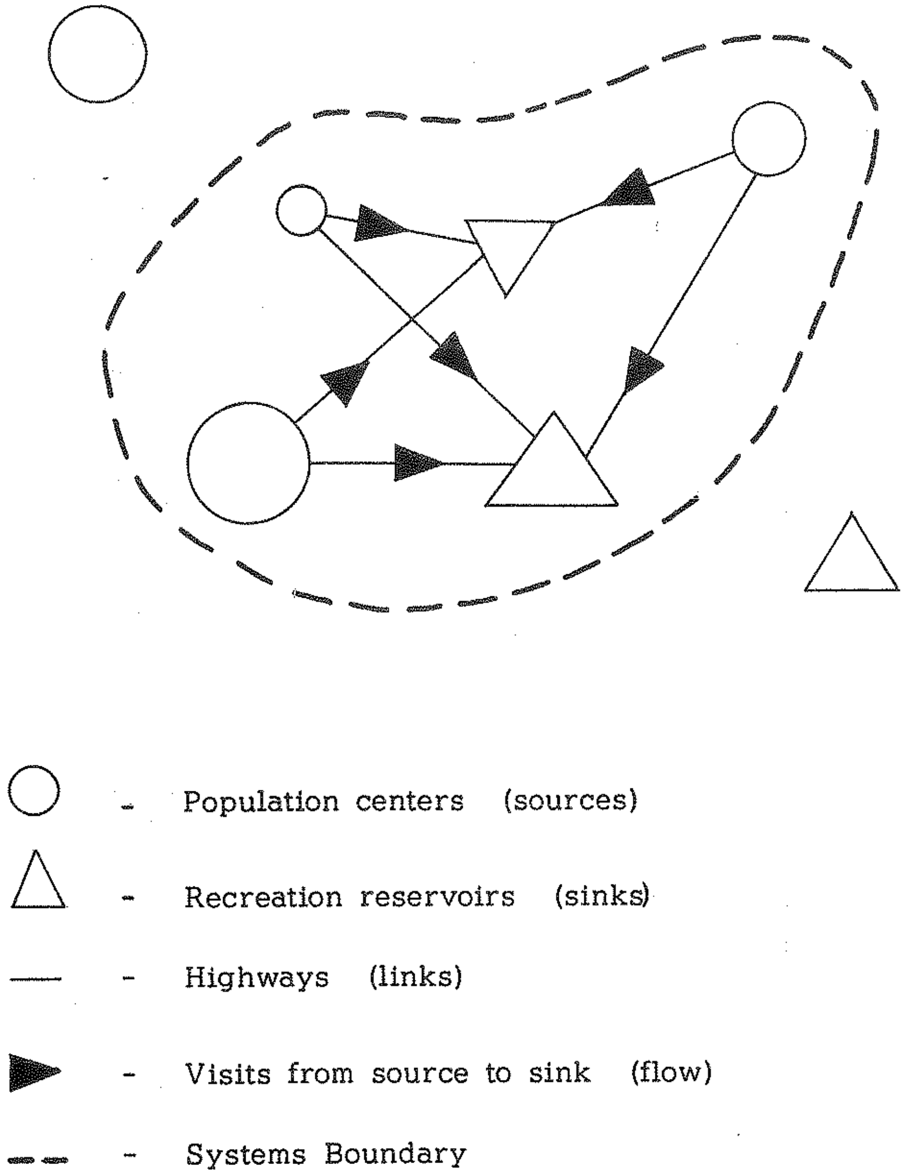

FIGURE II-1 RESERVOIR RECREATION NETWORK (CLOSED MODEL)

C. A Listing of Some Variables on Which Reservoir Recreation Visits Depend

Tables II-1 through 5 provide a listing of some reservoir recreation variables. The listing provides notation, definitions, as well as the units for the variables.

It is not claimed that this set of variables is complete. It is hoped, but not claimed, that they can represent most of the important factors of reservoir recreation. Essentially, the selection is largely circumscribed by data availability.

D. Origin-Destination Model

The above term is used to designate the elementary case of one population center and one reservoir connected by one link of varying length.

In a network model the quantity or quality conveyed by the network links is usually of main concern. In the present case this quantity is "flow of visits". The quantity of visits (i.e. arrivals at a site) to a reservoir j from a population center i is obtained from the product of the number of recreationists' cars which traveled over the link h and the average number of occupants per car. Herein h relates to travel time. The "flow" symbols are U_{ijw} and U_{ijy}, where the subscripts w and y represent visitation counting periods of a weekend and of a year,

Table II-1. Used Subscripts

Notation	Definition
i; $i=1,2,\ldots,I$	index for population center
j; $j=1,2,\ldots,J$	index for recreational reservoirs (system components)
y; $y=1,2,\ldots,Y$	index for year
y_{jo}	subscript for initial year of reservoir operation
w; $w=1,2,\ldots,W$	index for weekend
h; h=street, state road, federal road, interstate	index for type of link (links are part of the systems structure)
m; $m=1,2,\ldots,M$	index for weekend having "accurate" results (based on correlation coefficients ≥ 0.73)

Table II-2. Flow Variables

Notation	Definition	Units
V_{ijw}	recreation trips (cars) from population center i, to reservoir j, on weekend w	[trips]
N	average number of visits (people) per trip (car)	$[\frac{\text{visits}}{\text{trip}}]$
U_{ijw}	visits flowing from systems population center i, to reservoir j, on weekend w	[visits]
U_{ijy}	visits flowing from systems population center i, to reservoir j, during year y	[visits]
DF_j	deflation factor to determine the portion of the total visits to reservoir j originating from systems population centers	[-]
B	blow-up factor to convert measured weekend data into estimates of annual visitation data	[-]

Table II-3. Source Variables

Notation	Definition	Units
EBI_y	effective buying income in year y	[$]
CPI_y	ratio of consumer price index in year y to consumer price index in 1960	[-]
γ_y	annual rate of change of adjusted effective buying income in year y	[-]
I_y	increase in recreation demand (as it is assumed to depend on EBI_y) multiplier for year y	[-]
P_i	total population of population center i	[people]
RP_i	"recreation propensity" of population center i	[people]

Table II-4. Link Variables

Notation	Definition	Units
D_{ijk}	total or partial length of highway type h between population center i and reservoir j	[miles]
SP_h	average vehicle speed on link h	[miles/hour]
T_{ij}	travel time from population center i to reservoir j	[hours]
α	behavioral or constraint parameter related to time spent in travel between population centers and reservoirs (also a regression coefficient of the calibrated model)	[-]
Y_h	beginning year of interstate operation	[-]

Table II-5. Sink Variables

Notation	Definition	Units
IN_j	capital investment for the recreational facilities of reservoir j	[$]
BCI_y	ratio of Engineering News Record Building Cost Index in year y to ENRBCI in 1960	[-]
CI_j	cumulative adjusted capital investment for the recreational facilities of reservoir j	[$]
Q_j	quality coefficient of reservoir j (also a regression coefficient of the calibrated model)	$[\frac{visits}{people} * \frac{hrs^{\bar{\alpha}}}{\$}]$
A_j	attractiveness index for reservoir j	$[\frac{visits}{people} * hrs^{\bar{\alpha}}]$

respectively. The model for the magnitude of the "visit" flow, i.e. a statement of the relationships between the factors on which U_{ijw} or U_{ijy} depend in the "one population center - one reservoir" case, will be called the "Origin-Destination Model". It forms the basis for the network model.

The variables assumed to be involved in the elementary origin-destination model were listed in Section II-C. The mathematical structure that has been employed in much previous work (Ullman, 1964; Knetsch, 1964; Tussey, 1967; among many) to represent this relationship is some specific form of:

$$U_{ij} = A_j P_i D_{ij}^{-\alpha} \qquad (2\text{-}1)$$

(for notations please see Tables II-1 through 5). Figure II-2 illustrates this relation when using D_{ij} as the vertical axis and U_{ij}/P_i as the horizontal axis. This choice of axes is usually made because, when interpreting D_{ij} as proportional to travel price (which is taken as a proxy for the willingness to pay), then the Figure II-2 would represent a common demand curve.

The variables in Equation 2-1 are time-dependent. For the purpose of statistically fitting the model to actual data, the data were corrected for time trends. The present study also attempts to refine the variables by subtracting

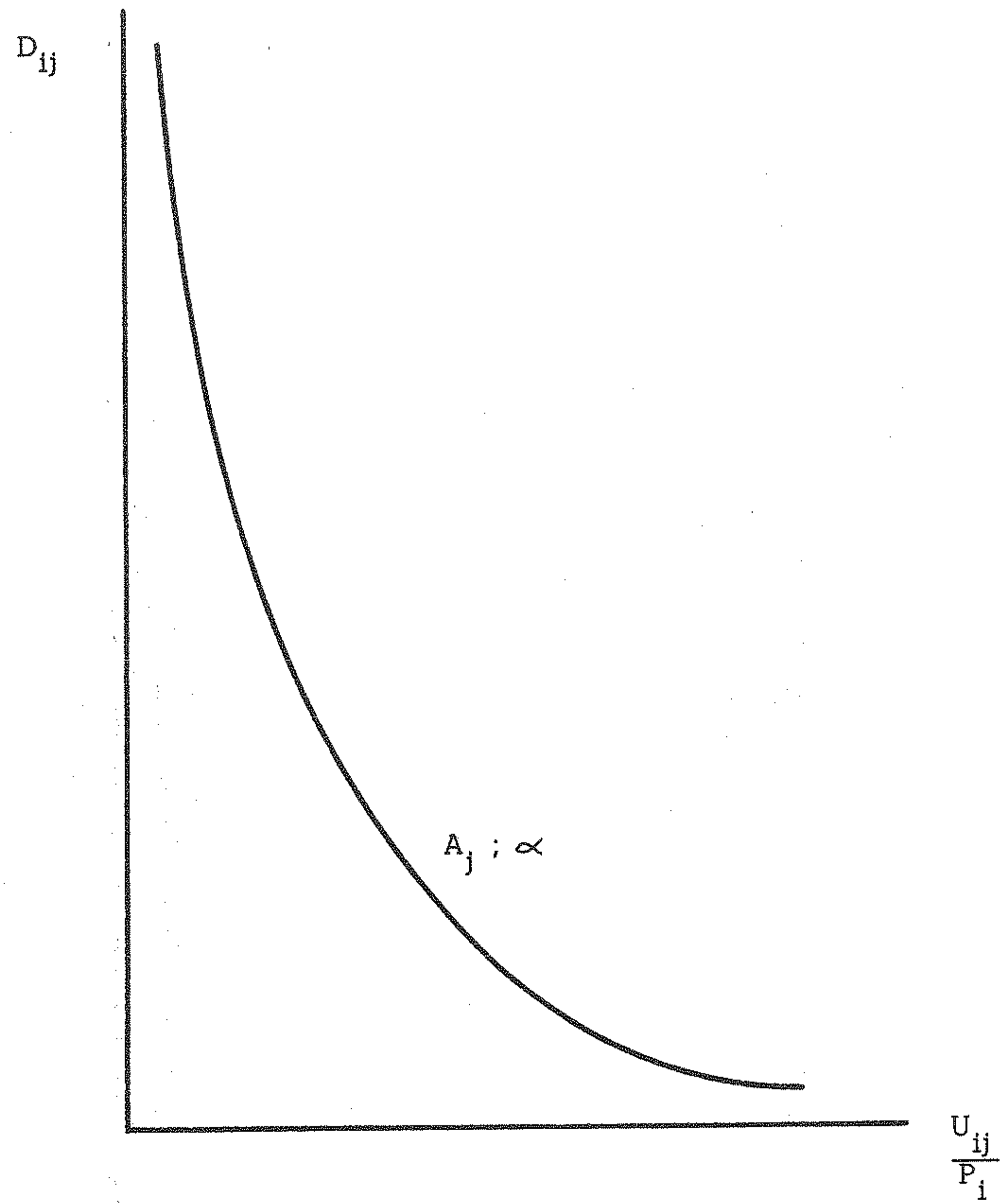

FIGURE II-2 ORIGIN - DESTINATION MODEL

out other presumed dependencies. For example, the highway length D_{ij} was replaced by the average travel time, T_{ij}, needed to drive from i to j. This was done on the assumption that systems constraints will as likely, if not more likely, apply to time, rather than to out-of-pocket expenses.

In addition, the attractiveness index A_j of the reservoir has been split into an investment factor and a natural quality factor. Finally, the population magnitudes were modified in order to model assumed changes in recreation demand (or "propensity to recreate") as it depends on effective buying (or disposable) income. The imposition of a systems constraint on the maximum number of visits flowing from each source is discussed but has not yet been implemented.

1. Travel Time

Road distance or air distance is the attribute of the link which is typically used to represent the magnitude of the link length. In turn, this is commonly used as a measure of recreation costs. These costs would presumably be the major determinant of or constraint on the link flows. However, using recreation cost as the major attribute of the link neglects the importance of time constraints and route appreciation in determining which reservoir, among other competitors, a recreationist would choose to visit.

In view of the travel facilitating effects of the interstate highways constructed in Indiana during the period for which recreational travel data were collected, it was decided to replace D_{ij} by T_{ij}, i.e. by estimates of travel duration.

Equation 2-2 shows how travel time has been calculated.

$$T_{ij} = \frac{\text{D street}}{\text{SP street}} + \frac{\text{D state road}}{\text{SP state road}} + \frac{\text{D federal road}}{\text{SP federal road}} + \frac{\text{D interstate}}{\text{SP interstate}} \qquad (2\text{-}2)$$

From equation 2-2, it is obvious that construction of a new road which permits faster vehicle speeds could decrease the travel time between a reservoir and a population center. On the other hand, deterioration of an existing road or the imposition of lower speed limits could lengthen travel time. The effects on visitation due to changing travel times, according to the Origin-Destination Model are shown in Figure II-3, which is the same type of curve illustrated in Figure II-2.

A decrease in travel time increases the per capita visitation from a population center. The opposite effect is obtained from an increase in travel time.

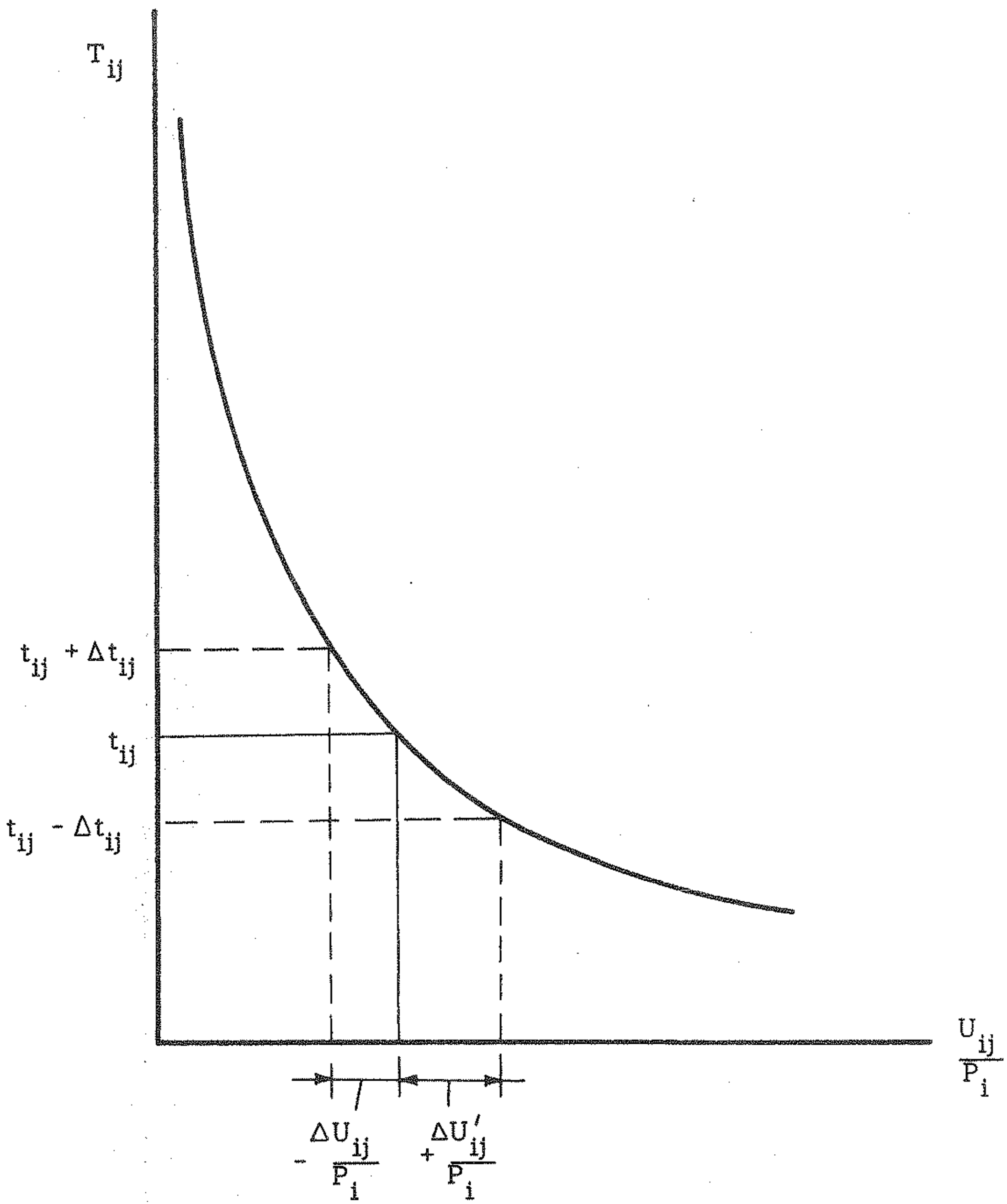

FIGURE II-3 EFFECTS OF TRAVEL TIME CHANGE

2. Behavioral Travel Time Parameter

The effect of the parameter α, called the "behavioral travel time parameter", and used in

$$U_{ij} = A_j P_i D_{ij}^{-\alpha} \qquad (2\text{-}1)$$

is illustrated in Figure II-4.

An increasing α-value would denote a relative increase in a recreationist's unwillingness to travel to more distant reservoirs. The parameter values obtained by previous workers have typically been greater than unity. Also, different values have been suggested for particular regional (geographical and/or cultural) areas (James and Lee, 1971).

3. Source Attributes

The attributes, or properties, of the sources that are of interest here are those that would affect the demand for recreation. Demand for recreation has definitely grown in the past two decades (Clawson and Knetsch, 1966). Some attribute of the sources, which represents the propensity to recreate (a term implying a measure of the size of the demand) should be contained in the model. Since pure demand is nearly impossible to isolate and measure, a proxy for the growth of the propensity to recreate is used in the model. It is assumed that the propensity to recreate is related to the relative amount of income which

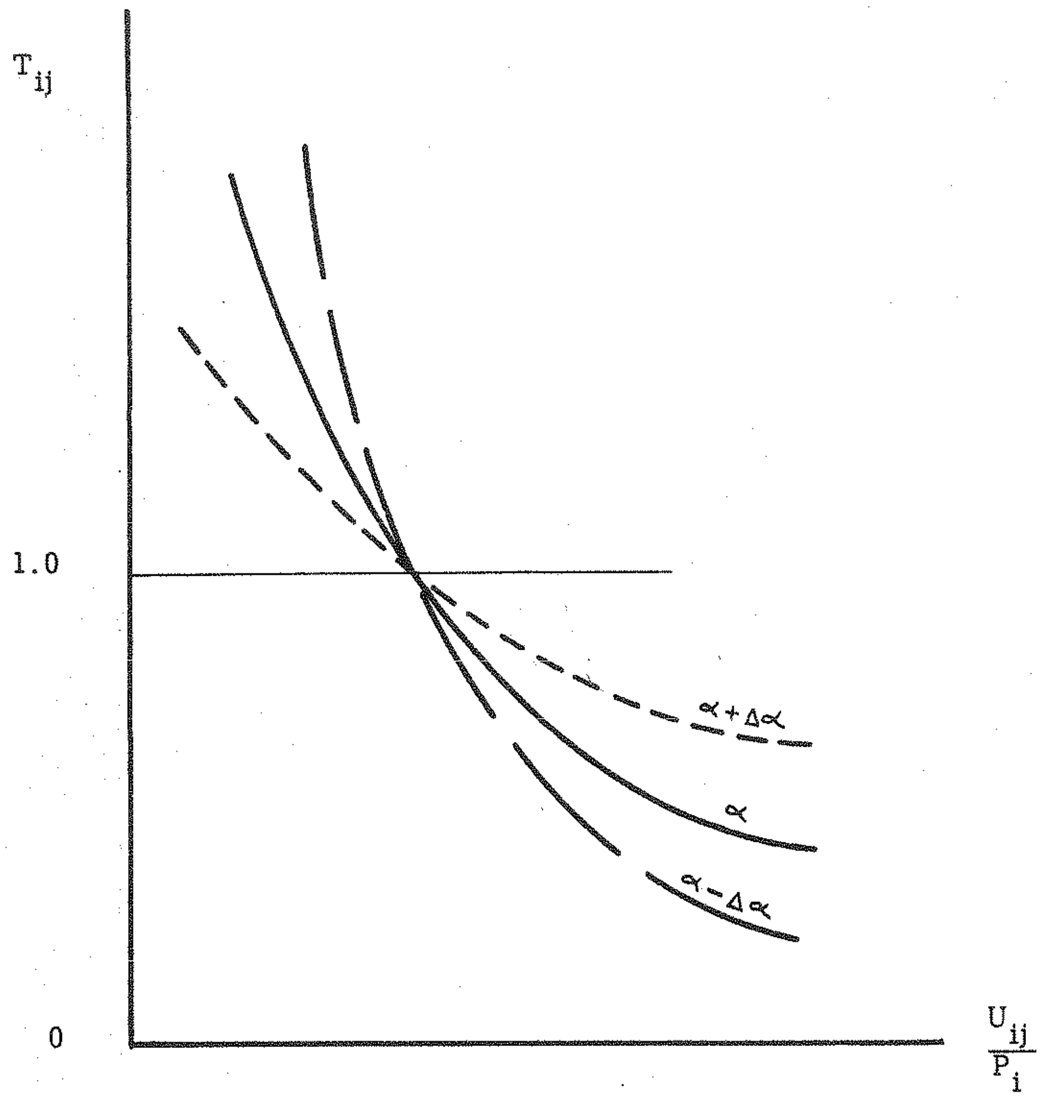

FIGURE II-4 EFFECTS OF BEHAVIORAL TRAVEL TIME PARAMETER CHANGE individuals might have available for recreation. The parameter γ in Equation 2-3 is a measure for the average individual's growth in real income. It was derived from:

$$\gamma_y = \frac{(EBI_y/CPI_y) - (EBI_{y-1}/CPI_{y-1})}{(EBI_{y-1}/CPI_{y-1})} \qquad (2\text{-}3)$$

This growth in individual income parameter used in a recreation demand multiplier, I_y, is as follows:

$$I_y = I_{y-1} + \gamma_y \qquad (2\text{-}4)$$

where y = index for calendar year.

The year 1960 was chosen as the base year (I_{1960}=1.00) because that is the first year for which visitation estimates became available. In essence, Equations 2-3,4 represent a steadily increasing recreation demand multiplier. This multiplier also has the ability to measure minor fluctuations in the annual rate of growth.

The product of demand multiplier and population will be called the "recreation propensity" of population center i:

$$RP_i = I * P_i \qquad (2\text{-}5)$$

Variations in disposable income are thus introduced into the model as an explanatory variable.

4. Sink Attributes

Sink attributes are properties of the supply of reservoir recreation. A quantitative value for the level of development and the availability of recreation facilities at a reservoir is incorporated in the model. The cumulative adjusted capital investment, CI_{jy}, was used for this purpose. Equation 2-6 shows how it is calculated.

$$CI_{jy} = \sum_{y_{jo}}^{y+y_{jo}} (IN_{jy}/BCI_y) \qquad (2\text{-}6)$$

A measure for the qualitative value of the uniqueness, scenic beauty, and aesthetics of a reservoir is also desired. A "quality coefficient", Q_j, is used as a sink attribute to represent this. The quantitative value of the quality coefficient can either be arbitrarily chosen or statistically estimated from the postulated model.

The model variable which would represent the supply of recreation at a reservoir is A_j. It will be called the pulling, or attractiveness index. It is taken to be the product of cumulative investment and the quality coefficient:

$$A_j = Q_j \ CI_j \qquad (2\text{-}7)$$

Figure II-5 shows that an increase in the attractiveness index would proportionately increase the per capita visitation.

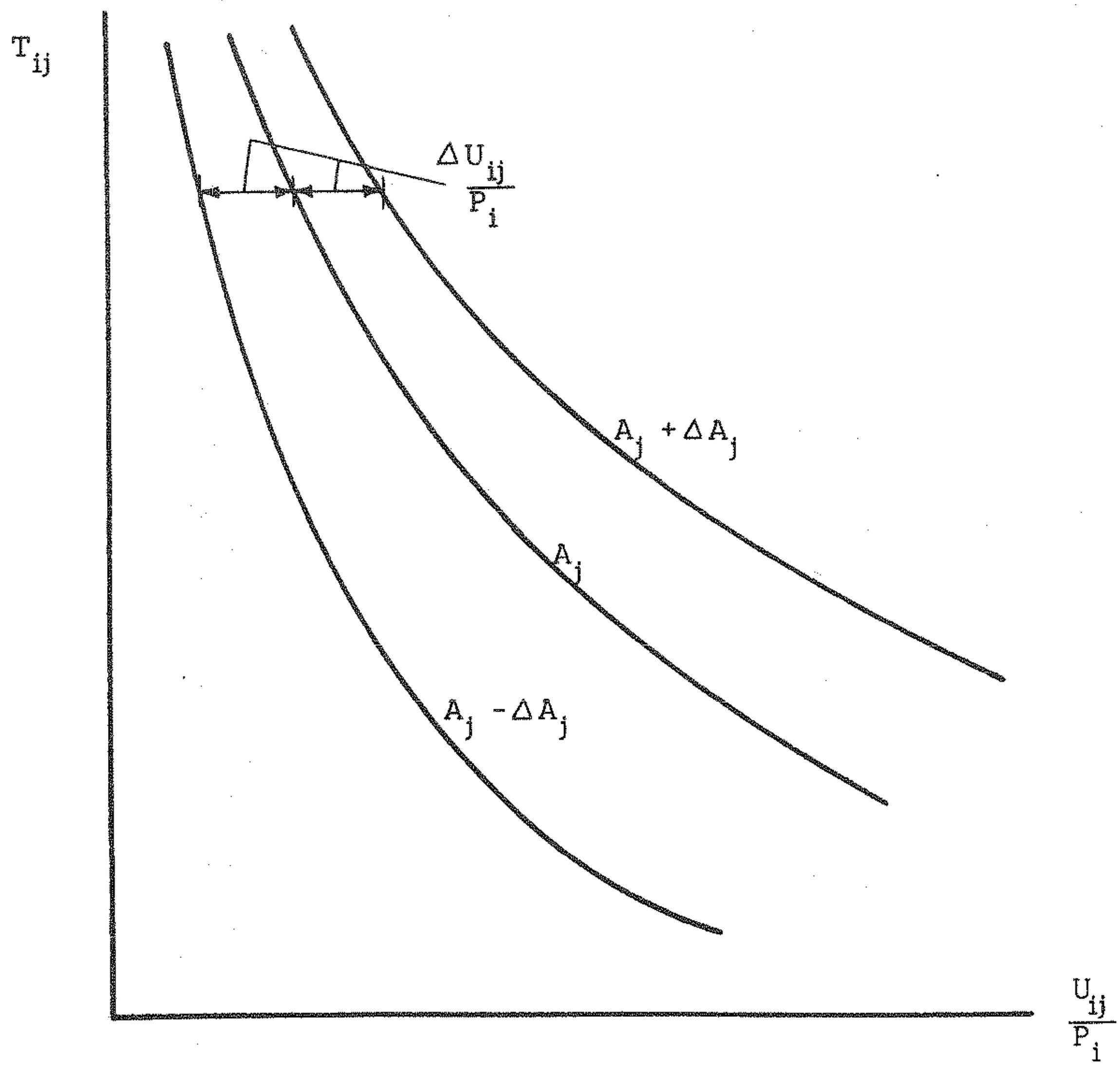

FIGURE II-5 EFFECTS OF ATTRACTIVENESS INDEX CHANGE

5. Modified Origin-Destination Model

The inclusion of the above attributes into the base model creates a "Modified Origin-Destination Model":

$$U_{ij} = (Q_j * CI_j) * (I*P_i) * T_{ij}^{-\alpha}$$

or

$$U_{ij} = A_j * RP_i * T_{ij}^{-\alpha} \qquad (2-8)$$

This model states that visitation to a reservoir from a population center is directly related to changes in either the supply or demand variables and that it is inversely related to travel time.

E. Constraints on Reservoir Recreation

The number of potential recreationists and the amount of time which they have available for recreation participation is limited. The number of recreation reservoirs and the size of their facilities is also limited. These two conditions constrain reservoir recreation, in effect imposing one flow constraint at each source (city) and another flow constraint at each sink (reservoir).

1. Sink Constraint

Previous studies on "sink" constraints have hypothesized that visits to a reservoir are constrained by psychological, as well as physical effects of crowding (Clawson and Knetsch, 1966; Sirles, 1968). Recreation areas often are designed and expanded with this in mind. A standard recreational visitation constraint is "carrying capacity", i.e. the limit to the use of recreational facilities for a given time period. This constraint sometimes is applied in the operation of reservoir recreation areas which are very small in size and located very close to large metropolitan areas (e.g. by closing the entrance gate when visitation exceeds some limit).

No such sink constraints have been adopted for the model. None of the reservoirs of the selected system fit the description just presented. Recreation specialists* in the Indiana Department of Natural Resources have expressed the opinion that reservoir recreation visits in Indiana have not yet been significantly constrained by crowding.

2. Source Constraint

A well-accepted economic empericism is that increased consumption of a good decreases the marginal utility of each additional unit. Accordingly, one may expect that there will be a demand constraint operative at each source, i.e. each population center. This would constrain visitation from sources if they become surrounded increasingly by sinks (i.e. reservoirs).

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*Interview with Mr. Jack Costello, Mr. Bill Walters, and Mr. Tom Huck of the Indiana Department of Natural Resources on June 30, 1973.

Although an effort was made to formulate a source constraint, it was not incorporated in the model. No satisfactory basis for selecting the constraint was found. Further comments on incorporating a source constraint are discussed in more detail in Chapter VI.

3. Systems Model

The modified origin-destination model discussed up to this point is only a forecasting model. Even though the formulated model has a causal basis for the selection of variables and relationships, it is not truly a systems model because no systems constraints have been incorporated. Application of systems constraints is a key feature (also, the feature often neglected in recreation visitation estimation work) in constructing a successful prediction model.

CHAPTER III

SELECTED SYSTEM AND THE DATA USED FOR MODEL CALIBRATION

A. Selected System

1. Sinks (reservoirs)

The selected sinks of the recreation reservoir network used for model calibration are the six Corps of Engineers reservoirs in Indiana which were in operation during all or part of the 1960-1972 time period. They were Cagles Mill Reservoir (operation began in 1953), Mansfield Reservoir (1960), Monroe Reservoir (1965), Salamonie Reservoir (1967), Mississinewa Reservoir (1968), and Huntington Reservoir (1969). Two other Corps of Engineers reservoirs, Brookville and Patoka, are presently under construction. Lafayette and Big Pine, two proposed Corps of Engineers reservoirs for which realization is presently stalled, are also located in Indiana. Figure III-1 shows the geographical location of these Indiana reservoirs.

The sets of reservoirs that were in operation during each of the years between the 1960-1972 time period were chosen as the model sinks. No reservoirs in Illinois, Michigan, Ohio, or Kentucky were made part of the network. The six reservoirs included in the sets are relatively

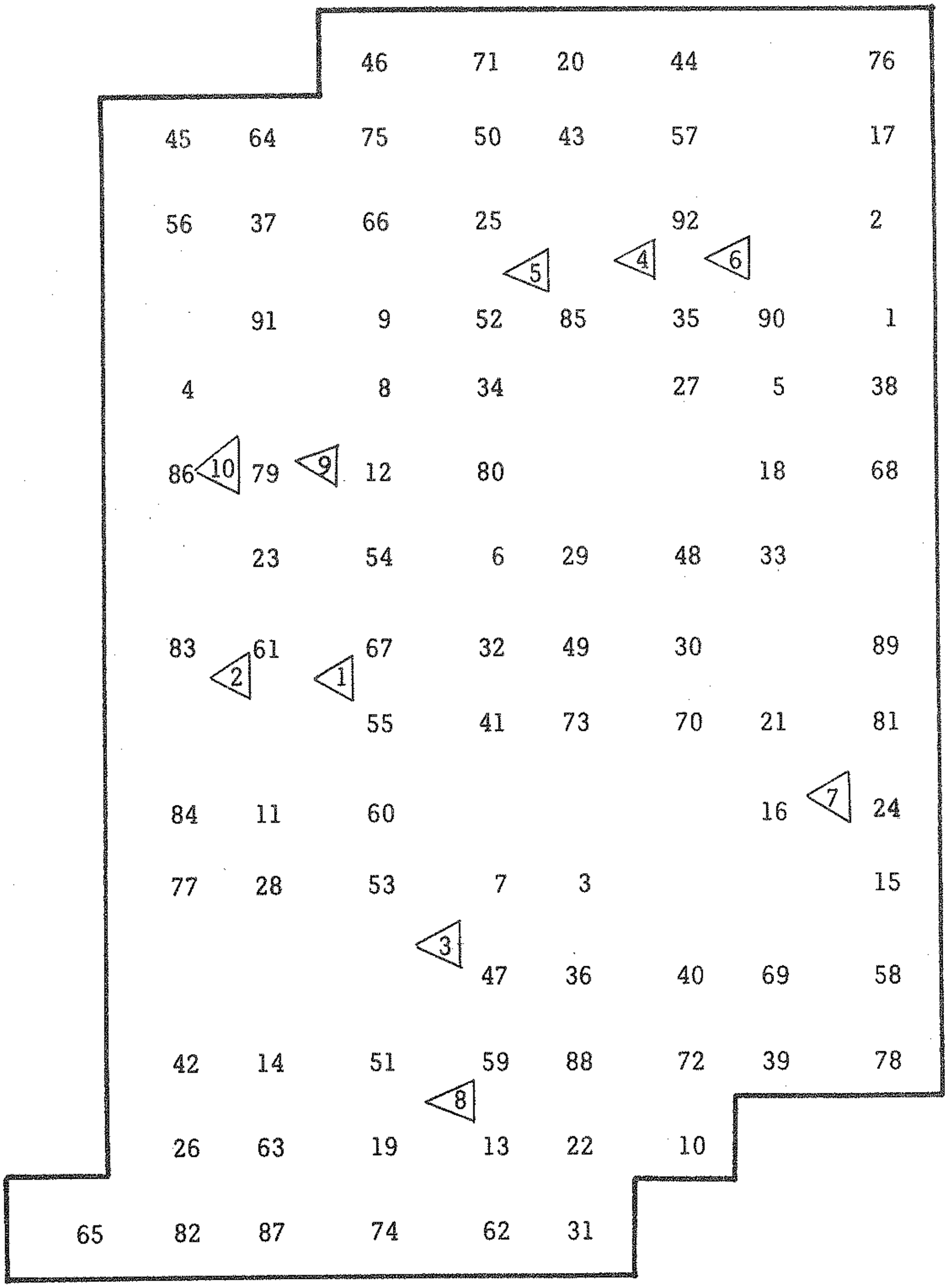

FIGURE III-1 INDIANA POPULATION CENTERS AND U.S. ARMY CORP OF ENGINEERS RESERVOIRS (See Appendix B for reservoir and county designations.)

isolated from other similar Federal recreation opportunities. Neglecting reservoirs in neighboring states permitted a simplification resulting in a finite-sized network model. Neglect of Lake Michigan and the Ohio River in the model are less defensible; however, visitation data for these areas were not available. The selected six reservoirs have in common that during the time period of interest, the recreation facilities of each of these was operated by the Indiana Department of Natural Resources.

2. Network Boundary

In keeping with the above limitation on network components, a corresponding geographic limitation on the population centra, or number of sources is introduced. This limitation is that recreationists are assumed to live in Indiana.

However, not all visitors to the six selected reservoirs originated their trips in Indiana. Mansfield and Huntington Reservoirs are each less than fifty miles from the Indiana border. Yet, a majority of the visits to the six reservoirs can be expected to have originated from Indiana sources, considering the location of the reservoirs and the population distribution around them. Initial results of weekend sample surveys (Appendix A) confirmed that 85-95% of visits came from Indiana sources. This percentage was considered large enough to obtain accurate results from the network sample. The Indiana visits were estimated by subtracting out the out-of-state visitation (multiplying visitation data by a deflation factor, DF_j) and by adopting the Indiana state line as the network boundary, i.e. as being impervious to incoming reservoir recreationists. Note that this assumes nothing about the efflux of Indiana reservoir recreationists, which may well be a substantial amount.

3. Sources (population centers)

Population centers in Indiana are the sources of the network. The designated location of every population center was the largest city of each Indiana county. The total county population was considered to originate its visits from that population center. Figure III-1 shows the location of Indiana's ninety-two population centers.

4. Links (highways)

The connector links of the network are the Indiana Highways. Average vehicle speeds were differentiated for four highway types - interstate (60 mph), federal (50 mph), state (45 mph), and city streets (25 mph)*. In calculating travel times, visits were taken to originate from the

*The average vehicle speeds were chosen after discussion with faculty of the Transportation Department, School of Civil Engineering, Purdue University.

Indiana population centers, and arrive via the shortest travel time route, entering the reservoir property at the closest access point. If an interstate and an alternative route had nearly equal times, the interstate route was chosen. Any combination of the above types of highways could form the shortest route.

B. Available Data

Table III-1 presents the data available for the selected system. Sources are referenced and listed below the Table. Definitions for the symbols are found in Tables II-1 through 5. Appendix B contains the raw data values.

C. Discussion of Data

1. Visits

The initial modeling attempts considered segregating visits by type of recreation activity (e.g. boating, picknicking, camping, hiking, etc.), but this procedure was eventually abandoned. Although standard units for participation in specific recreation activities have been adopted by some recreation specialists (Outdoor Recreation Resources Review Commission, 1962; Wabash River Basin Comprehensive Study, 1971), the process for commensuration of these units is ill-defined (U.S. Water Resources Council Special Task Force, 1970). Furthermore, good estimates of the durations of the different types of recreation

Table III-1. Available Data (for definitions of symbols See Tables II-1 through 5)

Variable	Time Period: Weekend (53 in 1965-1967)	Time Period: Annual (1960-1972)
Flows	V_{ijw}, N, DF_j [3]	$\sum_{i=1}^{I} U'_{ijy}$ [2]
Sources		P_{iy}, EBI_y [4]
Sinks		IN_{jy} [1,2*] Y_{jo} [2] BCI_y [6]
Links		D_h [7] SP_h, Y_h [8]

*Capital investments for Cagles Mill Reservoir were not available from 1953-1959.

SOURCES OF AVAILABLE DATA

1. Indiana Department of Natural Resources
2. U.S. Army Corps of Engineers, Louisville District
3. Joint Highway Research Project, Purdue University and Indiana State Highway Commission
4. Sales Management
5. U.S. Bureau of Labor Statistics
6. Engineering News Record
7. 1972-1973 Indiana Official Highway Map, Indiana State Highway Commission
8. Purdue University, School of Civil Engineering, Transportation Department

participation were not available from the visitation data, none of which contained the duration of the visits.

2. Weekend Surveys*

The weekend surveys yielded the V_{ijw}, N, and DF_j data in Table III-1. At three reservoirs (Cagles Mill, Mansfield, and Monroe) and during a number of weekends (not necessarily the same ones for each of the reservoirs), a 25% sample of cars entering at access points had been made. A total of fifty-three sets of such reservoir-weekend data sets was collected in a period covering the 1965-67 recreation seasons. For Indiana license plates, the county number of each car and the number of persons in each car was noted. Cars from states other than Indiana were also counted. The weekend surveys consisted of approximately 18,000 samples.

Since these surveys identified both the source and the sink of the sample visit, they were used for calibration of the origin-destination model.

3. Corps of Engineers' Estimates

Total annual visit estimates for each Federal recreation reservoir in Indiana were available from the Corps of Engineers. These estimates did not specify the sources of the visits; therefore, the data were used to calibrate the "Consumption Model" for individual reservoirs (see Section IV-D).

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*Data provided by Joint Highway Research Project.

4. Source and Sink Attributes

The source and sink data listed in Table III-1 except for the investments are for calendar year periods. The investments were computed on a fiscal year basis. Also, each annual capital investment at a reservoir was the sum of Corps of Engineers and Indiana Department of Natural Resources investments. Maintenance costs were neglected assuming that these would be proportional to investment and would not have an independent effect.

Some transformations of the raw data were made to adjust for inflation. These adjustments are discussed in detail in Chapter II.

5. Links

The interstate highway system in Indiana was under construction during the 1960-1972 time period. Since completion of a section of interstate could and did change travel patterns and trip durations, travel times were adjusted from year to year, as interstate construction was completed. The better overall condition of Indiana roads and the development of faster automobiles also caused the estimated travel times to be shortened slightly each year.

CHAPTER IV

CALIBRATION OF THE MODEL

A. Model Parameters

There were two sets of model parameters to be calibrated. The first parameter was the average behavioral travel time parameter, $\bar{\alpha}$, in the origin-destination model. The second parameter was the recreation quality coefficient, Q_j, for each of the reservoirs.

The first parameter, $\bar{\alpha}$, was constrained to be an averaged constant throughout the sampling period considered herein. A compelling reason for selecting $\alpha \neq \alpha\ (t)$ is that the data available for calibrating, i.e. fixing the value of α, only covered a period of three years, which is too short to establish a trend. By contrast, the parameters Q_j were assumed to be time dependent.

B. Modified Origin-Destination Model

A calibration of the modified origin-destination model was performed so that the value of the behavioral travel time parameter α for the "one population center - one reservoir" case might be estimated. As explained in Chapter III, the weekend sample surveys made for the JHRP under the direction of Dr. William Grecco were used for the calibration.

In order to use linear regression analysis, a rearranged and transformed version of the modified origin-destination model was used, namely Equation 4-2. The original equation from which α was derived is:

$$U_{ijw} = A_j * RP_i * T_{ij}^{-\alpha} \tag{2-8}$$

When expanding the various terms using the definitions in the Tables II-1 through 5, one can obtain:

$$(V_{ijw} * N) = (Q_j * CI_j) * (I * P_i) * (T_{ij})^{-\alpha}$$

or:

$$V_{ijw}/P_i = (Q_j * CI_j * I/N) * T_{ij}^{-\alpha}$$

let:

$$K = Q_j * CI_j * I/N$$

then:

$$V_{ijw}/P_i = K * T_{ij}^{-\alpha} \tag{4-1}$$

Taking logarithms one obtains the linear model or regression equation:

$$\log (V_{ijw}/P_i) = \log K - \alpha \log T_{ij} \tag{4-2}$$

Other transformations were suggested to eliminate possible heteroscadasticity in the visition data, but none of them significantly improved the results (Matthias, 1967; Robinson, 1970).

The cumulative investment, CI_j, the demand multiplier, I, and the average visits per trip N, were found to be insignificant variables because they are constant for particular reservoir-weekend regression equations. In other words, for a given weekend, the I, Q_j, CI_j, and N variables do not depend on the links associated with each $V_{ijw}/P_i - T_{ij}$ set. Regressions were made on the transformed Equation 4-1 because it best represented the most basic, causal model structure (see Section II-D). The behavioral travel parameter α is one of the regression parameters of the origin-destination model. The other regression parameter, K, contains the only other unknown model parameter, namely the quality coefficient, Q_j.

Table IV-1 shows the results of the reservoir-weekend regressions. The behavioral travel time parameter is seen to vary from 0.14 to 2.01 and the K-values range from 0.309×10^{-4} to 2.76×10^{-4}. The correlation coefficients of the regressions have values from 0.117 to 0.880, where 1.000 signifies complete correlation.

The Figures IV-1, 2 show the existance of weak trends of α with R, the correlation coefficient value and with K, the other regression parameter containing the quality coefficient. Larger α-values gave better correlation (higher R's), as shown in Figure IV-1. The larger α-values came from bigger sample sizes (larger K's), as shown in Figure IV-2. Possible dependencies on other proposed

Table IV-1. Reservoir-Weekend Regressions

No.	Date	Reservoir	Parameter α	Parameter $K(10^{-4})$	Correlation Coefficient R
1	6/11-13/65	Mansfield	1.90	2.11	.812
2	6/25-27/65		1.89	2.76	.880
3	7/9-11/65		1.91	2.59	.863
4	7/23-25/65		1.37	1.42	.798
5	8/6-8/65		1.65	2.61	.868
6	8/20-22/65		1.81	1.85	.833
7	5/27-29/66		1.49	1.66	.795
8	6/3-5/66		1.68	1.40	.830
9	7/1-3/66		1.61	1.57	.803
10	7/8-10/66		1.32	1.07	.826
11	7/15-17/66		1.66	.990	.871
12	8/5-7/66		1.39	.904	.810
13	10/14-16/66		0.25	.432	.244
14	5/13-15/66		1.56	.757	.810
15	7/14-16/67		1.86	1.97	.828
16	7/27-29/67		1.60	1.56	.791
17	8/4-6/67	Mansfield	1.81	2.08	.866
18	6/18-20/65	Cagles Mill	2.01	1.27	.814
19	7/2-4/65		1.73	2.06	.801
20	7/16-18/65		1.88	1.10	.858
21	7/30-8/1/65		0.86	.708	.510
22	8/13-15/65		1.88	1.12	.833
23	11/19-21/65		1.30	.309	.846
24	4/1-3/65		1.84	.987	.810
25	4/29-5/1/66		1.05	.774	.553
26	5/13-15/66		1.14	.479	.667
27	5/20-22/66		1.21	.585	.586
28	5/27-29/66		1.78	1.07	.875
29	6/10-12/66		1.74	1.73	.763
30	7/8-10/66	Cagles Mill	1.82	1.50	.781

Table IV-1. (Continued)

No.	Date	Reservoir	Parameter α	Parameter $K(10^{-4})$	Correlation Coefficient R
31	7/15-17/66	Cagles Mill	1.64	1.59	.744
32	--	|	--	--	--
33	6/23-25/67	|	1.98	1.44	.818
34	7/7-9/67	|	1.73	1.08	.767
35	8/11-13/67	Cagles Mill	1.39	1.02	.769
36	6/18-20/65	Monroe	0.99	.767	.676
37	7/2-4/65	|	1.48	1.11	.760
38	7/16-18/65	|	1.68	1.15	.764
39	7/30-8/1/65	|	1.85	1.16	.783
40	8/13-15/65	|	1.71	1.16	.785
41	6/24-26/65	|	1.60	1.26	.747
42	7/22-24/66	|	1.47	1.54	.779
43	7/29-31/66	|	1.77	1.66	.818
44	8/12-14/66	|	1.71	1.14	.838
45	6/16-18/67	|	1.73	2.02	.854
46	6/30-7/2/67	|	1.69	2.62	.830
47	7/21-23/67	|	1.84	2.70	.830
48	10/21-23/66	Monroe	0.96	.784	.677
49	10/15-17/65	Mansfield	1.06	.888	.709
50	11/19-21/65	|	1.36	.413	.805
51	4/1-3/66	|	0.97	.510	.629
52	4/29-5/1/66	|	1.36	.992	.780
53	5/6-8/66	|	1.15	.627	.759
54	10/14-16/66	Mansfield	0.14	.428	.117

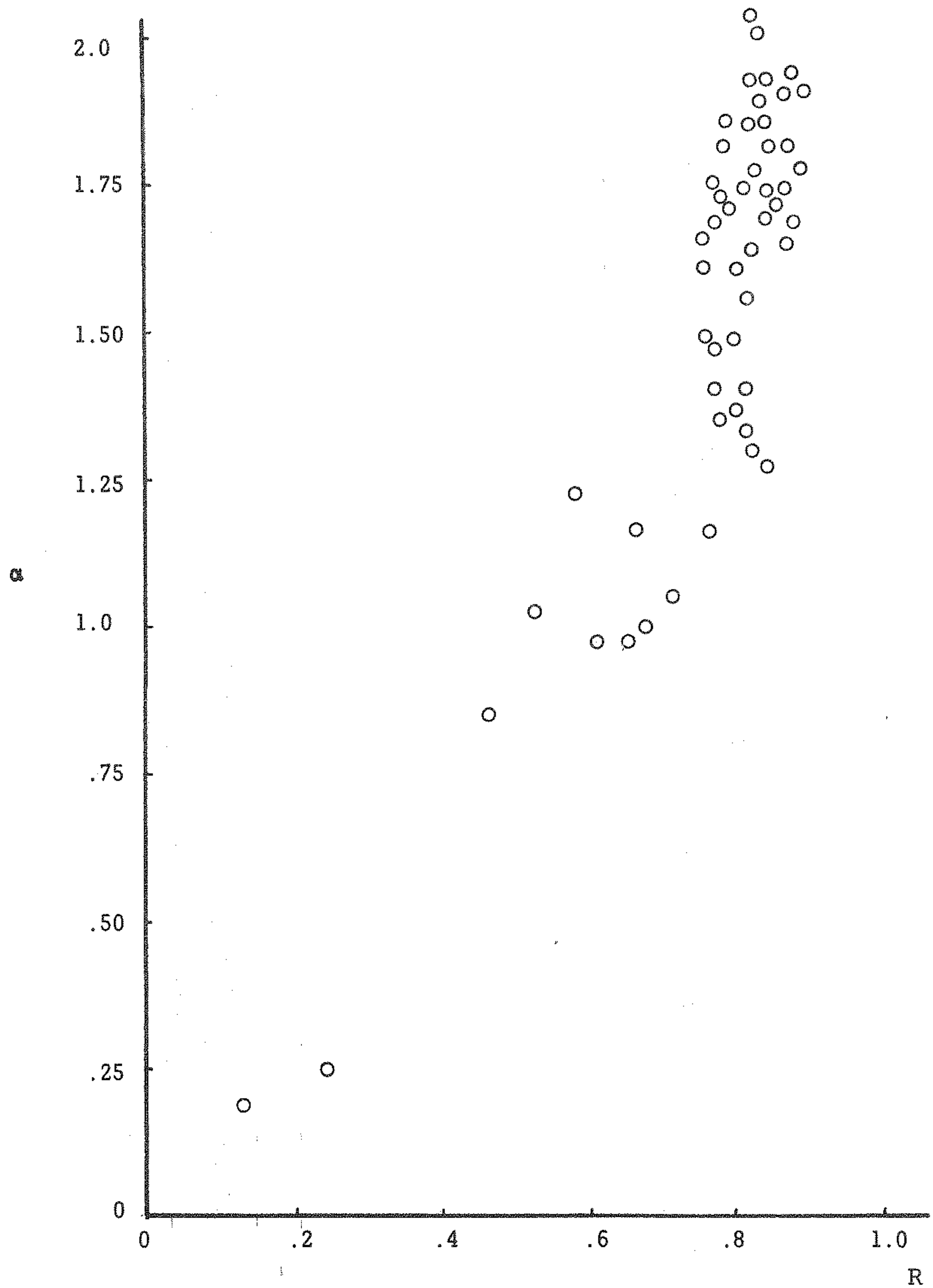


FIGURE IV-1 BEHAVIORAL TRAVEL TIME PARAMETER VS. CORRELATION COEFFICIENT

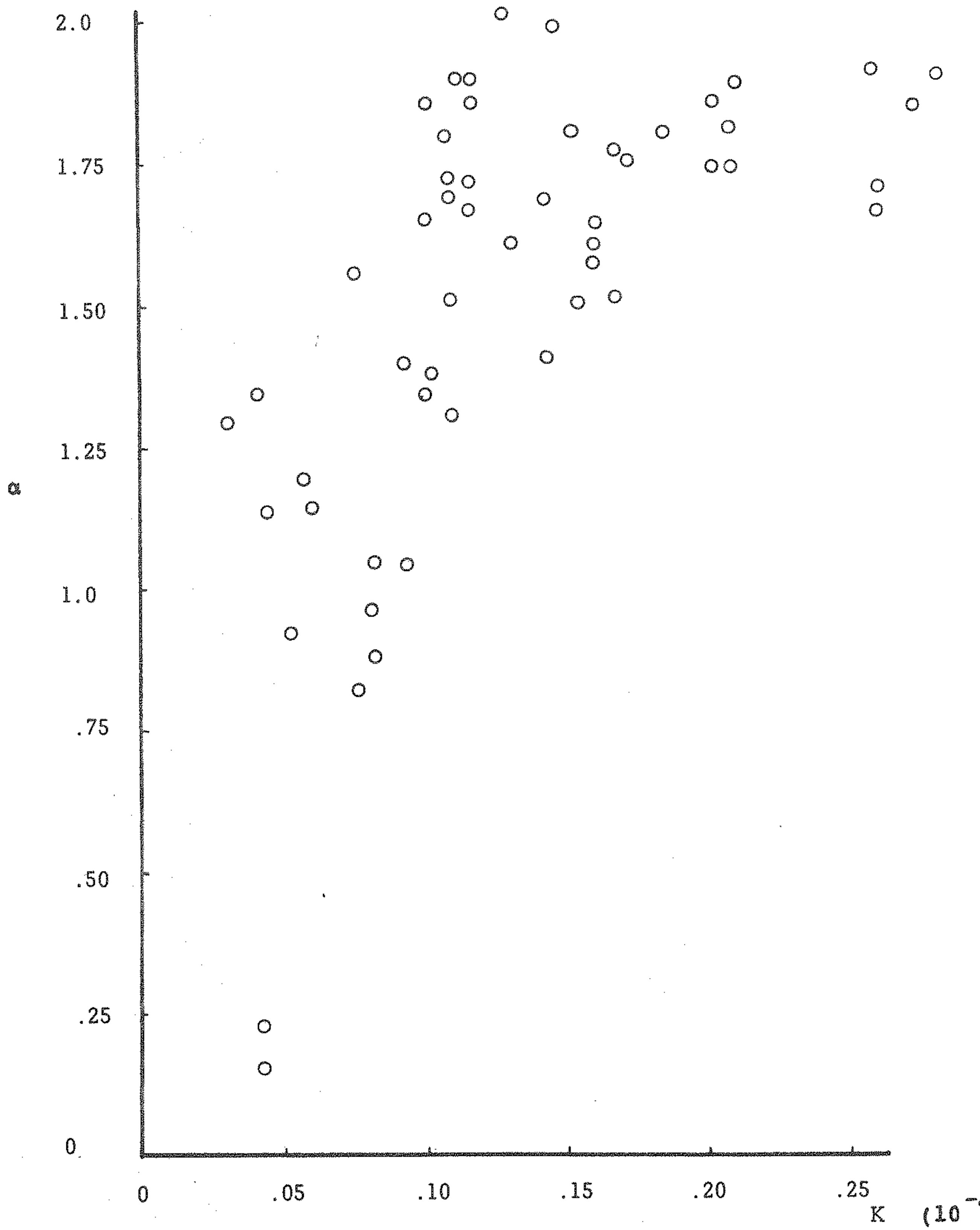


FIGURE IV-2 BEHAVIORAL TRAVEL TIME PARAMETER VS. REGRESSION PARAMETER CONTAINING QUALITY COEFFICIENT variables, such as weather or season of the year, were investigated but found to be insignificant (see Appendix C).

Since the resulting α-values were observed to be independent of both reservoir and year (see Table IV-1), it was decided to use one average α-value for further calibration of the consumption model (see Section IV-B). The α-values from those regressions that had correlation coefficients larger than a selected value, namely $R \geq 0.730$, were averaged as shown in Equation 4-3:

$$\bar{\alpha} = \left(\sum_{m=1}^{M} \alpha_m \right) / M \qquad (4\text{-}3)$$

This averaged α-value was calculated to be 1.67, which compares favorably to other previous estimates (Schulmann and Grecco, 1964; James and Lee, 1971).

C. Consumption Model

Using the estimated behavioral travel time parameter value, $\bar{\alpha}$, resulting from the modified origin-destination model calibration, the consumption model for reservoir-year combinations was calibrated. The consumption model is similar in structure to the modified origin-destination model, but does have a few differences.

To permit calibration of an annual visitation model using the $\bar{\alpha}$-value obtained from weekend data calibration, a scaling or "blow-up" factor, B, is introduced. Its use implies that the annual visitation patterns and causes are the same as the weekend-visitation patterns and causes. James and Lee (1971) ascertained that behavioral patterns on weekends are similar in nature to behavioral patterns over an annual time base. Adopting this finding, weekend visits were converted to annual visits by a blow-up factor B according to Equation 4-4:

$$U_{ijw} = B * U_{ijy} \tag{4-4}$$

Then, by applying the averaged behavioral travel time parameter to the modified origin-destination model with an annual time base, Equation 4-5 is obtained:

$$U_{ijy} = Q_{jy} * CI_{jy} * I_y * P_{ij} * T_{ijy}^{-\alpha} \tag{4-5}$$

The annual visitation estimates made available by the Corps of Engineers consist of annual reservoir attendances. These are: $\sum_i U'_{ijy}$-values. They cannot be used directly in Equation 4-5. Rather, Equation 4-5 must first be transformed into an aggregated origin-destination model, called a "Consumption Model". This is done by summing Equation 4-5 over all network population centers for each reservoir. This gives the consumption model, Equation 4-6:

$$\sum_{i=1}^{I} U_{ijy} = Q_{jy} * CI_{jy} * I_y * \sum_{i=1}^{I} (P_{iy} * T_{ijy}^{-\bar{\alpha}}) \tag{4-6}$$

Because the Corps of Engineers visitation estimates give visitation from all population centers and not just the network population centers in Indiana (the only ones considered herein; see Section II-C), the annual visitation data were multiplied by a deflation factor. The deflation factor, i.e. the network percentage of total visits must be applied to the Corps of Engineers aggregated estimates to factor out the visits originating from outside the selected network boundary. This is defined as:

$$\sum_{i=1}^{I} U_{ijy} = DF_j \sum_{i=1}^{I} U'_{ijy} \qquad (4\text{-}7)$$

where DF_j = deflation factor for reservoir j.

Each of the six reservoirs has its own deflation factor. The deflation factors for Cagles Mill, Mansfield, and Monroe Resèrvoirs were determined from the weekend sample surveys. The deflation factors for Salamonie, Mississinewa, and Huntington Reservoirs (for which no weekend data are available) were interpolated from a graph showing the deflation factor versus distance from the Indiana state line, Figure IV-3.

D. Consumption Model Calibration Results

The yearly quality coefficients Q_{jy}, can now be computed for the six reservoirs during the 1960-1972 time period from a computer program containing the consumption model (see Appendix E). Figure IV-4 presents these results.

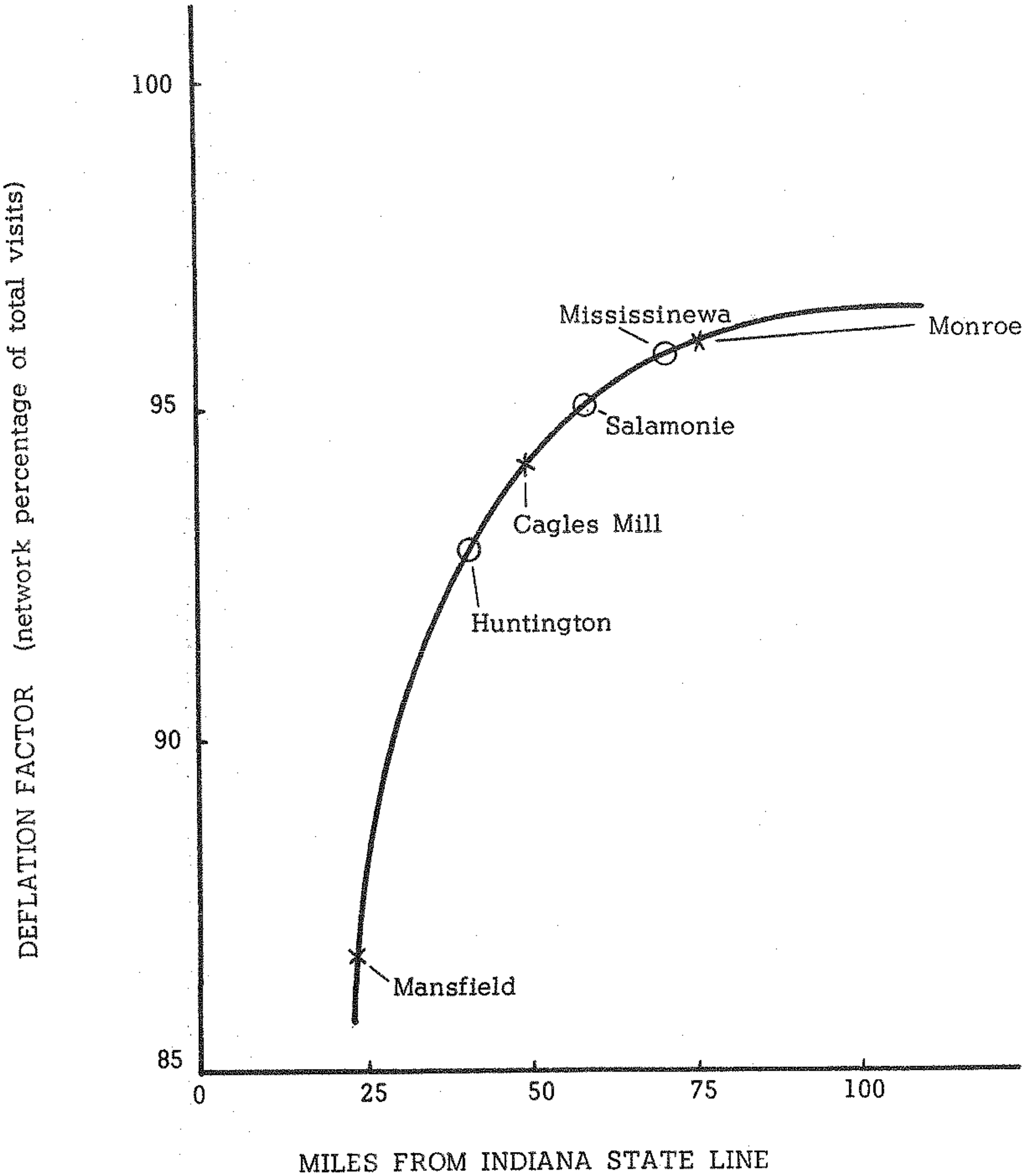


FIGURE IV-3 DEFLATION FACTOR CURVE

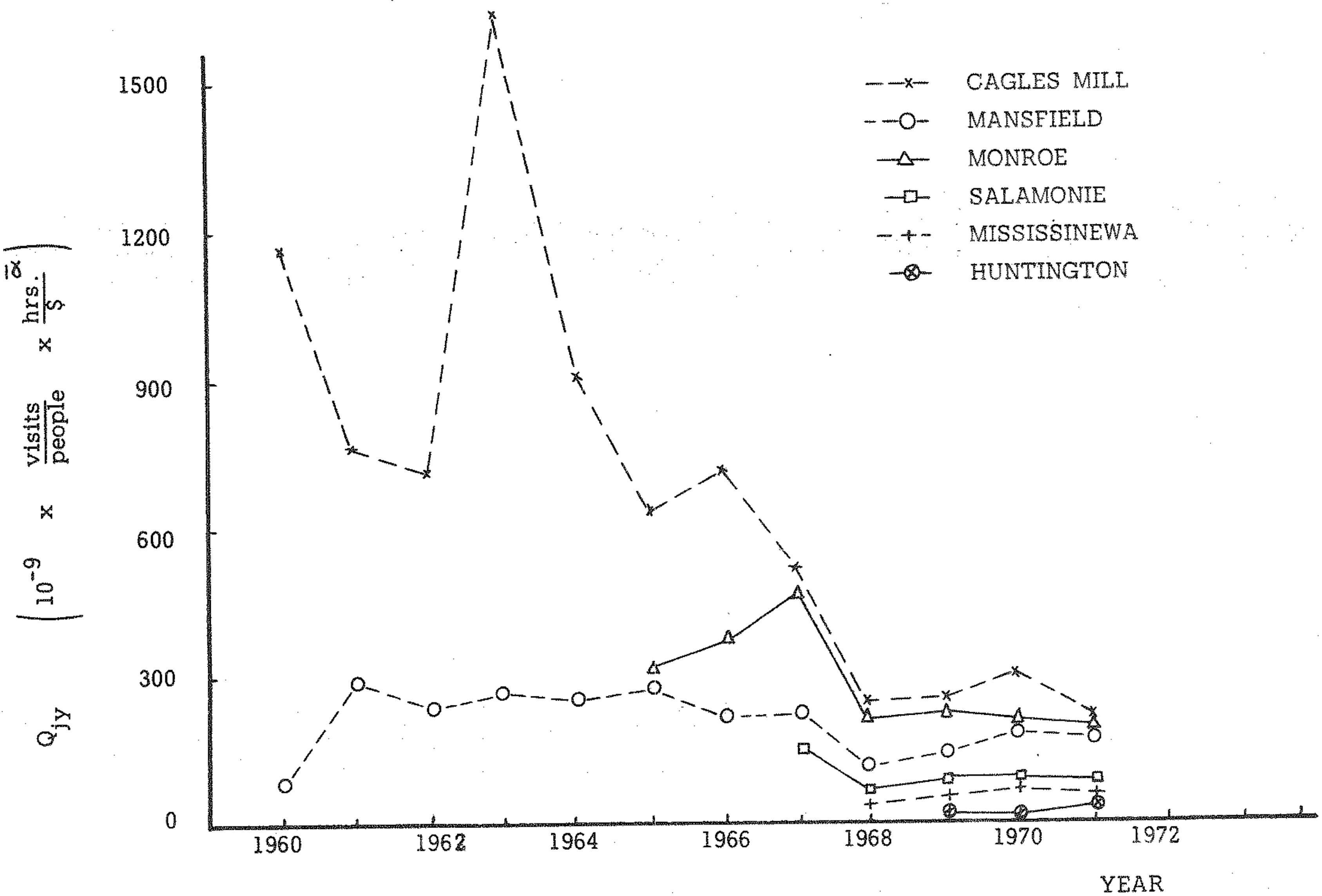


FIGURE IV-4 QUALITY COEFFICIENTS

Before discussing these results, it should be noted that the quality coefficient is supposed to be a measure of the "natural quality" of a reservoir (Section II-D). These estimates reflect a reservoir's appeal to recreationists, based on subjective factors such as uniqueness and natural beauty and more objective factors, such as investments made for site development. The trends observed in Figure IV-4 might indicate preferences and fashion among recreationists. They also contain variations which associate with all the factors not considered herein.

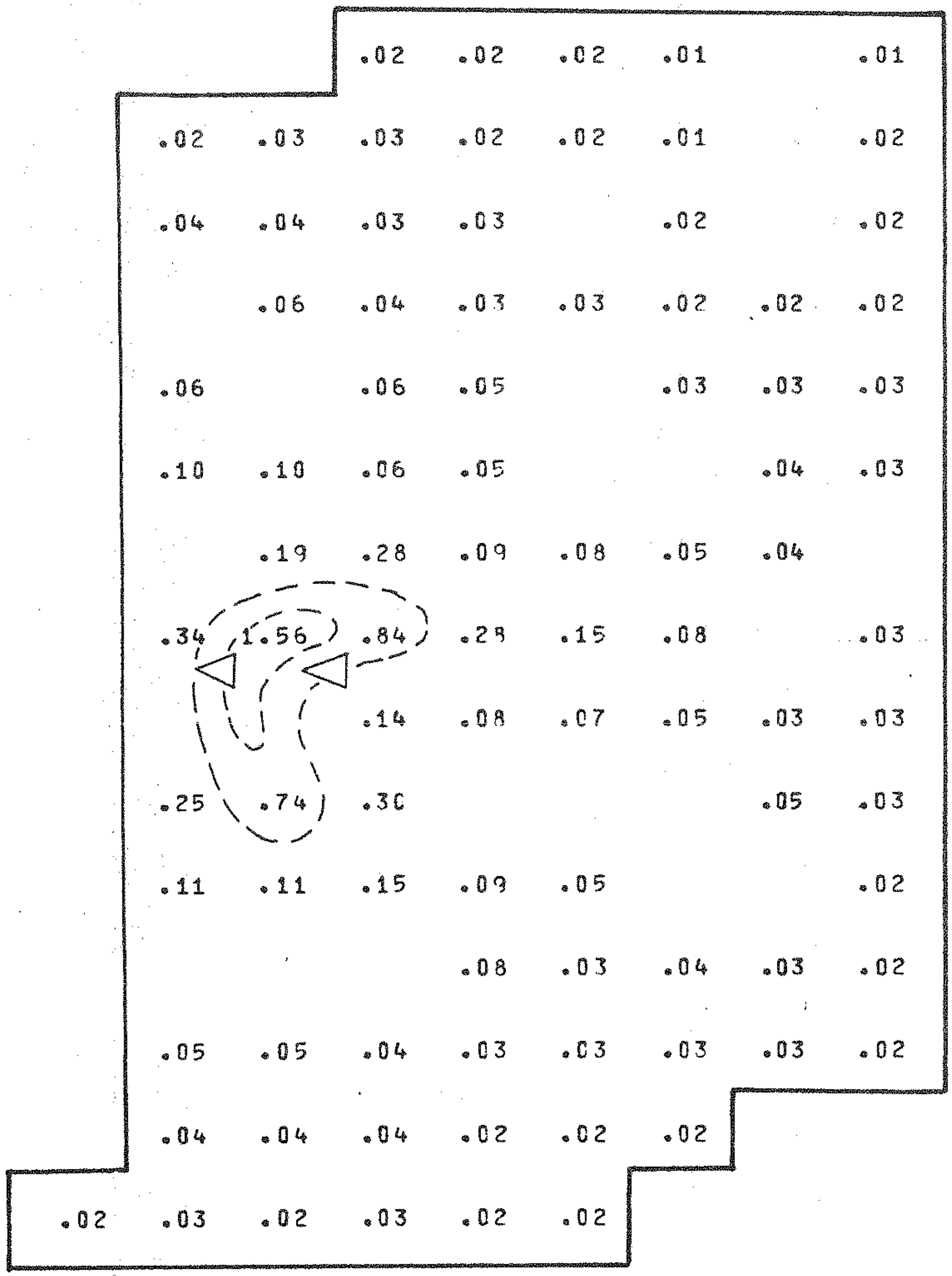
A first observation from Figure IV-4 is that calibrations for all of the reservoirs, except for Cagles Mill, yield fairly stable and consistent quality coefficient estimates. No explanation is offered for the extraordinarily large value for Cagles Mill in 1963. It quite possibly could have been some external influence. The overall downward trend of the Cagles Mill quality coefficient, and to a lesser extent, a downward trend for Mansfield and Monroe Reservoirs, might have been due to the introduction of competitive opportunities over the years in question.

A conclusion that Huntington Reservoir had less recreation appeal during these years than the other reservoirs could be supported by the fact that motorboats were not allowed there during that time period.

Monroe reservoir showed a gradually increasing quality coefficient for its first three years, then fell off for the next four. During the last year for which its quality coefficient increased, Monroe Reservoir had the largest annual attendance ever estimated for an Indiana Federal reservoir. It may have been that some recreationists have stayed away from Monroe since that time to avoid observed and well-known heavy traffic and long lines at public boat ramps during periods of peak use.

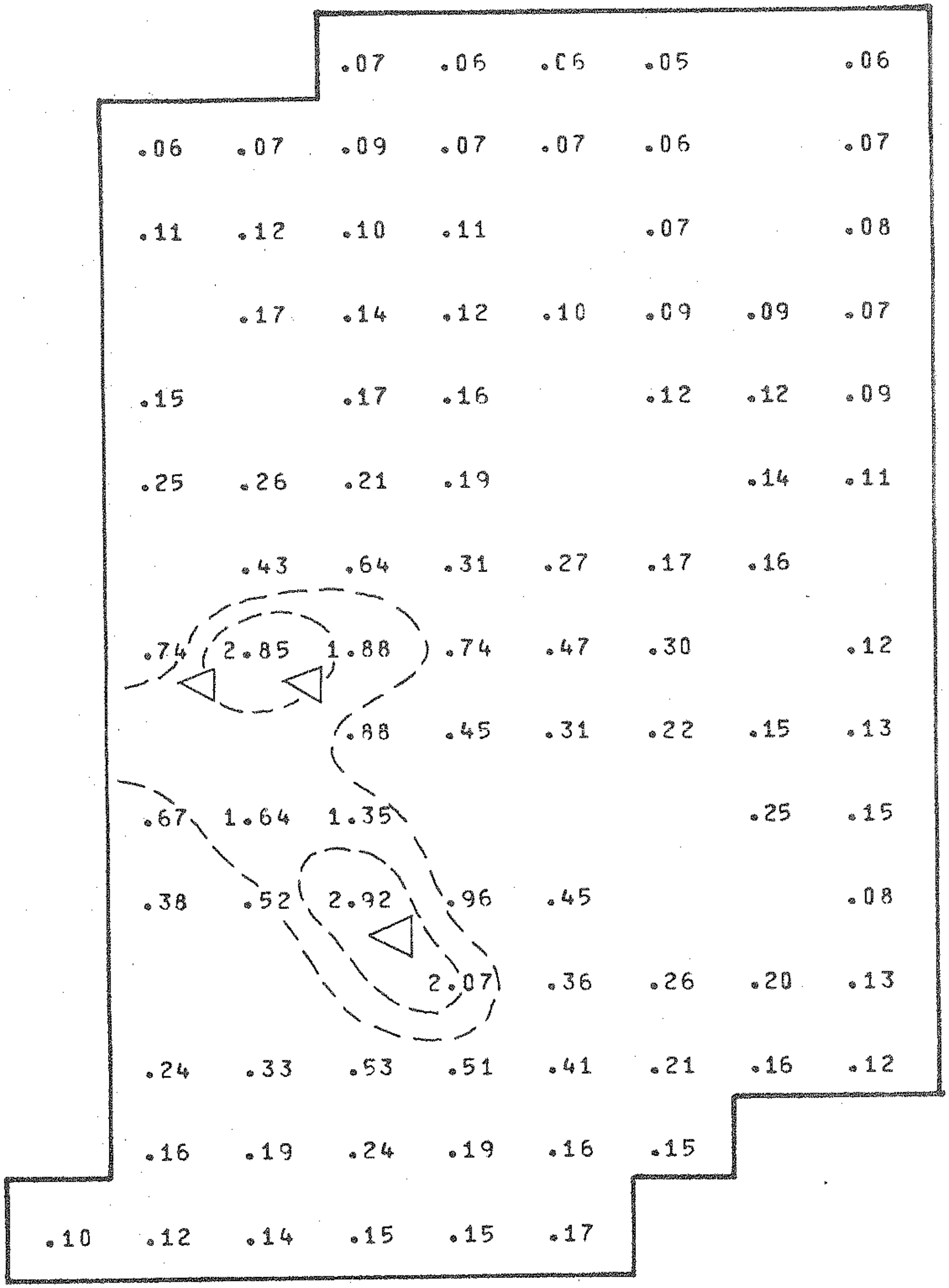
E. Annual Per Capita Visitation Rates

Using the quality coefficients obtained in Section IV-D, total annual per capita visitation rates for each population center, $\sum_{j=1}^{J} U_{ijy}/P_{iy}$, can be calculated in the computer program. Figures IV-5, 6, and 7 present estimated rates for 1961, 1966, and 1971, respectively. Visitation rates are contoured on an Indiana map so that the intensity of recreation use by geographical area might be shown. The shifting of these use intensities after the introduction of new reservoirs into the network is apparent. Comparison of the 1961 and 1966 map patterns clearly shows the influence of Monroe Reservoir on recreation use. The effects on recreation use from the operation of the Upper Wabash River reservoirs, Salamonie, Mississinewa, and Huntington, is evident by comparing the contour patterns of the 1966 and 1971 maps.



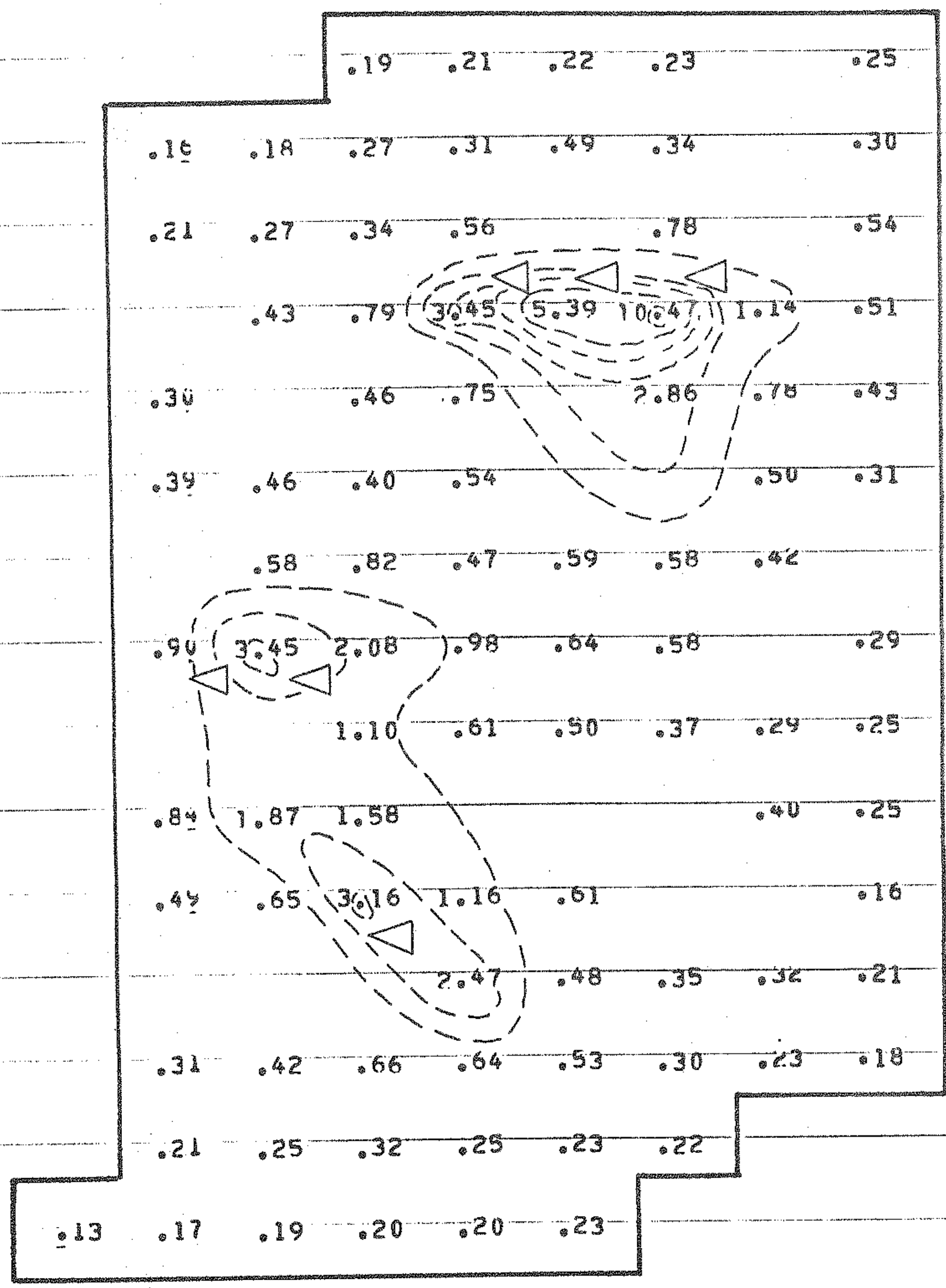
408,900 ANNUAL VISITS

FIGURE IV-5 PER CAPITA VISITATION RATES FOR 1961



1,596,500 ANNUAL VISITS

FIGURE IV-6 PER CAPITA VISITATION RATES FOR 1966



3,818,500 ANNUAL VISITS

FIGURE IV-7 PER CAPITA VISITATION RATES FOR 1971

CHAPTER V

MODEL USE IN FORECASTING VISITATION

The results of the calibration of the annual consumption model in Chapter IV may now be used to forecast reservoir visitation. The origin-destination model can be used to forecast the consequences to reservoir recreation visitation from changes in systems features, such as:

a. additional reservoirs

b. relative changes in the attractiveness of reservoirs due to facility investment policies

c. changes in population

d. changes in exogenous constraints, e.g. speed limits and road capacities that become binding.

These possible changes will first be described (Sections A through D). Following this the computed model response to these changes will be presented and discussed.

A. Additional Reservoirs

The network of Indiana Federal reservoirs now includes Cagles Mill, Mansfield, Monroe, Salamonie, Mississinewa, and Huntington Reservoirs. There are also two reservoirs under construction, Brookville and Patoka. They are certain to be operative in the future. Two reservoirs in northwestern Indiana, Big Pine and Lafayette, seem to have the best chance of being built, if one estimates the likelihood of construction of all proposed Indiana reservoirs. The construction of Big Pine and Lafayette is presently delayed. There is opposition to their construction, and the present model can contribute to an assessment of the impact on recreation of their being, or not being, built. Even if their construction were to begin now, they could not be operated much before 1980.

The network configurations that have been used with the forecasting model to obtain reservoir recreation estimates are the following:

1. An Eight Reservoir Network - this includes the existing six reservoirs plus those now under construction
2. A Ten Reservoir Network - this includes Big Pine and Lafayette Reservoirs

B. Facility Investment Policies

The past facility investment policies for the six existing Indiana reservoirs is presented in Figure V-1. Cumulative capital investments versus year of operation are graphed. As shown in the figure, more or less identical capital investment rates (CI_j per year) occurred at the six reservoirs. Cagles Mill Reservoir is probably an exception because it is the oldest lake and a capital investment policy was yet being developed. After three or four years,

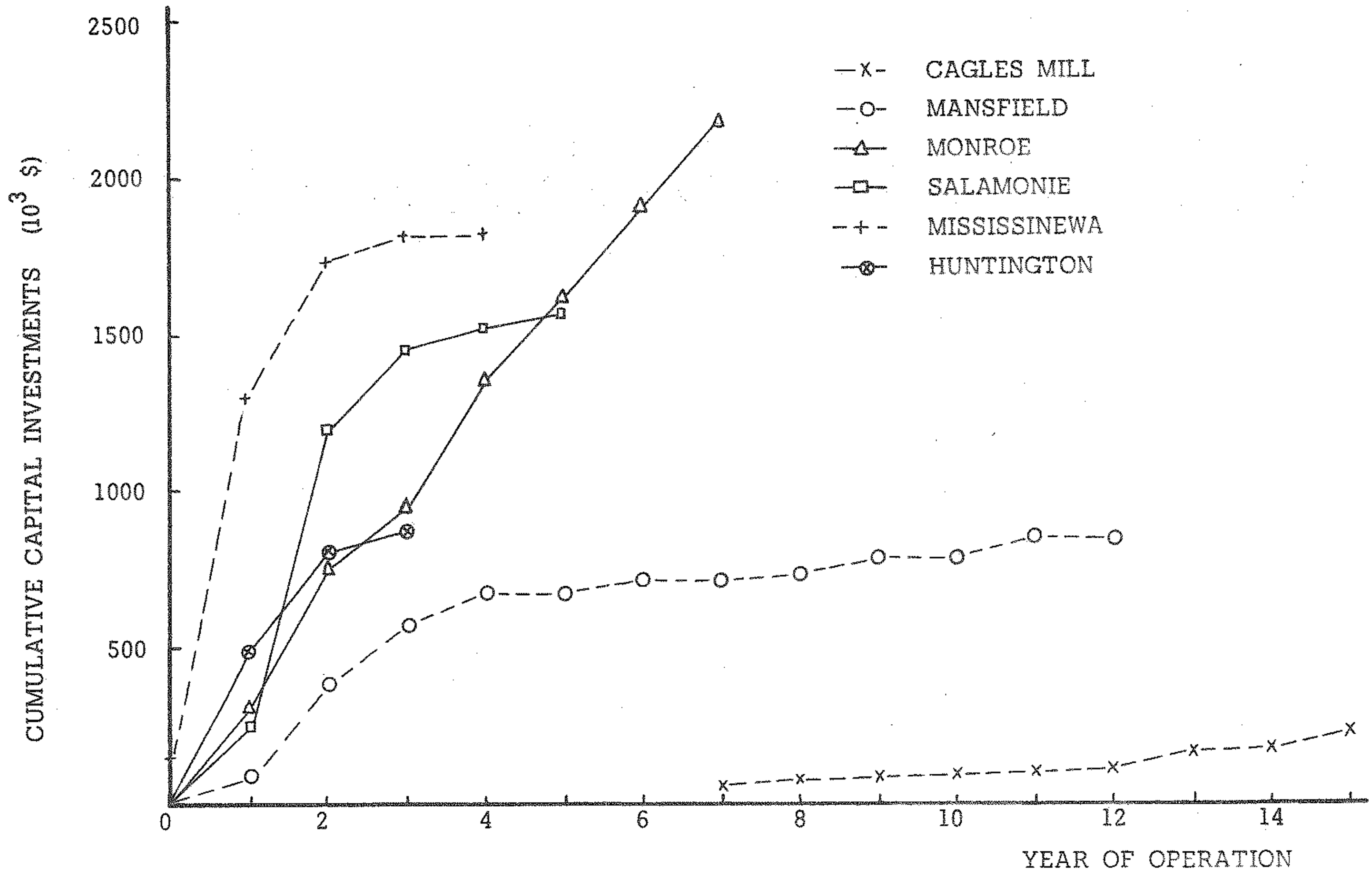


FIGURE V-1 RESERVOIR INVESTMENT POLICIES the rate of capital investment at a reservoir begins to decline; consequently, the cumulative capital investment levels off. The total investment at a reservoir may be expected to be dependent on reservoir characteristics and proximity to large metropolitan areas. In order to better estimate the final "level of development", as it might be estimated from the leveling-off of facility investments at a reservoir, it was decided to account for reservoir characteristics in terms of the length of shoreline. This characteristic is taken to represent a reservoir's potential for development. Therefore Figure V-2 shows for the six existing lakes the cumulative capital investments per mile of a particular reservoir's shoreline versus year of operation of that reservoir. It appears that each reservoir has its own "level of development". From this information, some extrapolated investment patterns for the existing reservoirs are shown in Figure V-2. How close the extrapolations are to the actual, future investment patterns depends upon what investment policies are adopted in the coming years. For the reservoirs under construction or only proposed, it will be assumed that they follow investment patterns of "similar" reservoirs. Similarity is judged in terms of proximity to metropolitan areas and topography (flat land or rolling hills). The assumed similarities are:

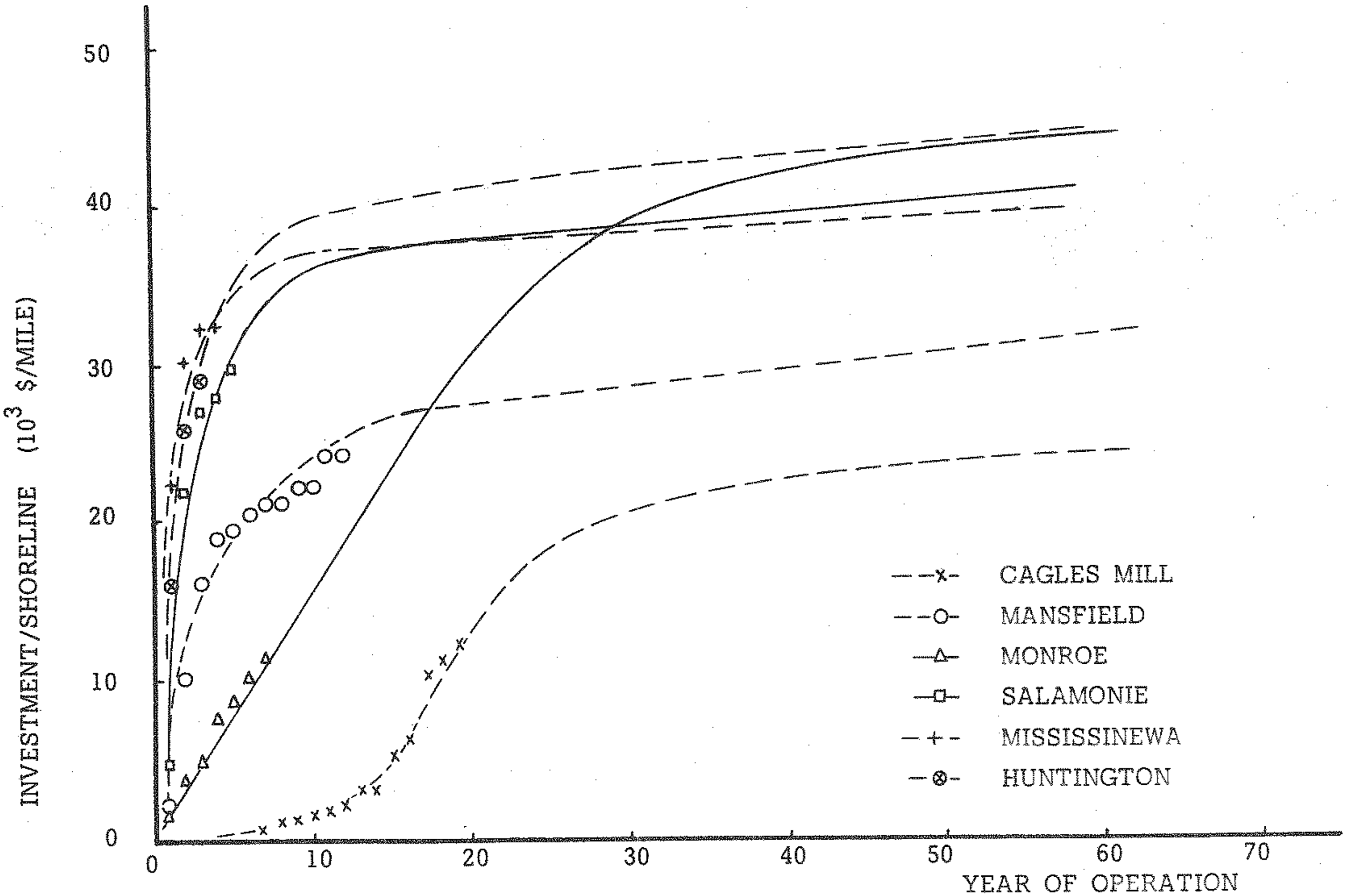


FIGURE V-2 EXTRAPOLATED RESERVOIR INVESTMENT POLICIES

1. Brookville-Mississinewa-Salamonie
2. Patoka-Monroe
3. Big Pine-Huntington
4. Lafayette-between Monroe and Salamonie

C. Population

Population predictions for Indiana are presented in Figure V-3. Series B represents an increasing birthrate and inward migration for Indiana. Series C shows the effect of a slight increase in birthrate and no inward migration. Series A contains a declining birthrate and no inward or outward migration for Indiana. Series A best represents today's situation. The ratios of Indiana population in 1980, 2000, and 2020 to the 1960 Indiana population may be used to estimate the future sizes of Indiana population centers. The 1960 population of each center was multiplied by the appropriate ratio to obtain a particular forecasted population.

D. Exogenous Constraints

The origin-destination model developed in Chapter II described recreation visitation for a closed system. In real life there are very few closed systems. Even now, an exogenous constraint has just been put on recreation. The 55 mph maximum speed limit imposed throughout the country will lengthen travel times. This will probably constrain recreational travel.

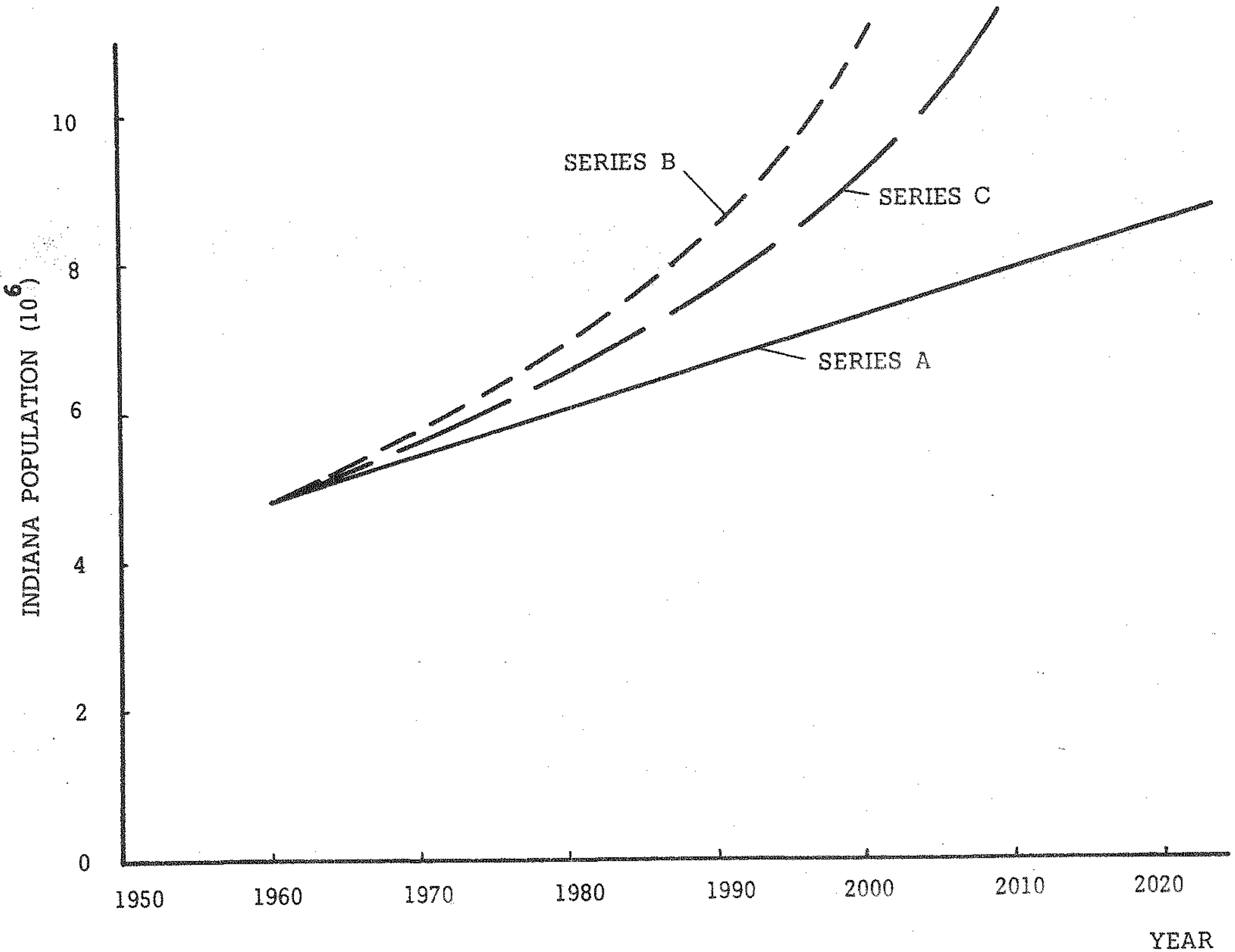


FIGURE V-3 POPULATION FORECASTS

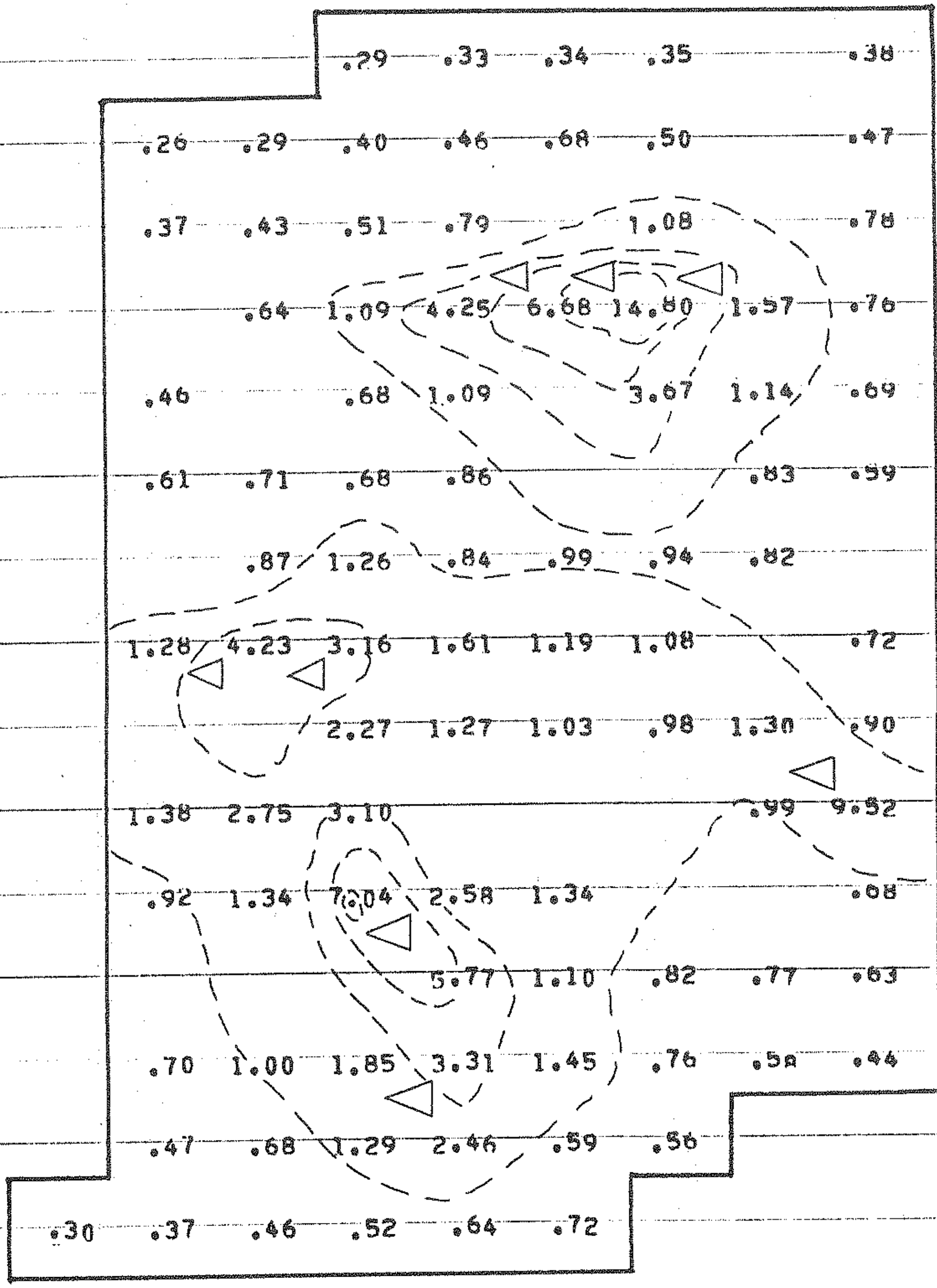
Insufficient access road capacity to handle larger future traffic volumes could become a binding constraint that limits visitation to reservoirs. The model does not incorporate this constraint. External constraints are difficult to predict far into the future. Thus none have been incorporated in the model.

E. Forecasting Results

A comparison between the eight reservoir network and ten reservoir network per capita visitation maps for 1980, 2000, and 2020, found in Figures V-4 through 9, shows the increasing and the possibly large effects which construction of Lafayette Reservoir might have on Indiana reservoir visitation.

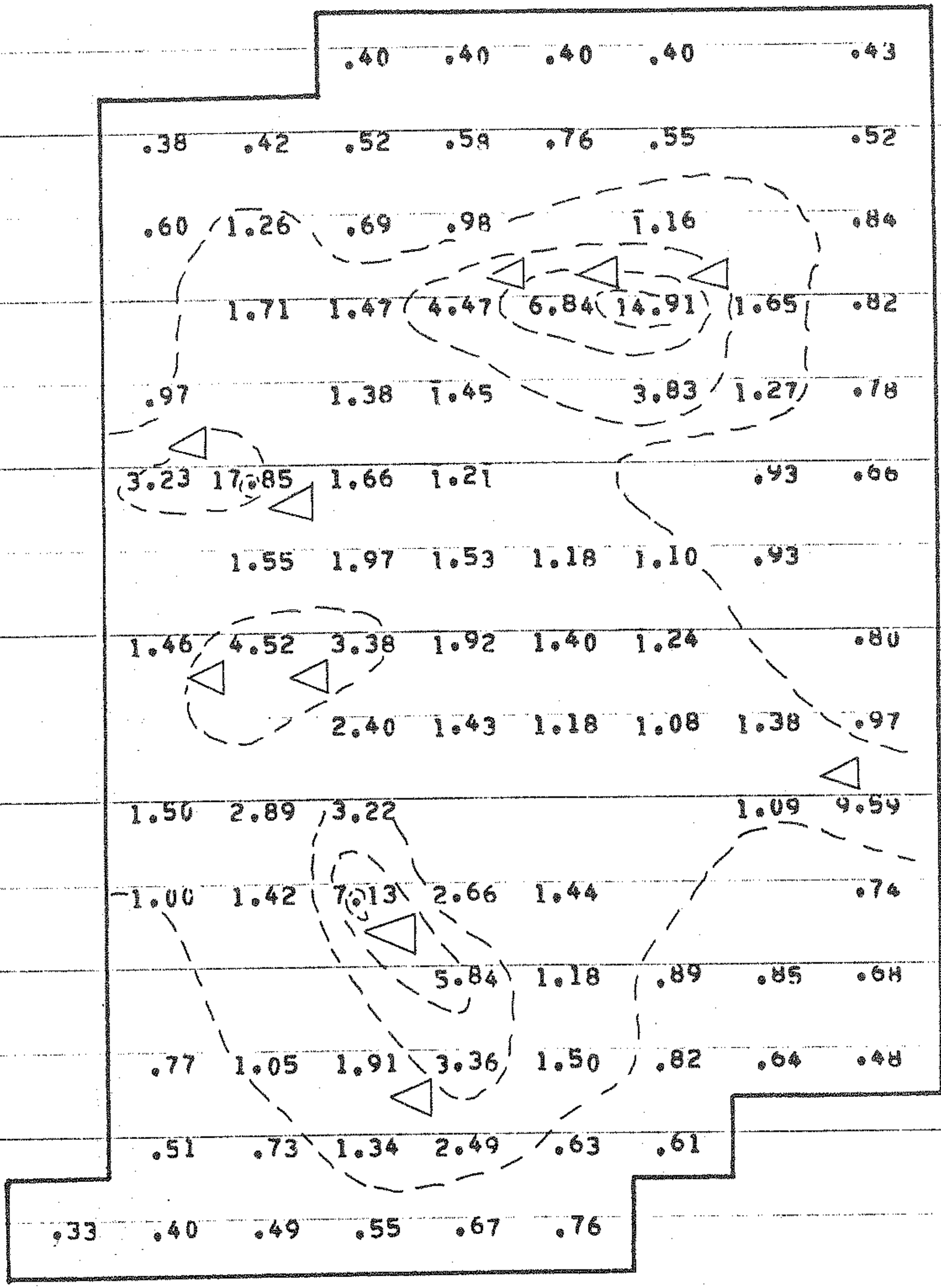
The model forecasts show that by 2020 Lafayette Reservoir would be second in recreation attendance only to Monroe Reservoir and that Tippecanoe County would have the largest per capita visitation rate in the State. It also is estimated that in 2020, 6,300,000 more water related recreation days would be enjoyed in Indiana if Lafayette Reservoir was constructed by 1980, than if it was not constructed at all.

Recreation visitation that would be generated by the Big Pine Reservoir, if built, does not appear to be significantly important. Its 2020 estimated visitation from Indiana is only 225,000, about 3% of the Lafayette Reservoir visitation.



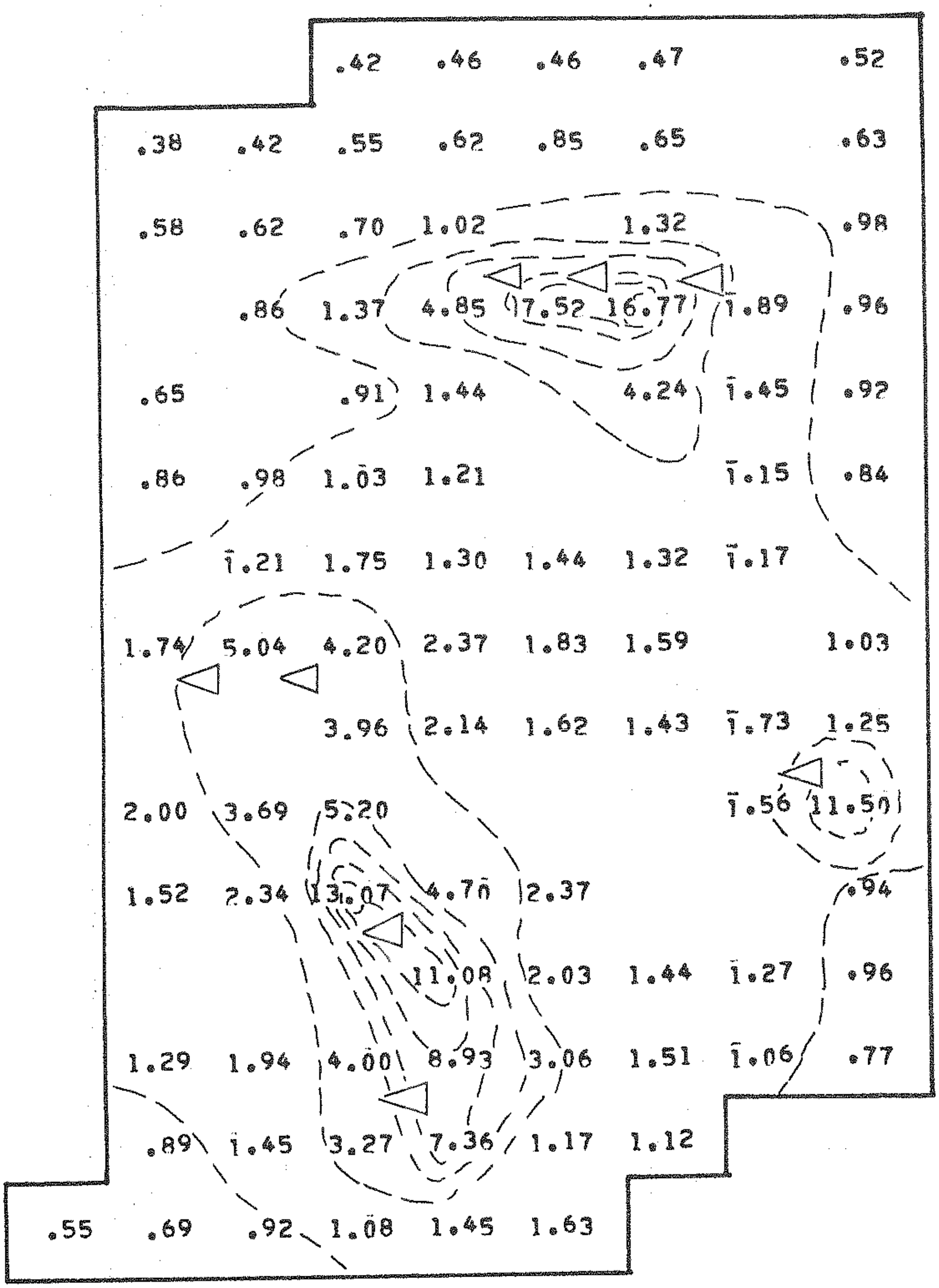
6,948,600 ANNUAL VISITS

FIGURE V-4 PER CAPITA VISITATION RATES FOR 1980 WITHOUT LAFAYETTE AND BIG PINE RESERVOIRS



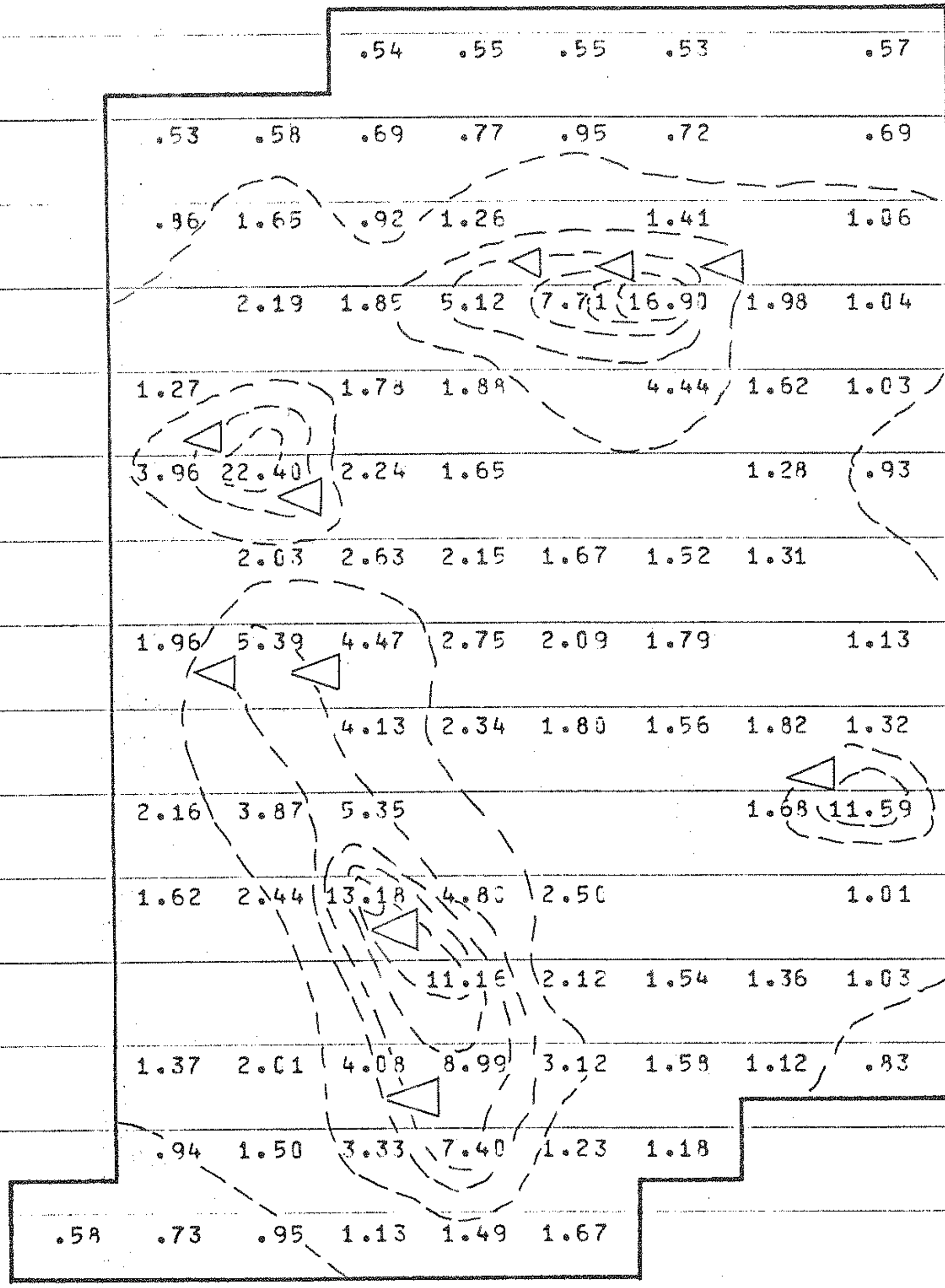
9,904,400 ANNUAL VISITS

FIGURE V-5 PER CAPITA VISITATION RATES FOR 1980 WITH LAFAYETTE AND BIG PINE RESERVOIRS



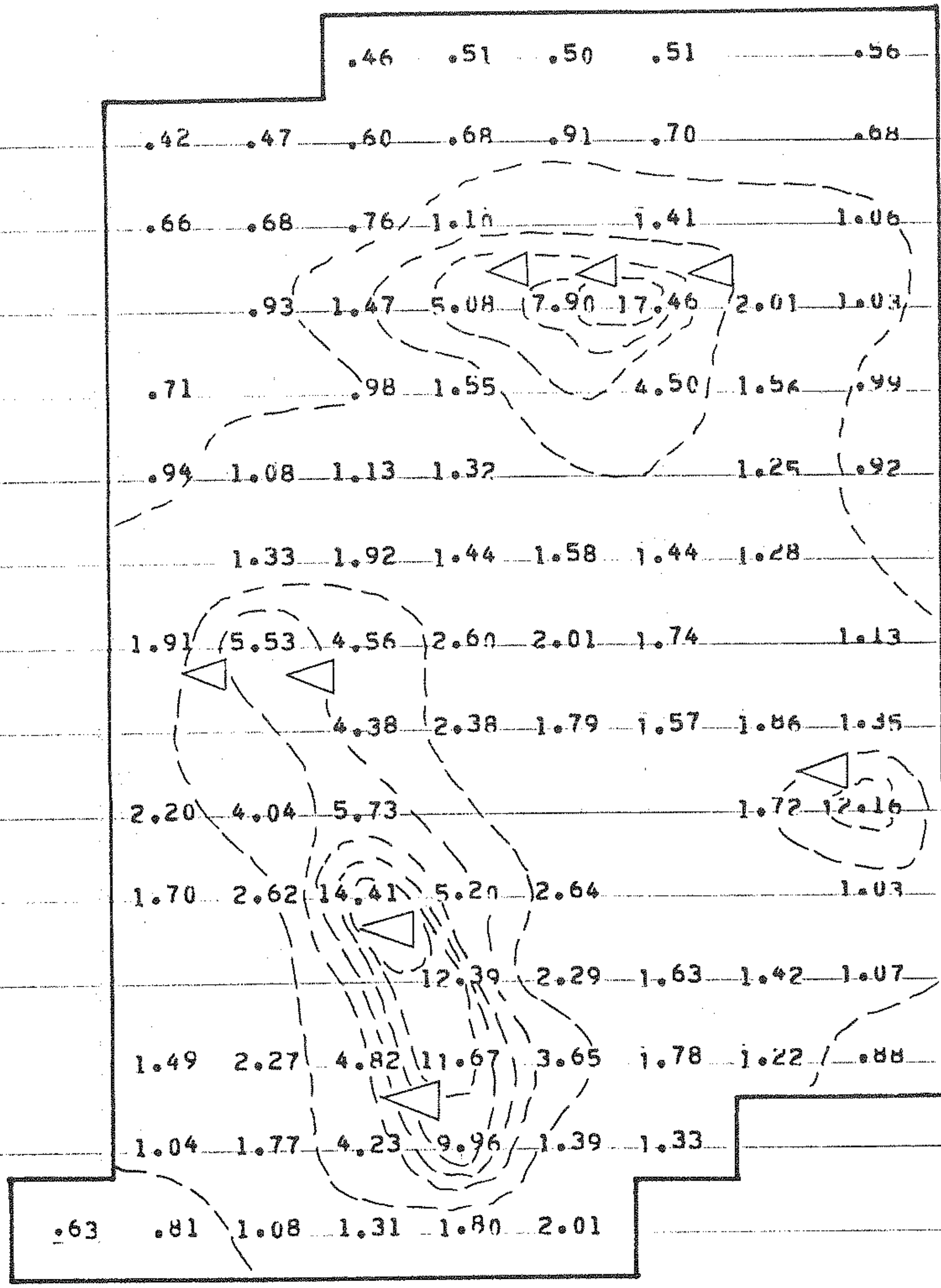
12,571,200 ANNUAL VISITS

FIGURE V-6 PER CAPITA VISITATION RATES FOR 2000 WITHOUT LAFAYETTE AND BIG PINE RESERVOIRS



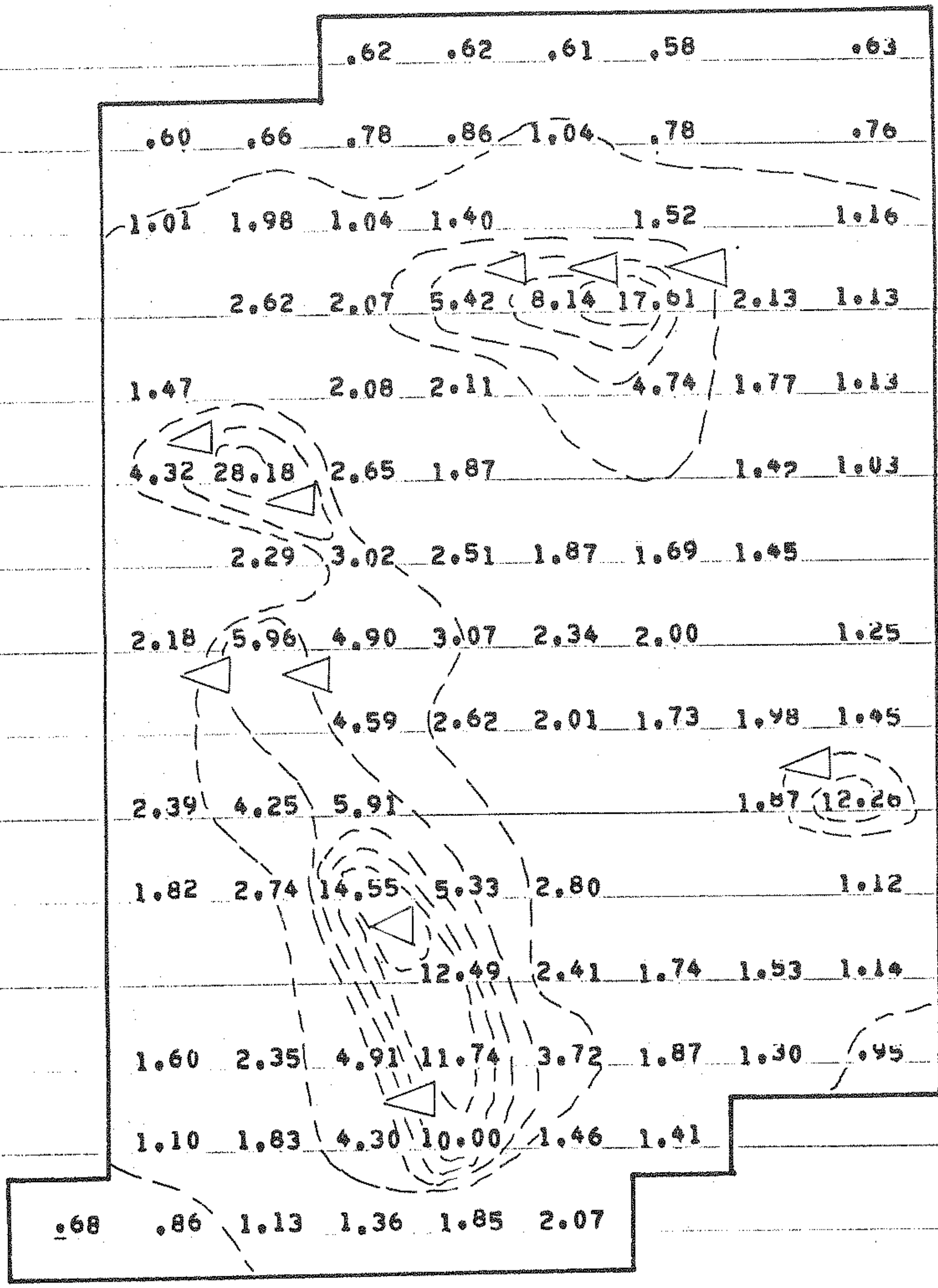
17,025,300 ANNUAL VISITS

FIGURE V-7 PER CAPITA VISITATION RATES FOR 2000 WITH LAFAYETTE AND BIG PINE RESERVOIRS



16,177,300 ANNUAL VISITS

FIGURE V-8 PER CAPITA VISITATION RATES FOR 2020 WITHOUT LAFAYETTE AND BIG PINE RESERVOIRS



22,705,100 ANNUAL VISITS

FIGURE V-9 PER CAPITA VISITATION RATES FOR 2020 WITH LAFAYETTE AND BIG PINE RESERVOIRS

The Wabash River Basin Comprehensive Study (1971) made projections of future visitation for the six Indiana Federal reservoirs operating in 1972. These are compared to the estimates from the forecasting model in Table V-1.

The forecasting model estimates compare well to the 1971 Wabash River Basin Comprehensive Study, or WRBCS for short, estimates for all reservoirs except for Monroe Reservoir. The present model, for example, predicts 3,000,000 more visits for Monroe in 2020 than the WRBCS estimates. The long shoreline of Monroe is the basic factor in the difference for the estimates. Because Monroe Reservoir is unique in the State in that aspect, it is quite conceivable that private development will provide much stimulation for visits to Monroe. At present a high rise hotel is being planned near the lake front.

The Figure V-2 actually shows a lesser rate of investment in Monroe than the other reservoirs. However this is observed when shoreline length is taken as a normalizing parameter. The actual investment policy has been to give Monroe about as much investment per year as other reservoirs, disregarding Monroe's larger size. In addition, a presently apparent access road capacity constraint, and possibly also an expressed desire for policy makers to leave large areas around Monroe Reservoir free from development, are possible explanations for the lower Monroe investment rates shown in Figure V-2.

The presence of an existing external constraint on Huntington Reservoir, namely the banning of large motor boats, could cause the model visitation forecasts for the reservoir to be too high.

Table V-1. Comparison of Visitation Estimates

	1980-Visits*		2000-Visits*		2020-Visits*	
Reservoir	WRBCS	Model	WRBCS	Model	WRBCS	Model
Cagles Mill	500	650	600	900	800	1100
Mansfield	800	600	800	850	800	1050
Monroe	1500	2550	2500	5000	4400	7450
Salamonie	750	1050	1000	1400	1500	1750
Mississinewa	640	800	1050	1050	1500	1250
Huntington	400	550	483	750	500	900
Total	4590	6200	6433	9950	9500	13,500

*in thousands

CHAPTER VI

FURTHER WORK

More work is needed to improve the reservoir visitation model that was formulated and applied in Chapters II-V. Possible model improvements are: (a) the construction of a "better" elemental origin-destination model; (b) the use of crowding constraints for reservoirs; (c) the use of visitation constraints for population centers.

A. A "Better" Elemental Origin-Destination Model

In Figure VI-1, the curve A represents the elemental origin-destination model on which the model formulated in this thesis, as well as many previous studies, has been based. The curve B represents a type of curve for visitation levels that might more logically represent actual demand curves outside of the I_1-I_2 portion. The shape of Curve B was suggested by Clawson and Knetsch (1966).

A typical approach to creating such an improved model would be to formulate a new elemental model which more closely resembles curve B than the curve A resembles it. Unfortunately, any mathematical model which is a significant improvement over curve A will require at least two more parameters beyond the two which define a curve of type A.

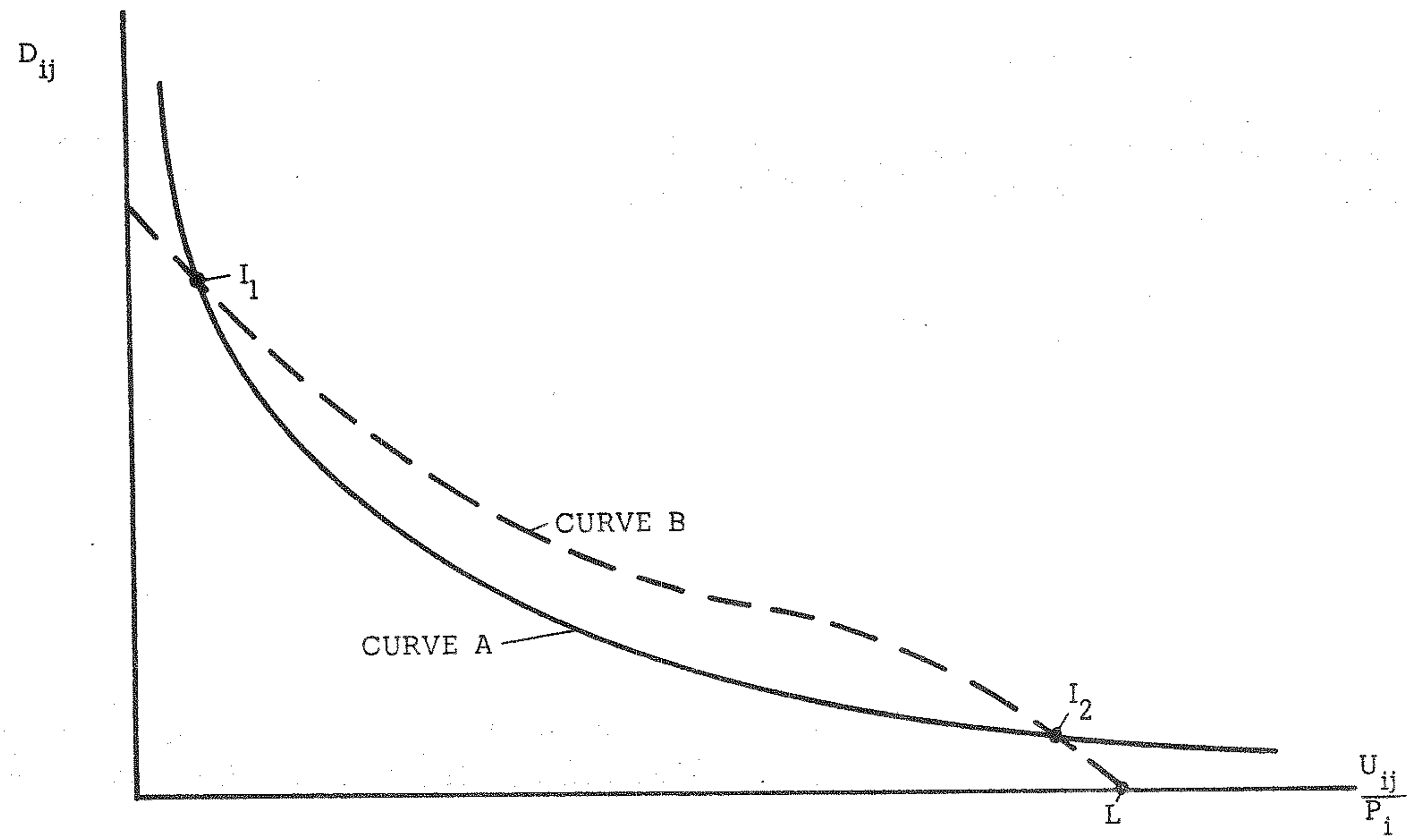


FIGURE VI-1 TWO REPRESENTATIONS OF RESERVOIR RECREATION VISITATION LEVELS AS FUNCTION OF TRAVEL DISTANCE

Since there are usually only four or five points (population centers close to reservoirs) from which one would have to determine point L, i.e. the U_{ij}/P_j cut-off of curve B and since there must be two parameters associated with this portion, an accurate determination of L is not feasible. In addition, an examination of the residuals of the weekend-reservoir regressions of Chapter IV indicates that the portion of the origin-destination model near L has a weaker dependency on travel time than the upper portion does. For these reasons, calibrating a model representing curve B is not a very suitable approach. The search for an improved model continues.

B. Crowding Constraints for Reservoirs

The need for a constraint that would reflect crowding, i.e. the degree of overuse (or underinvestment, depending on one's point of view) which would tend to constrict reservoir attendance or decrease its attractiveness, was discussed in Section II-E.

Because there was no evidence of crowding, no such constraint was applied to the formulated model. Yet there is evidence that crowding exists at small reservoirs in high population density areas (Sirles, 1968). Increases in future population, coupled with lagging investments in site development could well lead to crowding at large, isolated reservoirs also. Kalter (1971) considered this situation.

It might prove useful to study the effects of crowding using hypothesized constraints. This would require an extension of the visitation algorithm.

C. Visitation Constraints for Population Centers

The need for a constraint that would reflect that potential recreation visits from a given population center are limited was discussed in Section II-E.

The available data again precluded finding emperical evidence of this constraint, but it may not be realistic to ignore the possibility of its existance. Recreation visitation models which do not consider this constraint risk forecasting more visitors at some reservoirs than actually will be registered. An extended visitation algorithm might also be useful in studying the effects of this constraint.

D. Work Toward an Extended Algorithm

Within the thick border lines of Figure VI-2 are illustrated the typical results that may be obtained with the present recreation visitation algorithm. Consider summing the U_{ij}/P_i's in the rows. This gives the total per capita visitation rate of a population center. Multiplying each U_{ij}/P_i by its associated P_i and then summing this product over the columns gives total visits to each reservoir.

		Reservoir j						Total Per Capita Visitation $\sum_j \frac{U_{ij}}{P_i} =$
		1	2	...			J	$C_{source\ i}$
POPULATION CENTER i	1	$\frac{U_{11}}{P_1}$	$\frac{U_{12}}{P_1}$					$C_{source\ 1}$
	2	$\frac{U_{21}}{P_2}$	$\frac{U_{22}}{P_2}$					$C_{source\ 2}$
	...							
	I							$C_{source\ I}$
Total Reservoir Attendance $\sum_i P_i \times \frac{U_{ij}}{P_i} =$	$C_{sink\ j}$	$C_{sink\ 1}$	$C_{sink\ 2}$				$C_{sink\ J}$	

FIGURE VI-2 PER CAPITA VISITATION RATES AND SUMMATIONS FOR A PARTICULAR YEAR

An extended algorithm may include the performing of adjustments such as to redistribute visits throughout the model when per capita visitation rates or the reservoir visitation level exceeded some maximum, or constraint value. "Gravity variables" have been used in some recreation models (Schulmann and Grecco, 1964; Texas Water Development Board, 1968) to accomplish this purpose. The extended algorithm might include a uniform, regional constraint or a variable, functional constraint.

Investigations were made of various structural forms of these constraints, but lacking data to define the exact form of such constraints, it seemed fairly pointless to adopt any particular one.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions obtained from the reservoir visitation model results follow:

(1) A reservoir visitation model was designed that can show the comparative effects of different management decisions.

(2) Lafayette Reservoir could become the second largest Indiana-Corps of Engineers reservoir in attendance; drawing over 6,000,000 visitors per year by the year 2020.

(3) Annual attendance at Big Pine Reservoir was estimated to be about 3% of the Lafayette Reservoir yearly visits.

The recommendations for additional study on this subject are as follows:

(1) Run the formulated model with 1972 and 1973 data.

(2) Determine the effects of likely external constraints (highway speed limits, road capacities, etc.).

(3) Make an effort to construct systems constraints.

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IX. APPENDICES

Table A-1. Weekend Samples

Mansfield Reservoir Date	Mansfield Reservoir % Out-of-State	Cagles Mill Reservoir Date	Cagles Mill Reservoir % Out-of-State	Monroe Reservoir Date	Monroe Reservoir % Out-of-State
6-65	11.7	6-65	3.8	6-65	1.7
6-65	16.0	7-65	7.6	7-65	4.5
7-65	10.9	7-65	10.3	7-65	2.1
7-65	12.8	7-65	8.8	7-65	3.3
8-65	18.4	8-65	6.8	8-65	2.5
8-65	14.9	11-65	8.0	6-66	4.0
10-65	18.6	4-66	2.2	7-66	1.4
11-65	6.8	4-66	6.2	7-66	1.5
4-66	9.8	5-66	2.3	8-66	1.6
4-66	4.2	5-66	2.6	10-66	2.1
5-66	11.0	5-66	4.1	6-67	5.9
5-66	9.8	6-66	4.1	6-67	4.7
5-66	8.7	7-66	6.1	7-67	4.9
6-66	12.1	7-66	4.8		
7-66	16.4	8-66	9.5		
7-66	19.8	6-67	8.6		
7-66	13.3	7-67	7.9		
8-66	14.1	8-67	7.9		
10-66	24.8				
7-67	14.3				
7-67	16.6				
8-67	12.3				
Ave.	13.7	Ave.	6.1	Ave.	3.6

Table B-1. Population Centers in Indiana

No.	County Name	No.	County Name	No.	County Name
1	Adams	32	Hendricks	63	Pike
2	Allen	33	Henry	64	Porter
3	Bartholomew	34	Howard	65	Posey
4	Benton	35	Huntington	66	Pulaski
5	Blackford	36	Jackson	67	Putnam
6	Boone	37	Jasper	68	Randolph
7	Brown	38	Jay	69	Ripley
8	Carroll	39	Jefferson	70	Rush
9	Cass	40	Jennings	71	St. Joseph
10	Clark	41	Johnson	72	Scott
11	Clay	42	Knox	73	Shelby
12	Clinton	43	Kosciusko	74	Spencer
13	Crawford	44	La Grange	75	Starke
14	Daviess	45	Lake	76	Steuben
15	Dearborn	46	La Porte	77	Sullivan
16	Decatur	47	Lawrence	78	Switzerland
17	Dekalb	48	Madison	79	Tippecanoe
18	Delaware	49	Marion	80	Tipton
19	Dubois	50	Marshall	81	Union
20	Elkhart	51	Martin	82	Vanderburg
21	Fayette	52	Miami	83	Vermillion
22	Floyd	53	Monroe	84	Vigo
23	Fountain	54	Montgomery	85	Wabash
24	Franklin	55	Morgan	86	Warren
25	Fulton	56	Newton	87	Warrick
26	Gibson	57	Noble	88	Washington
27	Grant	58	Ohio	89	Wayne
28	Greene	59	Orange	90	Wells
29	Hamilton	60	Owen	91	White
30	Hancock	61	Parke	92	Whitley
31	Harrison	62	Perry		

Table B-2. Corps of Engineers Reservoirs in Indiana

No.	Reservoir	Operation Began	Shoreline (miles)
1	Cagles Mill	July, 1953	37
2	Mansfield	December, 1960	35
3	Monroe	January, 1966	190
4	Salamonie	April, 1967	47
5	Mississinewa	April, 1968	59
6	Huntington	October, 1970	18
7	Brookville	Under Construction	30 (est.)
8	Patoka	Under Construction	60 (est.)
9	Lafayette	Proposed	50 (est.)
10	Big Pine	Proposed	25 (est.)

Table B-3. Corps of Engineers Reservoir Visitation Data (Visits)

Year	Cagles Mill	Mansfield	Monroe	Salamonie	Mississinewa	Huntington
1960	185,500	14,600	--	--	--	--
1961	143,500	265,400	--	--	--	--
1962	157,200	305,100	--	--	--	--
1963	409,300	532,500	--	--	--	--
1964	251,500	537,700	--	--	--	--
1965	276,600	677,000	254,200	--	--	--
1966	344,100	460,600	791,800	--	--	--
1967	398,200	486,500	1,235,100	201,200	--	--
1968	204,500	334,700	749,400	351,000	162,300	--
1969	318,300	419,500	981,200	704,600	350,400	31,500
1970	407,600	615,900	1,022,500	744,100	724,400	47,800
1971	405,500	573,600	1,043,600	795,300	633,600	366,900

Table B-4. Capital Investments (in thousands of dollars)

Year	Cagles Mill	Mansfield	Monroe	Salamonie	Mississinewa	Huntington
1953-59	50.0 (est)	--	--	--	--	--
1959-60	25.0	68.6	--	--	--	--
1960-61	11.7	305.0	--	--	--	--
1961-62	8.8	209.3	--	--	--	--
1962-63	4.0	99.8	--	--	--	--
1963-64	4.0	4.0	--	--	--	--
1964-65	57.9	49.6	357.2	--	--	--
1965-66	3.0	8.6	532.1	--	180.8	--
1966-67	86.4	8.0	182.9	297.5	--	--
1967-68	40.2	64.0	523.5	1170.0	1418.0	--
1968-69	182.1	5.1	384.3	349.6	632.5	676.0
1969-70	10.5	65.5	363.9	101.7	150.6	450.1
1970-71	126.9	8.3	439.7	104.2	11.9	134.3

Table B-5. Other Variable Values

Year	Consumer Price Index	Building Cost Index	Effective Buying Income (10^6 $)
1960	1.00	1.00	9.18
1961	1.01	1.02	9.17
1962	1.02	1.03	9.74
1963	1.03	1.05	10.3
1964	1.05	1.09	11.0
1965	1.07	1.11	11.8
1966	1.10	1.15	13.6
1967	1.13	1.16	14.2
1968	1.18	1.25	15.0
1969	1.24	1.39	16.0
1970	1.31	1.44	15.4
1971	1.37	1.66	18.2

Table B-6. Deflation Factors

Reservoir	Deflation Factor (%)
Cagles Mill	94
Mansfield	86
Monroe	96
Salamonie	95 (est.)
Mississinewa	96 (est.)
Huntington	93 (est.)

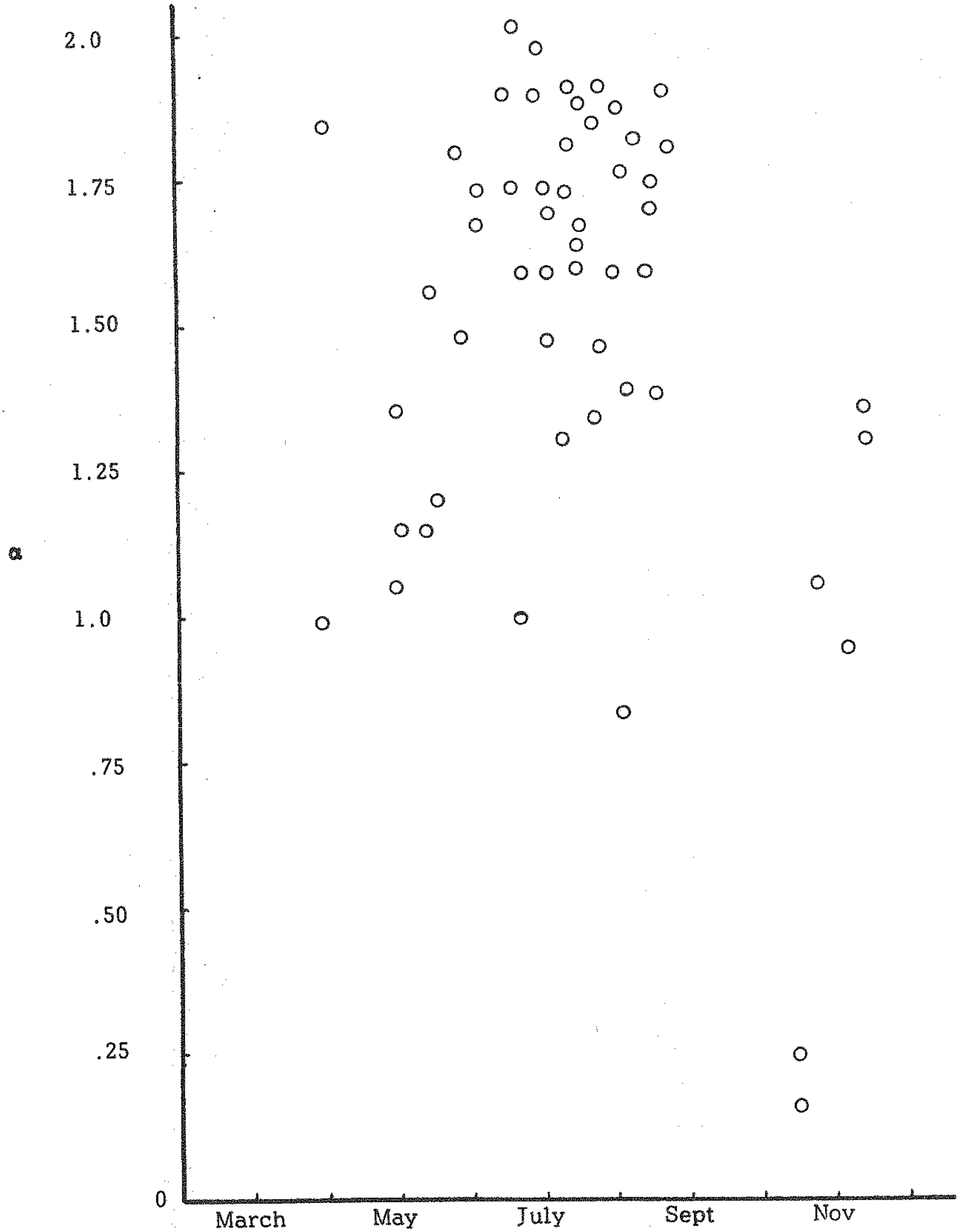


FIGURE C-1 BEHAVIORAL TRAVEL TIME PARAMETER VS. TIME OF YEAR

Table C-1. Weekend Weather

Numbers in boxes represent number of weekends.

Reservoir	Weather			
	Clear-Hot	Cloudy-Cool	Rain	Cloudy
Mansfield	8	7	2	6
Cagles Mill	8	5	0	4
Monroe	6	6	0	1

Year	Weather			
	Clear-Hot	Cloudy-Cool	Rain	Cloudy
1965	4	13	1	1
1966	12	4	1	8
1967	6	1	0	2

Table D-1. Forecasting Data

Cumulative Capital Investments (in thousands of dollars)				Quality Coefficients
Reservoir	1980	2000	2020	$(10^{-9} * \frac{\text{visits}}{\text{people}} * \frac{\text{hrs}}{\$}^{\bar{\alpha}})$
Cagles Mill	740	850	890	206
Mansfield	950	1050	1150	151
Monroe	4370	7790	8500	166
Salamonie	1900	2060	2170	88
Mississinewa	2110	2280	2340	63
Huntington	1170	1290	1320	37
Brookville	960	1140	1200	100
Patoka	540	1800	2500	175
Lafayette	1200	1500	1900	150
Big Pine	900	1050	1100	37

E. DOCUMENTATION FOR COMPUTER PROGRAM

-- RESREC --

Subject Description

This computer program was developed at the Hydraulics Department, School of Civil Engineering, Purdue University. It is a result of research conducted under the direction of Dr. G. H. Toebes. Kevin Wolka, graduated research assistant, was the author and programmer.

Two reservoirs in Indiana for which funding has been authorized, Big Pine and Lafayette, have had their construction delayed by environmental groups. An estimate of the number of recreationists that would visit these reservoirs, if they were built, should be helpful to policy-makers in deciding the worth of the reservoirs. Both reservoirs have recreation listed as a primary economic benefit by the Corps of Engineers.

The computer program can calibrate reservoir recreation network parameters from past data or forecast visits using the model with estimated future data values. Sensitivity of the model to included parameters can also be observed. The particular case for which the model was used was a system of reservoirs in Indiana. It could be used for other reservoir systems and is also applicable to other types recreational facility systems.

Technical Features

This computer program contains no use of sophisticated techniques. The computations could have just as easily been performed by hand methods. The computer was chosen because of its computational efficiency and ease in outputting results in a format.

Fortran IV language was used. It is a common language and can be inputted into most computers. The only technical restriction which might be encountered is memory storage requirements. Since the program contains subscripted variables, considerable storage for a large program may be required. Storage capacity for the computer and the estimated storage requirements of the program should be compared before starting.

Program Description (See Table 1 for listing of variables.)

As was stated above, calibration or forecasting visits can be accomplished by the program. Two main equations are incorporated.

The first is the "one population center - one reservoir" case. It is:

$$VISITS_{ij} = Q_j \times CI_j \times XIN \times POP_i \times TIME_{ij}^{-ALPHA} \quad (1)$$

The second is a "consumption or aggregated" case for a reservoir. It is:

$$VISIND_j = Q_j \times CI_j \times PTSUM_j \quad (2)$$

Table 2 contains the program listing with comment statements inserted.

Figure 1 is a flow diagram of the computational process. Figure 2 contains a description of the input data deck.

Figures 3, 4 and 5 show the typical output from the program. This includes quality coefficients from the calibration model; reservoir attendances from the forecasting model; and contour maps of population center per capita visitation rates output in the shape of the state of Indiana.

TABLE 1 PROGRAM VARIABLES

Notation	Definition	Units
i; $i=1,2,\ldots,I$	index for population center	
j; $j=1,2,\ldots,J$	index for recreational reservoirs	
k; $k=1,2,\ldots,K$	index for year	
M=1 or 2	designation for either calibration (=1) or forecasting (=2)	
KYEAR	the year for which calibration or forecasting is desired	
$VISITS_{ij}$	annual visits flowing from systems population center i, to reservoir j	(visits)
DF_j	deflation factor to determine the portion of the total visits to reservoir j originating from systems population centers	(-)
$VISTOT_j$	total annual visits at reservoir j	(visits)
$VISIND_j$	network portion of total annual visits at reservoir j	(visits)
$VISPOP_i$	total annual visits from population center i	(visits)
$VRATE_i$	total annual per capita visitation rate for population center i	(visits)/(person)
EBI_k	effective buying income in year	($)
CPI_k	ratio of consumer price index in year k to consumer price index in 1960	(-)
$GAMMA_k$	annual rate of change of adjusted effective buying income in year k	(-)
XIN	increase in recreation demand (as it is assumed to depend on EBI) multiplier of KYEAR	(-)
POP_i	total population of population center i	(people)
$RECPOP_i$	"recreation propensity" of population center i	(people)

Notation	Definition	Units
$PTSUM_j$	temporary variable - the sum of the products of RECPOP and $TIME^{-ALPHA}$	$\frac{(people)}{(hrs.^{alpha})}$
$TIME_i{}^j$	travel time from population center to reservoir j	(hours)
ALPHA	behavioral or constraint parameter related to time spent in travel between population centers and reservoirs	(-)
JRES	the number of reservoirs in the system	(-)
$XINV_{jk}$	capital investment for the recreational facilities of reservoir j for year k	(\$)
BCI_k	ratio of Engineering News Record Building Cost Index in year k to ENRBCI in 1960	(-)
CI_j	cumulative adjusted capital investment for the recreational facilities of reservoir j	(\$)
Q_j	quality coefficient of reservoir j (also a regression coefficient of the calibrated model)	$\frac{(visits}{(people} \times \frac{hrs^{alpha})}{\$\ )}$
A_j	attractiveness index for reservoir j	$\frac{(visits}{(people} \times hrs^{alpha})$

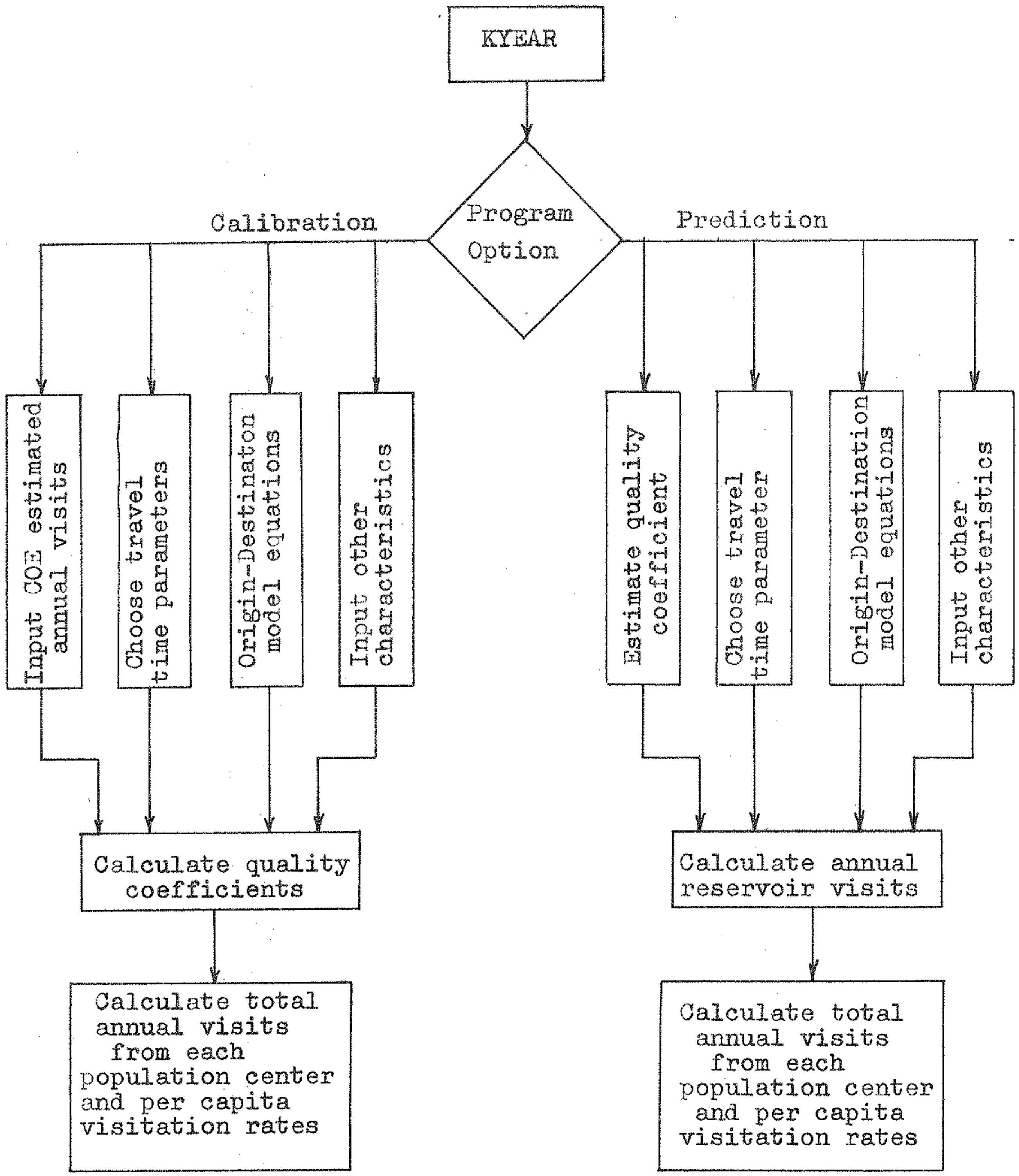


Figure 1. Resrec -- Flow of Computations

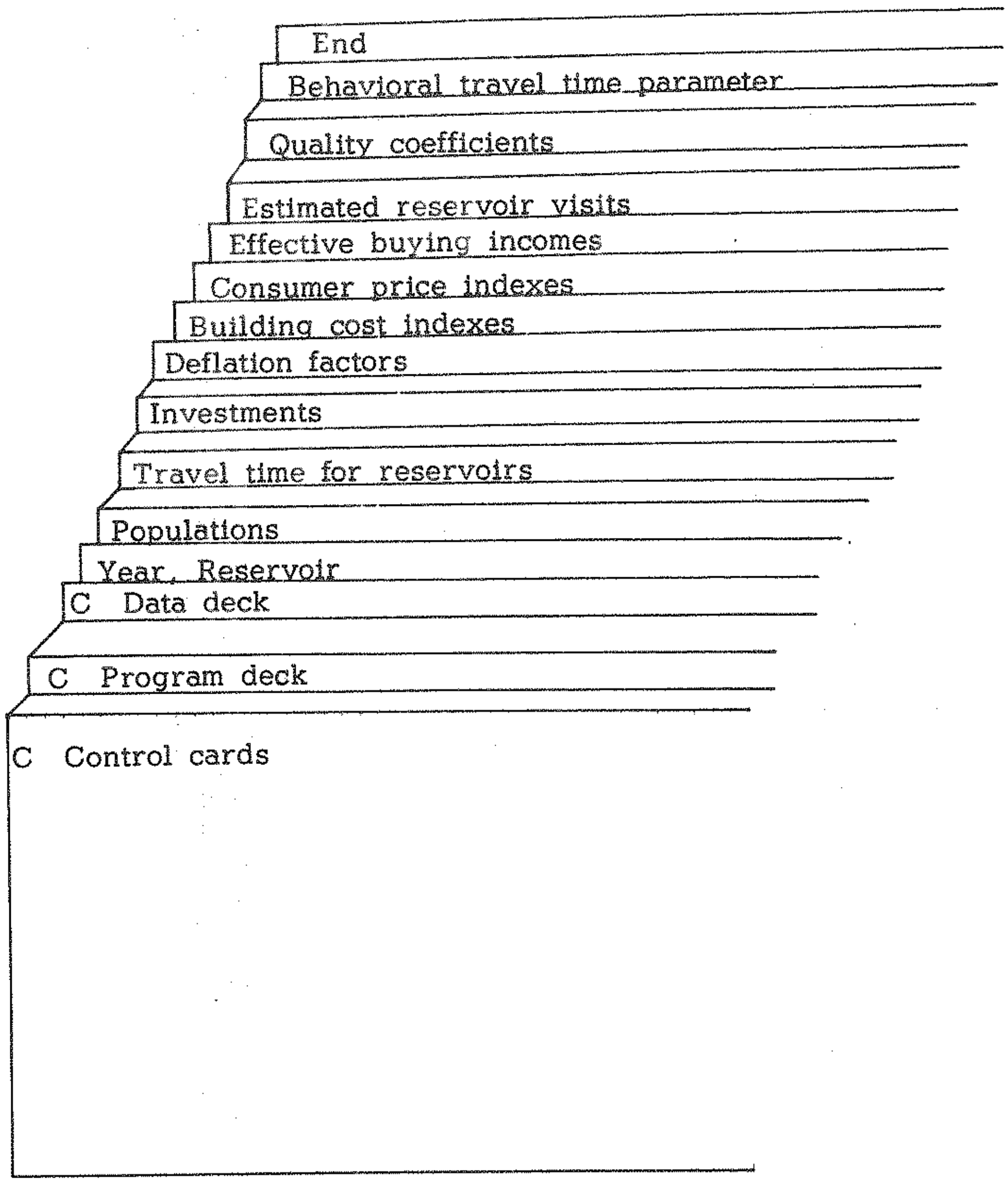


FIGURE 2 - INPUT DATA DECK

```
RESERVOIR  1     QUALITY COEFFICIENT =.000000206

RESERVOIR  2     QUALITY COEFFICIENT =.000000151

RESERVOIR  3     QUALITY COEFFICIENT =.000000166

RESERVOIR  4     QUALITY COEFFICIENT =.000000088

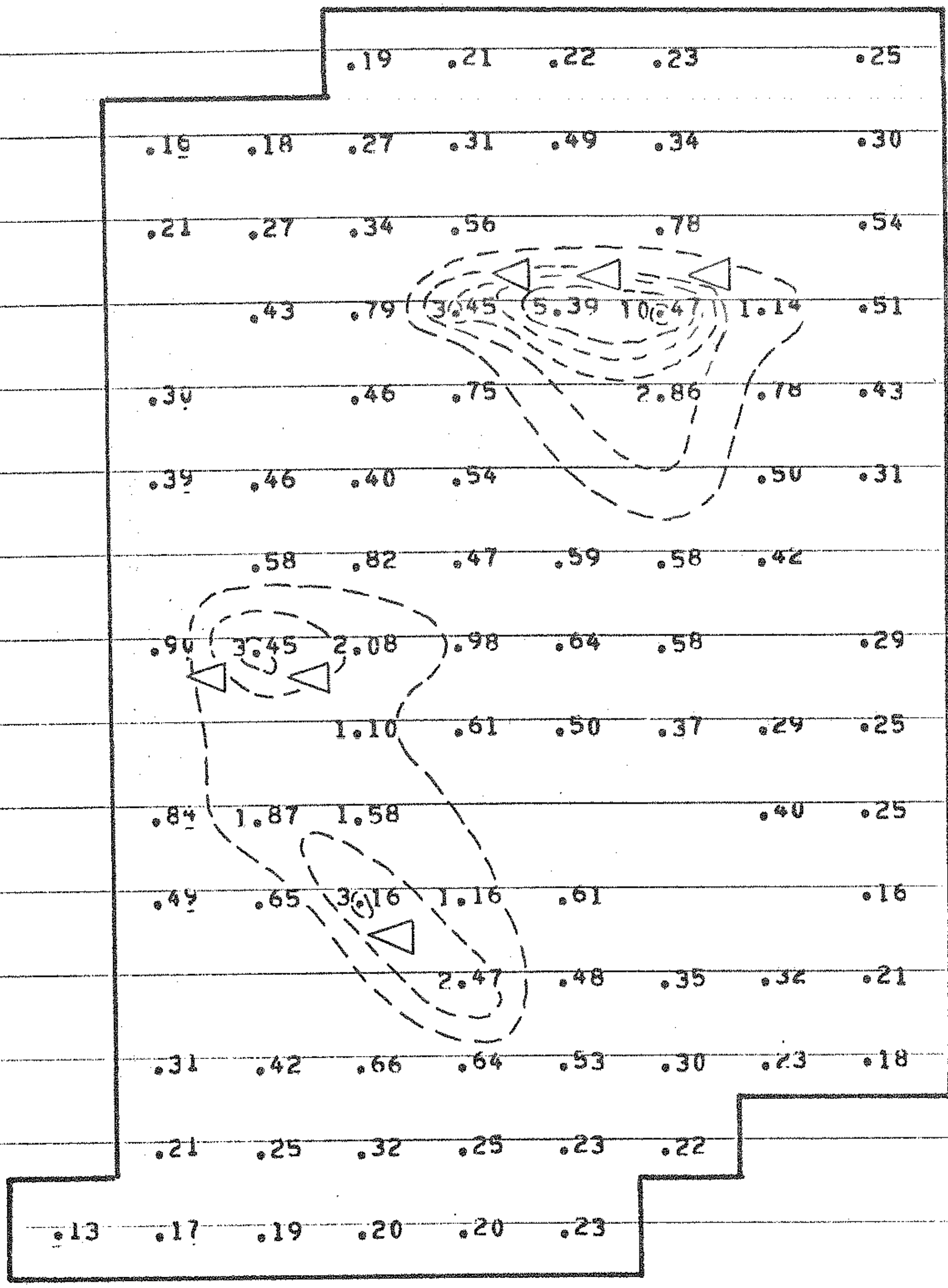
RESERVOIR  5     QUALITY COEFFICIENT =.000000063

RESERVOIR  6     QUALITY COEFFICIENT =.000000037
TOTAL NETWCRK    3818500VISITS
```

FIGURE 3 - CALIBRATION MODEL RESULTS

RESERVOIR 1	1095658	VISITS
RESERVOIR 2	1057367	VISITS
RESERVOIR 3	7434216	VISITS
RESERVOIR 4	1727260	VISITS
RESERVOIR 5	1255048	VISITS
RESERVOIR 6	915754	VISITS
RESERVOIR 7	828876	VISITS
RESERVOIR 8	1863154	VISITS
RESERVOIR 9	6301415	VISITS
RESERVOIR 10	226335	VISITS
TOTAL NETWORK	22705081	VISITS

FIGURE 4 - PREDICTION MODEL RESULTS



3,818,500 ANNUAL VISITS

FIGURE 5 - PER CAPITA VISITATION RATES FOR 1971

Table E-1. Listing of Computer Program

```
              C
              C     CALIBRATION AND FORECAST FOR RESERVOIR RECREATION VISITS
              C
                    PROGRAM RECRES (INPUT,OUTPUT,TAPE 5 = INPUT, TAPE 6 = OUTPUT)
000002              DIMENSION VISTOT(10), VISITS(100,10), VISIND(10), VISPOP(100)
000002              DIMENSION POP(100), RECPOP(100), VRATE(100)
000002              DIMENSION XINV(10,20), CI(10), J(10), A(10)
000002              DIMENSION GAMMA(20), BCI(20), CPI(20),EBI(20), DF(10)
000002              DIMENSION TIME(100,10), PTSUM(100)
              C
              C     INPUT YEAR AND NUMBER OF RESERVOIRS
              C
              C     ENTER WHETHER CALIBRATION OR FORECAST IS DESIRED
              C
000002              READ (5,900) M, KYEAR, JRES
              C
              C     INPUT COUNTY POPULATION ESTIMATES
              C
000014              DO 5 I = 1,92
000016              READ (5,908) POP(I)
000023            5 CONTINUE
              C
              C     INPUT TRAVEL TIMES
              C
000025              DO 10 J = 1,JRES
000027              DO 10 I = 1,92
000030              READ (5,908) TIME(I,J)
000037           10 CONTINUE
              C
              C     INPUT ANNUAL INVESTMENTS
              C
000044              DO 15 J = 1,JRES
000045              READ (5,901) (XINV(J,K), K = 1,KYEAR)
000061              DO 15 KK = 1,KYEAR
000071              XINV(J,KK) = 1000. * XINV(J,KK)
000072           15 CONTINUE
              C
              C     INPUT DEFLATION FACTORS
              C
000076              READ (5,903) (DF(J), J = 1,JRES)
              C
              C     INPUT BUILDING COST INDEXES
              C
000104              READ (5,906) (BCI(K), K = 1,KYEAR)
              C
              C     INPUT CONSUMER PRICE INDEXES
              C
000113              READ (5,902) (CPI(K), K = 8, KYEAR)
              C
              C     INPUT EFFECTIVE BUYING INCOMES
              C
000122              READ (5,902) (EBI(K), K = 8,KYEAR)
              C
              C     INPUT COE ESTIMATED RESERVOIR VISITS FOR CALIBRATING
              C
000131              DO 20 J = 1,JRES
000133              READ (5,907) VISTOT(J)
000140              VISTOT(J) = 1000. * VISTOT(J)
```

Table E-1. (Continued)

```
000143        20 CONTINUE
          C
          C     INPUT QUALITY COEFFICIENTS FOR FORECASTING
          C
000145           DO 25 J = 1,JRES
000146           READ (5,904) Q(J)
000153        25 CONTINUE
          C
          C     INPUT BEHAVIORAL TRAVEL PARAMETER
          C
000156           READ(5,905) ALPHA
          C
          C     COMPUTE CUMULATIVE INVESTMENTS
          C
000163           DO 30 J = 1,JRES
000165           CI(J) = XINV(J,1)/BCI(1)
000167           DO 30 K = 2,KYEAR
000177           CI(J) = CI(J) + (XINV(J,K)/BCI(K))
000201        30 CONTINUE
          C
          C     DETERMINE RECREATION DEMAND MULTIPLIERS
          C
000205           XIN = 1.0
000206           IF (KYEAR - 9) 40, 35, 38
000211        35 XIN = XIN + (((EBI(9)/CPI(9))-(EBI(8)/CPI(8)))/(EBI(8)/CPI(8)))
000217           GO TO 40
000217        38 DO 39 K = 9, KYEAR
000226           GAMMA(K)=((EBI(K)/CPI(K))-(EBI(K-1)/CPI(K-1)))/(EBI(K-1)/CPI(K-1))
000231           XIN = XIN + GAMMA(K)
000233        39 CONTINUE
000234        40 CONTINUE
          C
          C     CALCULATE RECREATION PROPENSITIES
          C
000234           DO 41 I = 1,92
000242           RECPOP(I) = XIN * POP(I)
000243        41 CONTINUE
          C
          C     CHECK WHETHER CALIBRATION OR FORECAST IS DESIRED
          C
000244           IF (M.EQ.1) GO TO 80
          C
          C     CALIBRATION
          C
          C
          C         COMPUTE QUALITY COEFFICIENTS FROM CONSUMPTION MODEL
          C
000246           DO 45 J = 1,JRES
000253           VISIND(J) = DF(J) * VISTOY(J)
000254        45 CONTINUE
000255           DO 50 J = 1,JRES
000256           PTSUM(J) = 0.
000257           DO 50 I = 1,92
000270           IF (TIME(I,J).EQ.0.) GO TO 50
000271           PTSUM(J) = PTSUM(J) + (RECPOP(I)/(TIME(I,J)**ALPHA))
000275        50 CONTINUE
000301           DO 55 J = 1, JRES
000302           IF (PTSUM(J)) 52,52,53
```

Table E-1. (Continued)

```
000304        52 Q(J) = 0.
000306           GO TO 55
000306        53 Q(J) = VISIND(J)/(CI(J)*PTSUM(J))
           C
           C        OUTPUT RESERVOIR QUALITY COEFFICIENTS
           C
000312           WRITE(6,909) J, Q(J)
000321        55 CONTINUE
           C
           C           CALCULATE ATTRACTIVENESS INDEXES
           C
000324           DO 60 J = 1,JRES
000331           A(J) = Q(J) * CI(J)
000332        60 CONTINUE
           C
           C           ESTIMATE VISITS FROM MODIFIED ORIGIN - DESTINATION MODEL
           C
000333           DO 70 I = 1,92
000334           DO 70 J = 1,JRES
000335           IF (TIME(I,J)) 67,67,68
000341        67 VISITS(I,J) = 0.
000345           GO TO 70
000345        68 VISITS(I,J) = RECPOP(I)*A(J)/(TIME(I,J)**ALPHA)
000360        70 CONTINUE
           C
           C           DETERMINE SUM OF VISITS FROM EACH POPULATION CENTER
           C
000365           DO 75 I = 1,92
000366           VISPOP(I) = 0.
000367           DO 75 J = 1,JRES
000377           VISPOP(I) = VISPOP(I) + VISITS(I,J)
000400        75 CONTINUE
000404           GO TO 100
           C
           C      FORECAST
           C
           C
           C           CALCULATE ATTRACTIVENESS INDEXES
           C
000404        80 DO 85 J = 1,JRES
000412           A(J) = Q(J) * CI(J)
000413        85 CONTINUE
           C
           C           ESTIMATE VISITS FROM MODIFIED ORIGIN - DESTINATION MODEL
           C
000414           DO 90 J = 1,JRES
000415           DO 90 I = 1,92
000416           IF (TIME(I,J)) 87,87,88
000422        87 VISITS(I,J) = 0.
000426           GO TO 90
000432        88 VISITS(I,J) = RECPOP(I)*A(J)/(TIME(I,J)**ALPHA)
           C
           C           ESTIMATE RESERVOIR VISITS
           C
000437           VISTOT(J) = VISTOT(J) + VISITS(I,J)
000441        90 CONTINUE
           C
           C           DETERMINE SUM OF VISITS FROM EACH POPULATION CENTER
```

Table E-1. (Continued)

```
      C
000446       DO 95 I = 1,92
000447       VISPOP(I) = 0.
000450       DO 95 J = 1,JRES
000460       VISPOP(I) = VISPOP(I) + VISITS(I,J)
000461    95 CONTINUE
      C
      C      OUTPUT RESERVOIR VISITS
      C
000465       DO 98 J = 1,JRES
000466       WRITE(6,910) J, VISTOT(J)
000475    98 CONTINUE
      C
      C      ESTIMATE POPULATION CENTER PER CAPITA VISITATION RATES
      C
000500   100 DO 105 I = 1, 92
000506       VRATE(I) = VISPOP(I)/POP(I)
000507   105 CONTINUE
      C
      C      OUTPUT TOTAL RECREATION RESERVOIR VISITS
      C
000510       VIS = 0.
000511       DO 110 J = 1, JRES
000516       VIS = VIS + VISTOT(J)
000517   110 CONTINUE
000520       WRITE(6,911) VIS
      C
      C      OUTPUT PER CAPITA VISITATION RATES
      C
000526       WRITE(6,950)VRATE(46),VRATE(71),VRATE(20),VRATE(44),VRATE(76)
000544       WRITE(6,951)VRATE(45),VRATE(64),VRATE(75),VRATE(50),VRATE(43),
            *VRATE(57),VRATE(17)
000566       WRITE(6,952)VRATE(56),VRATE(37),VRATE(66),VRATE(25),VRATE(92),
            *VRATE(2)
000606       WRITE(6,953)VRATE(91),VRATE(9),VRATE(52),VRATE(85),VRATE(35),
            *VRATE(90),VRATE(1)
000630       WRITE(6,954)VRATE(4),VRATE(8),VRATE(34),VRATE(27),VRATE(5),VRATE
            *(38)
000650       WRITE(6,955)VRATE(86),VRATE(79),VRATE(12),VRATE(80),VRATE(18),
            *VRATE(68)
000670       WRITE(6,956)VRATE(23),VRATE(54),VRATE(6),VRATE(29),VRATE(48),
            *VRATE(33)
000710       WRITE(6,957)VRATE(83),VRATE(61),VRATE(67),VRATE(32),VRATE(49),
            *VRATE(30),VRATE(89)
000732       WRITE(6,958)VRATE(55),VRATE(41),VRATE(73),VRATE(70),VRATE(21),
            *VRATE(81)
000752       WRITE(6,959)VRATE(84),VRATE(11),VRATE(60),VRATE(16),VRATE(24)
000770       WRITE(6,960)VRATE(77),VRATE(28),VRATE(53),VRATE(7),VRATE(3),
            *VRATE(15)
001010       WRITE(6,961)VRATE(47),VRATE(36),VRATE(40),VRATE(69),VRATE(58)
001026       WRITE(6,962)VRATE(42),VRATE(14),VRATE(51),VRATE(59),VRATE(88),
            *VRATE(72),VRATE(39),VRATE(78)
001052       WRITE(6,963)VRATE(26),VRATE(63),VRATE(19),VRATE(13),VRATE(22),
            *VRATE(10)
001072       WRITE(6,964)VRATE(65),VRATE(82),VRATE(87),VRATE(74),VRATE(62),
            *VRATE(31)
001112   900 FORMAT (3I3)
001112   901 FORMAT (10F8.1)
```

Table E-1. (Continued)

```
001112      902 FORMAT (12F5.1)
001112      903 FORMAT(10F5.2)
001112      904 FORMAT (F10.9)
001112      905 FORMAT (F10.4)
001112      906 FORMAT (16F5.1)
001112      907 FORMAT (8X,F8.2)
001112      908 FORMAT (55X,F5.1)
001112      909 FORMAT(5(/),10X,9HRESERVOIR,I3,5X,21HQUALITY COEFFICIENT =,F10.9)
001112      910 FORMAT(//,10X,9HRESERVOIR,I3,F10.0,2X,6HVISITS)
001112      911 FORMAT(//,10X,13HTOTAL NETWORK,F10.0,6HVISITS)
001112      950 FORMAT(1H1,6(/),37X,4F6.2,6X,F6.2,//)
001112      951 FORMAT(25X,6F6.2,6X,F6.2,//)
001112      952 FORMAT(25X,4F6.2,6X,F6.2,6X,F6.2,//)
001112      953 FORMAT(31X,7F6.2,//)
001112      954 FORMAT(25X,F6.2,6X,2F6.2,6X,3F6.2,//)
001112      955 FORMAT(25X,4F6.2,12X,2F6.2,//)
001112      956 FORMAT(31X,6F6.2,//)
001112      957 FORMAT(25X,6F6.2,6X,F6.2,//)
001112      958 FORMAT(37X,6F6.2,//)
001112      959 FORMAT(25X,3F6.2,18X,2F6.2,//)
001112      960 FORMAT(25X,5F6.2,12X,F6.2,//)
001112      961 FORMAT(43X,5F6.2,//)
001112      962 FORMAT(25X,8F6.2,//)
001112      963 FORMAT(25X,6F6.2,//)
001112      964 FORMAT(19X,6F6.2,3(/))
001112      965 FORMAT(20X,50HFIGURE IV-     ESTIMATED INDIANA POPULATION CENTER,
           */,35X,32HPER CAPITA VISITATION RATES-FOR ,I4)
001112          END

PROGRAM LENGTH INCLUDING I/O BUFFERS
011042

UNUSED COMPILER SPACE
057700
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