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AN APPROXIMATION OF MICHIGAN'S SPATIAL WATER NEEDS

By

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ABSTRACT

AN APPROXIMATION OF MICHIGAN'S
SPATIAL WATER NEEDS

By

Michael Edwin Mc Guire

Water has been in the past, and will continue to be in the future, of vital importance to Michigan's continued growth and development. Demands on the state's water resource base are increasing, however, and if all of the various uses of water are to be satisfied forecasts of future use will have to be made. The purpose of this study, therefore, was to examine the factors which have been instrumental in affecting the present spatial pattern of water use in Michigan, to consider changes in these factors over time, and to estimate what the future demands for water in Michigan may be.

Water withdrawals in any area have a certain structure, the principle withdrawals in Michigan being made for domestic, municipal, and commercial uses, industrial uses, and for agriculture. Estimates of future spatial water demands were made by applying unit withdrawal factors to forecasted magnitudes of the withdrawal units.

Withdrawals for domestic, municipal, and commercial purposes are expected to increase at a rate greater than the corresponding growth of population, a result of improved socio-economic status. These estimates were made by multiplying a per capita withdrawal rate times the projected

population. The results indicate that domestic, municipal, and commercial withdrawals were approximately 162 billion gallons per year in 1940 and had grown to over 250 billion gallons by 1960. By the year 2000 annual withdrawals are expected to be almost 500 billion gallons.

Withdrawals for manufacturing purposes were estimated by multiplying a per employee withdrawal rate times the number of manufacturing employees expected in the state. Manufacturing withdrawals are believed to have been approximately 275 billion gallons per year in 1940. With the rapid growth of manufacturing this increased to about 775 billion gallons in 1960. By 2000 withdrawals for manufacturing should be over 1,000 billion gallons per year.

Domestic, municipal, and commercial withdrawals and withdrawals for manufacturing are highly concentrated in the southern third of the state; 15 counties account for over 80 per cent of these withdrawals. In addition, manufacturing withdrawals were concentrated in four manufacturing types.

Approximately one-half of one gallon of water is required to produce one kilowatt minute of electricity. In 1940 this amounted to slightly over 330 billion gallons per year. With the expected growth of population and economic activity this may increase to over 6,500 billion gallons per year by 2000. Most of the withdrawals will be concentrated along the Great Lakes because of the tremendous quantities of water available.

Rapid changes in Michigan's agriculture has precluded specific estimates of withdrawals for agricultural purposes. However, the expansion of irrigated acreage and technological developments in livestock production are expected to affect significant withdrawal increases. These should be concentrated in the southeastern and southwestern parts of the state, the major areas of irrigation at the present time.

ACKNOWLEDGMENTS

The participants in this thesis are legion and it would certainly be some form of plagiarism not to give full recognition to each. Unfortunately space does not permit this opportunity and a less ambitious attempt must be made.

Greatest help was received from members of my family who, through both encouragement and freedom from family responsibilities, provided an environment conducive to study. Perhaps over the years the debt can be repaid.

Faculty help from the Department of Resource Development has guided me around numerous pitfalls and renewed my confidence when this was sorely lacking. Appreciation especially is due to Drs. Barlowe and Steinmueller whose doors were always open.

Fellow graduate students in the department combined to establish a situation in which academic standards were held high. Without the competition offered by these men the completion of this thesis would have been in doubt.

Finally, gratitude is expressed to the Michigan Water Resources Commission whose financial assistance permitted undivided attention to the thesis for a year.

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CHAPTER I

BACKGROUND TO THE STUDY

Purpose

That water is of inestimatable value to an area is seldom disputed. Whatever the nature of the area, unless it is completely unpopulated, water is of major importance. It is not necessary to expand the discussion of this point other than to say that in virtually all aspects of water use the demand is increasing in almost every area of the nation. Population growth and the expansion of economic activity dictate that increasing amounts of water will be utilized in the future.

Water use in Michigan is particularly important. Michigan ranked seventh in population in 1960, and in value added by manufacturing in 1963 it ranked sixth. Thus from sheer size, vast amounts of water are required and more will undoubtedly be required in the future as population and economic growth continue.

In Michigan water quality has not been a major problem. With location on four of the Great Lakes, with a large amount of inland water, and with abundant groundwater resources, the state has not felt the pressure of the demand for water impinging on a limited supply as have other states. One measure of Michigan's surface water resources is indicated in Table 1.

Table 1

Michigan Surface Water Resources[a]

Source	Area
Great Lakes	24,688,000 Acres
Inland Lakes	841,000 Acres
Inland Streams	36,350 Miles

[a]Clifford Humphrys, Michigan Lakes and Ponds (East Lansing: Agricultural Experiment Station, Michigan State University, 1965), quoted in Raleigh Barlowe, Implications of Land and Water Use Developments in Michigan for Future Public Water Resource Policy (East Lansing: Department of Resource Development, Michigan State University, 1966), p. 1.

If all of the various uses of water in the state are to be satisfied in the future expectations of future uses will have to be made. Although adequate water resources to satisfy present uses are available there is no assurance that they will be adequate in the future. Water policy made today will affect the adequacy of water resources tommorow. These policy decisions can be made with some degree of certainty if some idea of future requirements can be obtained.

The developments which influence the amount of water utilized have not in the past been equally important in all areas of the state. Some sections of the state, notably the northern parts, are probably using less water in 1970 than in

1950. On the other hand, most of the overall increase in population and economic activity, and as a result increases in water use, are taking place in 15 or 20 of the southern counties.

If the supply and demand situation for water is to remain adequate information must be attained on the structure and amount of water use throughout the state. Consequently, the purpose of this study is to examine the factors which have been instrumental in influencing the present spatial patterns of water use in Michigan, and to consider the changes which may be expected in the future. The focus of this effort will be on the non-marginal changes which have taken place over the years in the elements of water use in order to indicate the probable developments in the next few decades.

Estimating water use for the state as a whole is a very complex matter and involves the use of more resources than were available for this project. Nevertheless, in order to give a better indication of what may be expected in the future patterns of water use, tentative estimates of selected uses will be made for 1980 and 2000. Although these estimates may, in themselves, be important to personnel concerned with planning for Michigan's future water requirements, it is believed that the value of these use estimates will not be so much with the amount of use predicted, but with the identification of spatial trends. Water policy established which is based upon an appreciation of the spatial aspects of water use will be a most important addition to the planning effort.

Conceptual Framework

A prerequisite for the initiation of any research is the establishment of parameters within which the research is to be carried out. Research which does not contain this essential element will very likely bewilder the reader with conflicting terms and with an unclear idea of the purpose and direction of the work. For the researcher, too, the early setting of the framework will better insure that the research plan is followed and that the purpose and objectives of the study are completed.

The major concepts which must be established at this point are the nature of water use and the types of water use with which this study will be concerned.

The Nature of Water Use

Water may be used but it is never destroyed in the sense that it is diminished in physical quantity. The form of the water may change, causing it to be less available for use, but the potential amount of water remains unchanged. This is exemplified by the concept of the hydrologic cycle whereby the world's potential supply of moisture is constanly moving from the atmosphere to the surface of the earth and back again. At some stages in the cycle the moisture is more available for use than others, but it is never destroyed.

It is necessary at this point to make a distinction between water use and water withdrawal. Water withdrawal is a rather straightforward concept, and it is essentially that amount of water which is removed from a surface water or groundwater source. This is also known as water intake and says nothing about the use made of water.

Water use is a more difficult term to define. Water use is not the same as water consumption yet they are related. To be consumed water must be used, yet not all water used is consumed. To be consumed water must be used in such a way that it is not readily available for subsequent users, although it is physically undiminished.

Consider, for example, a water user who withdraws 100 gallons of water from a water source. These 100 gallons may all be used in some industrial process but only 10 gallons may be consumed. The remaining 90 gallons are returned to a water source where they are again available for use. If a later user also withdraws 100 gallons and consumes 25, returning 75 gallons, the total water withdrawal will have been 200 gallons and the total use will have been 200 gallons. Consumption, however, will only have been 35 gallons.

There is one further consideration which complicates the issue of water use and consumption. Water which is withdrawn, minus that amount which is physically altered in form (for example, transfer to a vapor state) so as to make it less available, may be used and left in such a quality that it is virtually impossible to make further use of the water. Thus water may be left unfit for some uses but not be actually physically altered in form (the original definition of consumption). Therefore, a further criteria for consumption may be necessary, one that takes into consideration changes in water quality that cause it to be unavailable for other uses. However, different types of activities are tolerant of different quality water. Thus water may be consumed, quality wise, for some types of uses but not for others. To complicate matters even more, water used and left unfit for certain uses may, with passage downstream or by certain types of water treatment, again become fit for use (thus being renewed).

Types of Use

There appear to be two major types of uses, those uses which internalize water in the production of a tangible good, and those uses which do not use water internally but use it as a median for the achievement of objectives.

When water is used for industry, for agriculture, or for domestic purposes it is used for the production of something, although it is not necessarily consumed, either in form or in quality, in the process. Water in the factory may be used for the production of an automobile, on the farm for the irrigation of crops, and in the home for the growth of people.

Other types of uses do not internalize water, nor do they alter it significantly as a result. The use of water for transportation, for recreation, or for aesthetic purposes satisfies these criteria. Carried to extreme these types of uses may diminish the quality of the water for any of these purposes; excessive boating on a water body can decrease the quality of that particular resource for subsequent boaters. As a general rule, however, these uses of water do not diminish the water in quantity or quality, and thus impose no costs on subsequent users.

For the purpose of this paper, the water "use" which will be considered will be water withdrawals for those uses which internalize water in its use. These types of uses will be restricted to domestic, municipal, and commercial uses, agricultural use for irrigation and for the production of livestock and related products, and water use in manufacturing and power generation.

The other uses of water, such as for transportation and for recreation, are recognized as equally important uses of water. The rationale for excluding such uses from this research is two-fold. First, the types of problems are not exactly the same. While all water use is related to people, those uses which use water "externally" are sufficiently different from those which use water "internally" to require special types of research. The second reason for excluding these uses from the research is that there are special agencies whose main responsibility is directly concerned with transportation and recreation. While all uses of water must necessarily be related if a complete picture is to be achieved, initial research is probably best done within the confines of a special research effort.

Objectives

Objective A

The first objective is to identify spatial and temporal trends in the factors which are contributing most to the changing pattern of water use in Michigan.

The factors which are responsible for broad, spatial differences in water use patterns are non-marginal. These have been identified in a number of different research efforts, and are largely the characteristics of the population and the characteristics of economic activity. The focus of this objective will be on the historical development of the elements of population and economic activity which are most important in explaining changes in the amount and type of water use in Michigan over time.

With both population and economic activity the most critical elements influencing water use will depend to a great extent on the scale of the study. If the area selected for study is extremely small the important elements will be different than if the study is oriented toward a larger area or toward a comparison between areas. Within any one region the amount of water used will be influenced by more detailed characteristics, but when the inquiry is the spatial pattern of use, as between regions, it is likely that detailed information about individual regions will be less important than more general characteristics for which there are considerable variations among regions.

This is true of both population and economic activity. For example, the elements of population which may be important when the object of study is a single city may be income, age structure, housing characteristics, etc. When the study is directed toward the difference between cities, however, the difference in the amount of water used may be determined so much by sheer differences in numbers of people that the detailed characteristics of the populations are either obscured or become of much less importance.

Similarly, the elements of economic activity important for determining the amount of water used in a single city may be a number of detailed characteristics, such as the general availability of water, or the pricing policy facing each producer. When looking at the differences between cities or between regions factors such as these may become less important than the balance between agricultural or manufacturing activity, or the differences between types of agricultural or manufacturing activity.

Objective B

The second objective is to make tentative projections of selected water uses to 1980 and 2000 for Michigan and for regions thereof.

The Michigan Water Resources Commission has recently completed (1968) an inventory of existing water use throughout the state.[1] Although the reports have several deficiencies, they are the most comprehensive treatment of water use on a state-wide basis that have ever been completed for Michigan, and represent a relatively accurate picture of water use for 1967-1968.

The contribution which this thesis can make to an understanding of water use in Michigan is an estimation of future water use. There has been sufficient work done in this general area to determine that the use of water is going to increase. However, there have been no studies which have attempted to establish a spatial estimate of what this future use will be.

Even with abundant resources of money and personnel it is very difficult to make an accurate projection of water use. And the difficulty increases in direct proportion to the degree of detail which is attempted. For this study four separate projections have been made. Of these, three are directly related to the economic activities which are most important in influencing water use, manufacturing, power generation, and agriculture. The third projection which is presented represents a combination of the remaining types of water uses. For the purpose of this study it will be called domestic use,

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[1]Five separate regional reports (Southeastern Michigan, Lower Lake Huron, Lower Lake Michigan, Upper Peninsula, and Northern Lake Michigan and Lake Huron) from February, 1968 to December, 1968 (Lansing: Michigan Water Resources Commission).

although it includes far more than just household uses. Included within this category, in addition to household uses, would be uses by commercial establishments, by institutions, by governments, and by other potential non-manufacturing users which might draw water from municipal water systems.

The importance of these projections is not so much with the actual amount of water estimated to be withdrawn for use, but with the spatial patterns which develop. Therefore, as long as the estimates which are made are reasonable, and consistency is maintained between regions, the usefulness of these projections is not impaired.

Objective C

The third objective is to identify spatial patterns of future water uses which will be of importance to water planning efforts in the state.

The focus of this objective is on a regionalization of the 1980 and 2000 water use estimates. This will be concerned not only with the total amount of water use, but with changes in the type of uses which can be expected among the several regions. It is possible for the state as a whole to exhibit a relatively continuous increase in water use, but for there to be quite a variation among the regions. Therefore, it is necessary that regional changes be identified if the state agencies concerned with water planning are to meet their responsibilities.

Scope

In the consideration of a research effort the scope of the study is of great importance. With a given amount of resources which can be expended for a study, the magnitude of the problem, either in geographic size or in complexity, will significantly influence the purpose of the research, the objectives, and the methods used.

The geographical area covered by this research is state-wide. The examination of such a large area will necessitate a more general approach than if the focus was on one county or even on a group of counties.

Both the general the detailed approaches have merit. The detailed study of a small area will enable the identification of important variables, and the magnitude of their influence, to be more accurate, and as a result any quantitative estimates of water use at a future date will undoubtedly be more precise. The accuracy of such a study, however, does not indicate the nature of the situation for the larger area, a region or a state. There are important spatial considerations that can be understood only when the complete situation can be realized. In fact, a thorough understanding of water use relationships of the small area can often be seen only within the context of the larger area.

The manner in which data is presented, the size of the enumeration tract, is important with regards to the unity of the data. By reporting data in small tracts it is possible to reorganize it to conform to any number of regional areas. When the data is presented on a large area basis the flexibility of the data becomes less. And, data for small areas is often hidden within the larger ones.

For this research the preliminary data and resulting water use estimates have been organized according to a regionalization of counties which was recommended by the Michigan Water Resources Commission (see the map on page 14). Regions I, II, III, IV, and V represent the groupings of counties which most closely correspond to major watersheds of the state. Regions II and III have each been divided into parts A and B because of the relatively large size of regions II and III.

In estimating future conditions of water use the time framework is always a significant consideration. Some balance must be achieved between the extreme long range projections which are likely to be greatly in error because of the long span of time, and very short range projections which, although more precise, are less useful because of the restricted time period. For this study 1980 and 2000 were chosen as target dates. These were selected completely arbitrarily, and represent a compromise between short and long range projections.

Introduction to Methodology

The general research plan for the study is to identify the principle factors responsible for water use, to

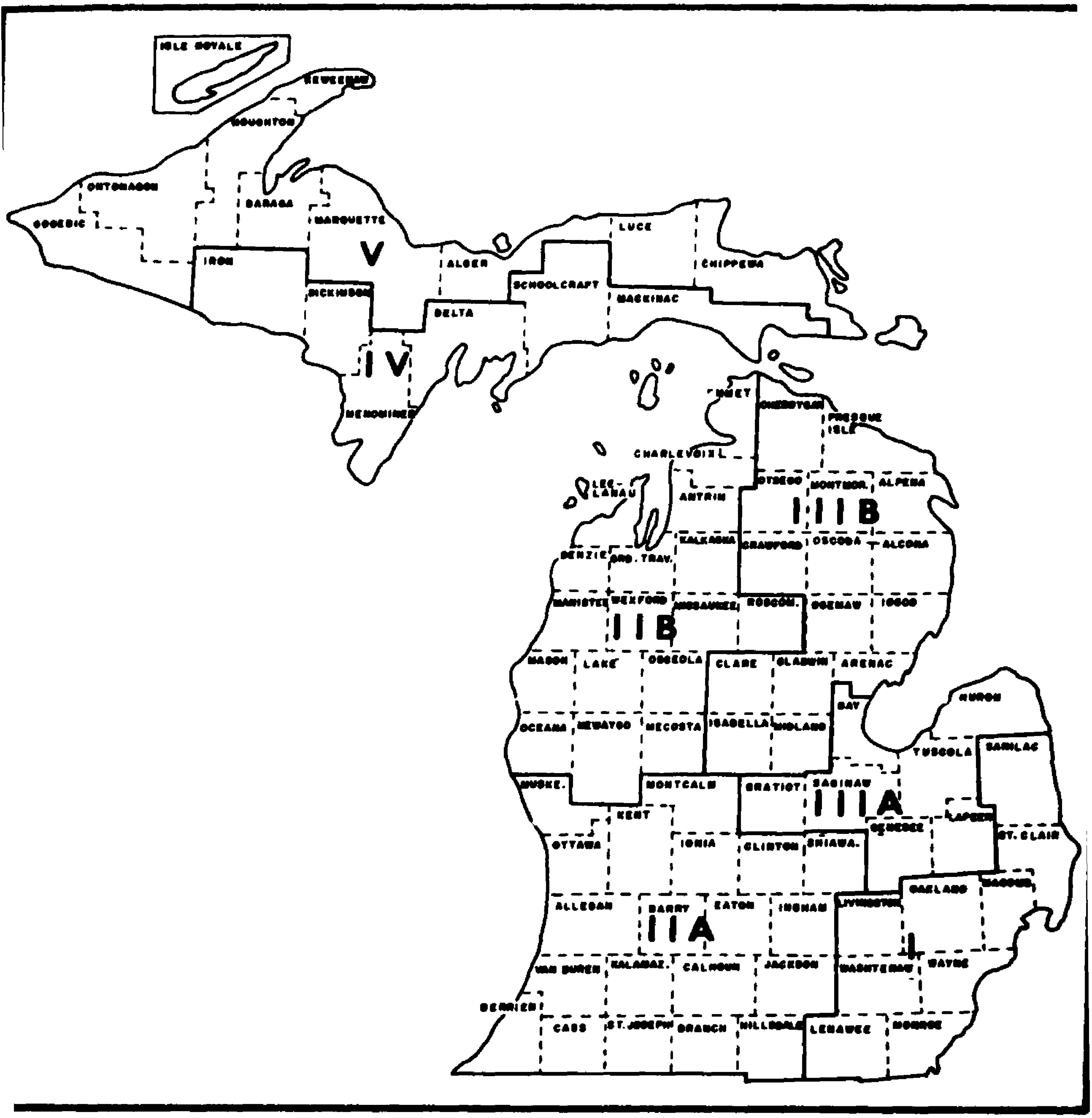

Figure 1. Planning Regions

project the magnitude of these factors to 1980 and 2000, and from these to estimate selected future water uses. A more detailed description of the methods used in making these estimates will be found in later chapters. However, there is one point which much be discussed at this time since it provides a basis for the rest of the study. This most important topic involves the nature of forecasts and projections.

Forecasts and Projections

In its most elementary form a forecast is nothing more than a statement about the condition in which something is expected to be at some future time. Such forecasts can be made on a continuum which ranges from pure guesses to those which are based on sophisticated models which rely upon perfect knowledge of future conditions of those factors which are responsible for the thing which is being examined.

At one end of the continuum, the guess, forecasts are generally rejected in favor of a method which has more predictive power. At the other extreme, the detailed knowledge which is needed if the relevant factors associated with the object under investigation is seldom present. Consequently, forecasts are generally based upon a compromise between the "guess" and perfect knowledge.

Most "compromise" forecasts rely to a great extent upon the observance of the past history of the object of the forecast and of the factors which are responsible for it. These compromise forecasts which utilize data on past conditions are commonly called projections. Kuznets defines projections as "...statements about the future that claim to be derived from empirically tested propositions concerning the past."[1]

The Nature of Projections[2]

Statements about the future which are based upon the past appear at first to be simple logic; since the future can never be known by the observation of empirical evidence it would seem realistic to assume that the events of the future would resemble those of the immediate past. Yet there are two criteria which must be met before such a statement can be valid. First, the past and the future must be interrelated in some logical manner. And second, the past events must have some semblance of order about it.

The first criteria, that of relationship between the past and the future, is an obvious necessity. Unless this relationship is present any attempt to assess the future would be in vain. It would be futile to expect that the amount of water used in Michigan in 1980 would be in any way related to the trends in the ratio of male-female births. However, it would be quite realistic to expect that changes

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[1]Simon Kuznets, "Concepts and Assumptions in Long-Term Projections of National Product," Studies in Income and Wealth, Vol. 16 (Washington: National Bureau of Economic Research, 1954), p. 9.

[2]This section is based upon the points developed in Kuznets, Ibid.

in population levels and economic activity might have an effect.

The second criteria which must be met before a projection can be made is that there must be some systematic ordering of past events. If the relevant factors have occurred randomly in the past there is no reason to expect that they will occur in any other way in the future. And it would be impossible to project a random past in any manner except randomness, a useless effort if the purpose is to determine what the future may hold. Therefore, unless past conditions are arranged in some meaningful pattern it will be useless to make projections based upon them. The extent to which order exists in past data can be tested. Therefore, it is possible to proceed with the realization of the probable validity of the projection.

The question of prediction versus forecast is an important one. The principle distinction is related to the existence of a causal relationship between the object of study and one or more associated variables. A prediction implies that one or more factors cause another factor to assume a certain condition. It assumes that specific magnitudes of A, B, and C will cause D to exist in a certain form.

A forecast does not necessarily involve the function of causality, yet may equally well approximate the future. A physicist and an illiterate may both throw a stone into the air and state that it will fall to earth. The physicist, to the extent that he applies the concept of gravity, is predicting that the stone will fall. The illiterate may have no understanding of physics, but from past experience believes that the stone will behave as previous stones have behaved. He then is making a forecast and not a prediction. In a sociological example, there is a strong correlation in Michigan between a county's total population and its population density. Thus one may make a statement about future population levels based upon trends in population density. This does not, however, involve a complete explanation since the matter of the area of the county has not been considered.

The extent to which either prediction or estimation is satisfactory will depend to a large extent on the purpose of the projection. If the object is to develop an understanding of why and how the causal variables operate one must work toward prediction. On the otherhand, if the intent is merely to determine the magnitude of a certain condition, an explanation may not be necessary. If it was possible each year to accurately forecast the first snowfall by the date of the last snowfall in the previous year this would be satisfactory if the object was just to determine the date of the first snowfall and not provide an explanation of why.

Such a spurious relationship is seldom, if ever, found. Most estimations as opposed to predictions are based upon relations which are obvious but are not well enough understood to be fully explained, or for which the lack of data is a restricting factor. This, however, does not prevent their usefulness. If the object is to estimate how much timber will be cut in the nation next year, and this can be done by projecting the quantity cut in previous years, it is not necessary to know what the demand for housing, furniture, etc. will be.

Often the addition of successive factors will increase the ability to forecast the future with accuracy. To the extent that data is available that permits this, this should be the goal. When data are lacking forecasts must be made with data at hand.

The present research must, of necessity, be more of a forecast than of a prediction. The detailed, historical data which is required for the more complex projection methods can not be obtained and, therefore, these methods must be passed over in favor of methods which can utilize the data which is available. The forecasts of water use which are presented are based, however, on sound relationships which have been tested in other research which has had access to the type and quality of input data which is necessary to utilize the more sophisticated methods.

Assumptions

Forecasts of the future must necessarily involve assumptions about the future. There are certain basic conditions which must be stabalized if any projections can be made.

It must be assumed that water availability will remain the same, and will play essentially the same role that it has played in the immediate past. There have been many schemes to increase the water in certain areas of the United States. The North American Water and Power Alliance and weather modification are examples. In Michigan, there has been discussion of a Lake Michigan to Lake Huron canal which would provide increased water for some areas of the state and undoubtedly influence the spatial pattern of water use. In addition, there are a few potential reservoir sites which could possibly be utilized to increase the available water. It is assumed that these developments will not take place to any appreciable extent prior to 2000. Further, it is assumed that there will be no major technological "breakthrough" which substantially lowers the per capita demand for water. Equally restrictive, it must be assumed that there will be no major droughts in 1980 or 2000. The "normal" available water must be considered as existing in the target years.

A second assumption is that there will be no major war or large inflationary or deflationary periods in the economy in the years 1980 and 2000. Such wars or economic changes may very well occur prior to these target years, but it must be assumed that by 1980 and 2000 their effect will have been ameliorated so that it is no longer significant.

There are several other assumptions which must be made with regards to each of the domestic, industrial, and agricultural projections. These will be discussed in the respective chapters.

CHAPTER II

FACTORS CONTRIBUTING TO DOMESTIC, MUNICIPAL, AND COMMERCIAL WATER WITHDRAWALS

Introduction

The category of water use labeled "domestic, municipal, and commercial" is a very important one in that it is one of the necessary elements of a modern urban system. This category of water use includes three principle types of withdrawals: (1) domestic - water withdrawals by private residences, (2) municipal - withdrawals for use in schools, hospitals, and other urban services, (3) commercial - laundries, restaurants, car washes, etc.

The purpose of this chapter will be to examine the factors behind differences in domestic, municipal, and commercial withdrawal rates among different parts of an area. No attempt will be made to relate these to the Michigan situation in particular because of the inability to handle such detail on a state-wide scale, but to just discuss in general the findings of related research.

Composition of Withdrawals

Per capita domestic, municipal, and commercial water withdrawal rates combined have increased considerably in the past and are expected to increase further in future years. The Water Resources Council has estimated that, nationally, the daily per capita withdrawal from municipal systems for all non-industrial uses will rise from 121 gallons in 1965 to 123 gallons in 1980 and 125 gallons in the year 2000.[1]

Of the total withdrawals, the amount required for commercial uses is expected to remain constant at 28 gallons per capita per day. The amount required for public or municipal purposes is expected to decrease from 20 gallons per capita per day in 1965 to 18 in 1980 and 16 in the year 2000. Thus the total category increase in per capita withdrawals is expected to result from increased domestic use. For the total Great Lakes region this is expected to increase from 73 gallons per capita per day in 1965 to 77 gallons in 1980 and 81 in the year 2000.[2]

Elements of Domestic Withdrawal Increases

The majority of the research which has been done on residential use points to three factors as being primarily responsible for the increased per capita use rates: (1) the development of modern home appliances which utilize large amounts of water, (2) increased incomes which allow the

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[1] Water Resources Council, The Nation's Water Resources (Washington: U.S. Government Printing Office, 1968), p. 4-1-2.

[2] Ibid.

purchase of the aforementioned appliances, (3) the movement of larger numbers of people to the suburbs.

Modern Appliances

There have four appliances which have been responsible for increasing the per capita withdrawal rates for domestic purposes. These are clothes washers, dishwashers, garbage disposals, and air conditioners. Depending on the type of washing machine the mean rate of water use is between two and seven gallons per minute. The normal load requires from 36 to 50 gallons.[1] The higher rates are found in the automatic washers, and the trend toward the use of automatic washers suggests that increasing amounts of water will be required for this purpose. The same general pattern is found in automatic dishwashers. An Ohio study found that the amount of water used for a single washing in an automatic washer was approximately 40 per cent greater than when the washing was done by hand.[2] This survey was taken in 1956 and it was suggested that modern washers probably use more water than did the older models. A study made in St. Louis indicated that homes with air conditioners used between four and one-half and seven times as much water in the summer as in the winter. In

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[1]J.G. Carns, "Service Lines and Meter Requirements of Domestic Water Connected Devices," Journal of the American Water Works Association, Vol. 58, No. 10 (October, 1966), p. 1256

[2]Rudolfo Silva, "Land Uses and Water Consumption Requirements," Public Works, Vol. 90, No. 4 (April, 1959), p. 123.

homes without air conditioning summer use was less than one and one-half times the winter rate.[1]

Increased Incomes

Increased incomes allow the populus to enjoy the fruits of technology, generally resulting in increased per capita withdrawal rates. In a study of per capita withdrawal rates in Illinois, a strong relationship was found between family income and per capita use rates. Families with high incomes used, on the average, five times as much water per person as did families with low incomes.[2] In addition to home appliances, higher family incomes have allowed the construction of homes with more complete sanitary facilities, including multiple bathrooms. Even home swimming pools are becoming commonplace.

A more detailed study of this type of use was made in Rhode Island. The purpose of the study was to see if the amount of water used in households was related to social status. The significance of a number of variables proporting to represent social status were tested. Only three of these, however, were found to be significantly correlated with the amount of household water use. These variables were

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[1]Kenneth S. Watson, "Water Requirements of Dishwashers and Food Waste Disposers," Journal of the American Water Works Association, Vol. 55, No. 5 (May, 1963), pp. 555-559.

[2]Brent O. Larson and H.E. Hudson, "Residential Water Use and Family Income," Journal of the American Water Works Association, Vol. 43, No. 7 (July, 1951), p. 610.

household income, house value (which is directly related to income), and household size.[1]

Other social variables have also been found to be related to residential water use. In a study in Kankakee, Illinois, assessed valuation of the house, family income, education, and occupation were statistically correlated with water use per household.[2] It is interesting to note that all of these variables are interrelated to a certain extent.

Suburban Living

The trend toward suburban living has accelerated the per capita water withdrawal rates for residential use. This is overwhelmingly the result of larger lawns and the demand for water to irrigate them. In fact, the increase in the demand for lawn sprinkling has changed the design of water systems in surburban areas. With the pre-World War II conditions most water systems were designed with the controlling factor being the quantity of water needed in case of a bad fire. In many suburban areas it has become necessary to make the potential lawn sprinkling requirements the controlling factor. Demands for any fire load are almost always covered

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[1] Irving A. Spaulding, Household Water Use and Social Status (Kingston: Agricultural Experiment Station, University of Rhode Island, 1967), pp. 7-25.

[2] Dorthy F. Dunn and Thurston E. Larson, "Relationships of Domestic Water Use to Assessed Valuation, with Selected Demographic and Socio-Economic Variables," Journal of the American Water Works Association, Vol. 55, No. 4 (April, 1963), pp. 441-449.

under the sprinkling capacity.[1]

The tremendous growth rate of the suburbs almost insures that this trend will continue. Between 1950 and 1955, 98 per cent of the population increase was in metropolitan areas, and the suburban growth rate was seven times as great as that of the central cities.[2] Although these are national data this trend is also evidenced in Michigan (see Table 5).

The amount of water required for watering lawns will not be uniform throughout a large area because of differences in climate, largely temperature and precipitation. Even in Michigan there is sufficient variety in climatic patterns to cause a potential difference in sprinkling requirements in different parts of the state. Figures 2 and 3 indicate the situation for the Lower Peninsula. The map of potential evapotranspiration indicates how much moisture would be evaporated and transpired if there was sufficient moisture available. The values for potential evapotranspiration generally diminish toward the northern part of the state. The map of normal moisture deficit shows the difference between the maximum possible evapotranspiration (given adequate moisture) and the actual evapotranspiration (which may be less than the maximum possible because of inadequate soil moisture). The greater the deficit the more critical is the lack of moisture.

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[1] Angus D. Henderson, " The Lawn Sprinkling Load," Journal of the American Water Works Association, Vol. 48, No. 4 (April, 1956), pp. 361-362.

[2] Silva, "Land Uses and Water Consumption Requirements," p. 121.

Figure 2. Normal Potential Evapotranspiration[ab]

[a]A. Stephen Messenger, "The Water Balance of the Lower ninsula of Michigan," Papers of the Michigan Academy of ience, Arts, and Letters, Vol. XLVII (1962), p. 386.

[b]Millimeters

Figure 3. Normal Deficit[ab]

[a]A. Stephen Messenger, "The Water Balance of the Lower Peninsula of Michigan," Papers of the Michigan Academy of Science, Arts, and Letters, Vol. XLVII (1962), p. 387.

[b]Millimetérs

It can be seen that there are definite spatial differences, at least in the Lower Peninsula, in the soil moisture deficit.

Pricing Policies

Although the withdrawal rates for domestic, municipal, and commercial uses have risen in the past and are expected to rise considerably in the future, the rate of increase is probably lower than it would have been without the operation of a very basic economic principal. This principal is the price elasticity of demand for water and the tendency for less water to be used when the cost of that water increases in certain kinds of situations.

A number of studies have shown empirically that this process actually works in the area of water utilization. In a study of municipal water systems throughout the nation a direct relationship was found between water use in urban areas and the price of water.[2] When 50 per cent of the water was metered there was no firm trend in the reduction of use rates. In the 50 to 95 per cent metered category there was a sharp decrease in the per capita use rates (approximately a six per cent reduction in per capita use). This trend was

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[1]For a most complete discussion of the water balance concept see C.W. Thornthwaite and J.R. Mather, The Water Balance (Centerton, New Jersey: Drexel Institute of Technology, 1955).

[2]Ralph Porges, "Factors Influencing Per Capita Water Consumption," Water and Sewage Works, Vol. 104, No. 5 (May, 1957), pp. 199-204.

accentuated in the over 99 per cent metered category. On the basis of these data the savings in water would be about 25 per cent when going from an unmetered system to 100 per cent metering.

In an analysis of the water use statistics of 441 cities as published by the American Water Works Association a close correlation was found between the price of water and the per capita use rate. A summary of their findings is presented in Table 2.

Table 2

Price Elasticity of Residential Water Demand[a]

Cost of Water (c/1000 gal.)	Per Capita Use (gal. per day)
.70	137
.60	143
.50	154
.40	178
.30	205
.20	246
.10	296

[a]H. Seidel and E. Baumann, "A Survey of Operating Data on Water Works in 1955," Journal of the American Water Works Association, Vol. 59, No. 5 (May, 1967), p. 553.

Figure 4 shows the demand-price relationship for water use for domestic purposes in western cities. This data again substantiates this economic relationship.

Despite these apparently strong relationships overall, it is often difficult to identify them when dealing with any

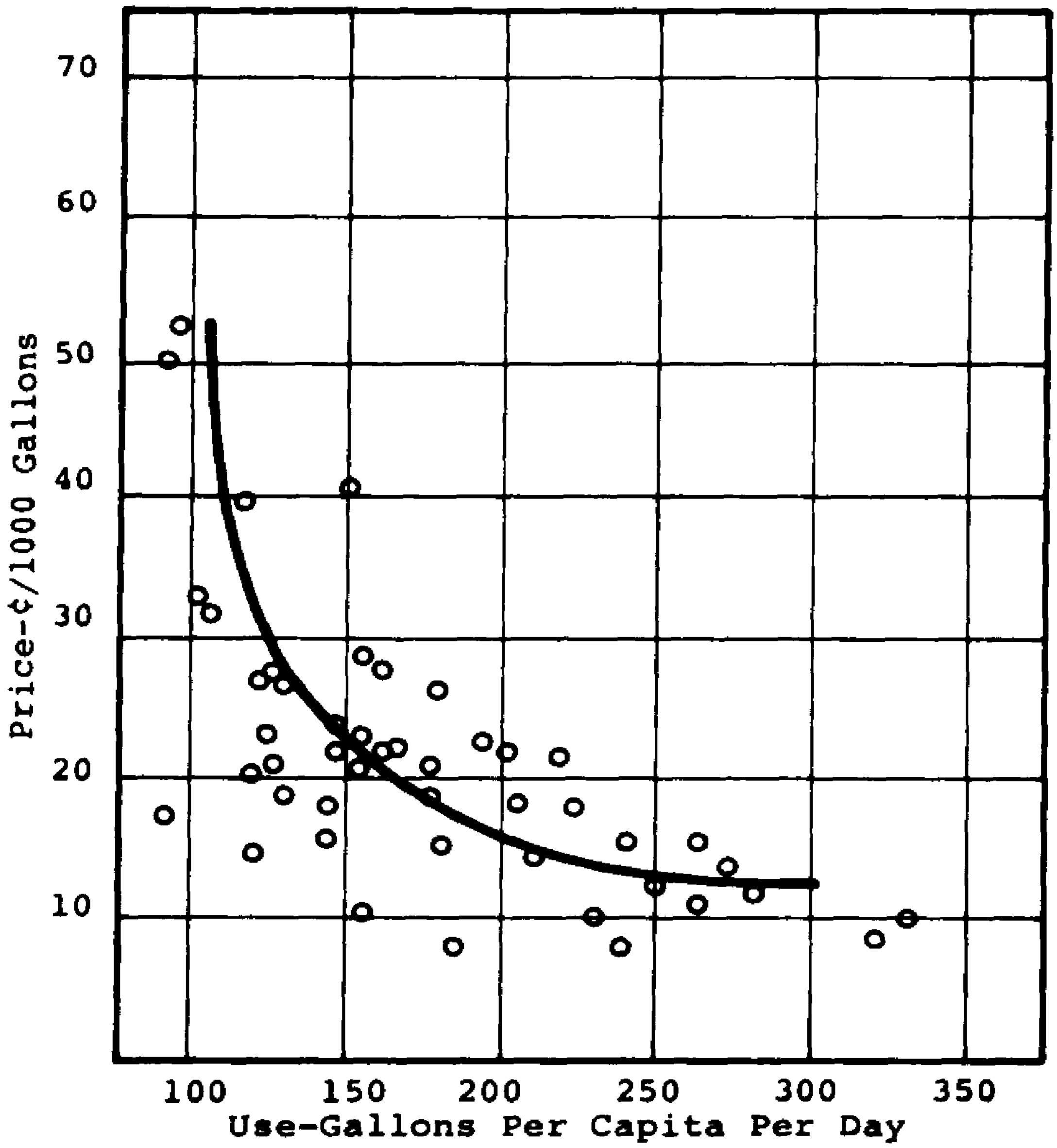

Figure 4. Price-Demand for Domestic Water: Western Cities[a]

[a]J. Ernest Flack and Fortunato Martinez-F, Urban Water Use Study (Denver: American Society of Civil Engineers Water Resources Engineering Conference, May 16-20, 1966), p. 4.

given city. It was found in Colorado Springs, for example, that the result of a price change for water was hidden by larger lawn areas and larger sprinkling loads of new housing developments, by water use restrictions, and by year-to-year climatological fluctuations.[1] Year-to-year variations in climate conditions are generally greater in more arid regions of the nation but certainly are not uncommon in the more humid Middle West.

Hanke points out that even metered water can lead to considerable wastage, especially when flat rate price structures are used.[2] In fact, the use of a flat rate is no better than no metering at all. After paying the fixed rate the customer is free to use as much water as he desires without any additional cost to him. It is obvious that the most effective sort of rate structure will be one which is sensitive to incremental amounts of water use.

A recent innovation in water metering is to charge for any strain placed on the peak capacity of the water system. Consider, for example, two users who use the same amount of water, one spreading the use throughout the day, the other concentrating his use during two or three hours of the day,

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[1] J. Ernest Flack and Fortunato Martinez-F, Urban Water Use Study (Denver: American Society of Civil Engineers Water Resources Engineering Conference, May 16-20, 1966), p. 6.

[2] Steve H. Hanke, "The Effects of Metering Urban Water," A paper presented to the Seventh Annual Institute for City Engineers, February 6-8, 1968, University of Colorado, Boulder, Colorado, p. 1.

morning and evening. Under this suggested pricing system the second user would be charged a higher rate than the first.[1]

A pricing system such as this would probably find its greatest effectiveness in reducing the peak demands caused by lawn sprinkling. The normal water use for household uses (exclusive of lawn sprinkling) are not too much different between metered and unmetered sources. The water used for lawn sprinkling varies considerably, however, and is much more susceptible to "peak" demands.[2] Thus, since sprinkling uses are more price elastic it may be possible by selective pricing to not only reduce the total amount of water used in an area, but to reduce the strain placed upon the water system. To the extent that different pricing systems (or none at all) are adopted by different communities the per capita withdrawal rates may vary considerably.

It should be brought out at this time that the effect of price elasticity of demand on water use is not a phenomena of residential use alone. The increased water conservation practiced in industry (such as recirculation) is evidence that the influence of external and internal water pricing is widely felt.

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[1]W. Patterson, "Demand Rates for Water Service," Journal of the American Water Works Association, Vol. 53, No. 10 (October, 1961), p. 1269.

[2]Hanke, "The Effects of Metering Urban Water," p. 7.

CHAPTER III

GENERAL POPULATION CHARACTERISTICS AFFECTING DOMESTIC, MUNICIPAL, AND COMMERCIAL WATER WITHDRAWALS IN MICHIGAN

Introduction

More than any other factor, the amount of water which will be needed for domestic, municipal, and commercial uses will be determined by levels of population in the state. It is true that there will be wide variations throughout the state in the factors which contribute to per capita withdrawal rates; however, when balanced against sheer numbers of people they are much less significant. The purpose of this chapter is to examine some of the general population trends in the state, largely changes in levels of population over time and projections to 1980 and 2000, which will have an influence on future levels of withdrawals.

Population Growth

Population growth in Michigan has had three important elements. These are : (1) the amount of growth, (2) source of growth, (3) spatial patterns of growth.

Amount of Growth

The population of Michigan has maintained constant increases between census periods since the middle of the 19th century. This increase has not been at a constant rate, however. The total population in Michigan for 13 census periods extending back to 1840 is presented in Table 3. It can be seen that, with the exception of the 1930 to 1940 period, the absolute increase from each census period to the next has been well over 1,000,000 per period. The per cent increase has decreased from the early high rates, reflecting the impact of a sparse population, to a relatively stabilized rate of increase in the last two census periods.

The population increases for the East North Central Region of which Michigan is a part (together with Illinois, Indiana, Ohio, and Wisconsin), and of the nation as a whole, is also presented in Table 3. Michigan has tended to follow the trend of both the larger region and the nation. Michigan has, however, maintained a higher rate of growth than either the region or the United States, with the exception of the 1890 to 1910 period.

Another indication of the rapid growth of population is revealed by the per cent of the total United States population which was in Michigan at different periods. With the exception of the 1890 to 1910 period, Michigan's share of the nation's population has been constantly increasing.

Table 3

Population Growth: US, ENC, Michigan[a]

Year	Michigan Population	Per Cent Increase Over Previous Census: Michigan	East North Central[b]	United States
1960	7,823,194	22.8	19.2	18.4
1950	6,371,776	21.2	14.2	14.5
1940	5,256,106	8.5	5.3	7.2
1930	4,842,325	32.0	17.8	16.1
1920	3,668,412	30.5	17.7	14.9
1910	3,810,173	16.1	14.2	21.0
1900	2,420,982	15.6	18.6	20.7
1890	2,093,890	27.9	20.3	25.5
1880	1,636,937	38.2	22.8	30.1
1870	1,184,059	58.1	31.7	22.6
1860	749,113	88.4	53.1	35.6
1850	397,654	87.3		
1840	212,267			

[a]U.S. Bureau of the Census, U.S. Census of Population: 1960. Vol. I, Characteristics of the Population. Part 24, Michigan and Part I, United States Summary (Washington: U.S. Government Printing Office, 1963).

[b]The East North Central Region includes the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin.

Of the 20 states which enjoyed a greater percentage increase than the nation as a whole between 1950 and 1960 only ten of these had growth rates greater than Michigan. However, when the data are examined in more detail it can be seen that of these states only one of them (California) had an absolute population larger than Michigan, and Michigan had only slightly less than double the population of the next largest state. When the base year populations are small even slight increases in population may result in a considerable increase in percentage points.[1]

Sources of Growth

Increases in population can result from either a natural increase or from net in-migration or from a combination of both. Natural increases occur when there are more people born during a given period of time than die. Increases from migration occur when more people move into an area than move out. As with births and deaths there will generally be some out-migration and some in-migration during any period; for there to be overall increases in net migration the numbers of in-migrants must exceed the numbers of out-migrants.

In the Michigan situation in recent years the increase in population has been dominated by natural increases. The source of growth for the state as a whole since 1900 is shown

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[1]William Haber, The Michigan Economy: Its Potentials and Its Problems (Kalamazoo, Michigan: W.E. Upjohn Institute 1959), pp. 70-71.

in Appendix Table 1. While there have been considerable differences in total migration from period to period, the per cent of the total increases accounted for by migration has been declining, although not at a constant rate. The low figure for the 1930 to 1939 period reflects the industrial slowdown during the depression. Had the depression not occurred the figure would probably have been between 35 and 60 per cent. During the latest period of record the state actually lost more people by migration that it gained. The natural increase was sufficient, however, to counter this loss and provide an overall increase.

The composition of the natural increase has been dominated by a steadily falling death rate and rising (although not continuously) birth rate. Figure 5 shows, diagramatically, these forces from 1900 to 1963, together with changes in the rate of natural increase. As the spread between the birth and death rate has increased the rate of natural increase has increased. The exception to this was during the 1930 to 1940 period which coincided with the depression years.

Population migration into and out of Michigan has played an important part in affecting the total population level of the state. The migration pattern for the state from 1900 to 1963 is presented in Appendix Table 1. It is important to note that Michigan has registered net in-migration in every period except the most recent post-1960 period. This is undoubtedly a result of Michigan's importance as an

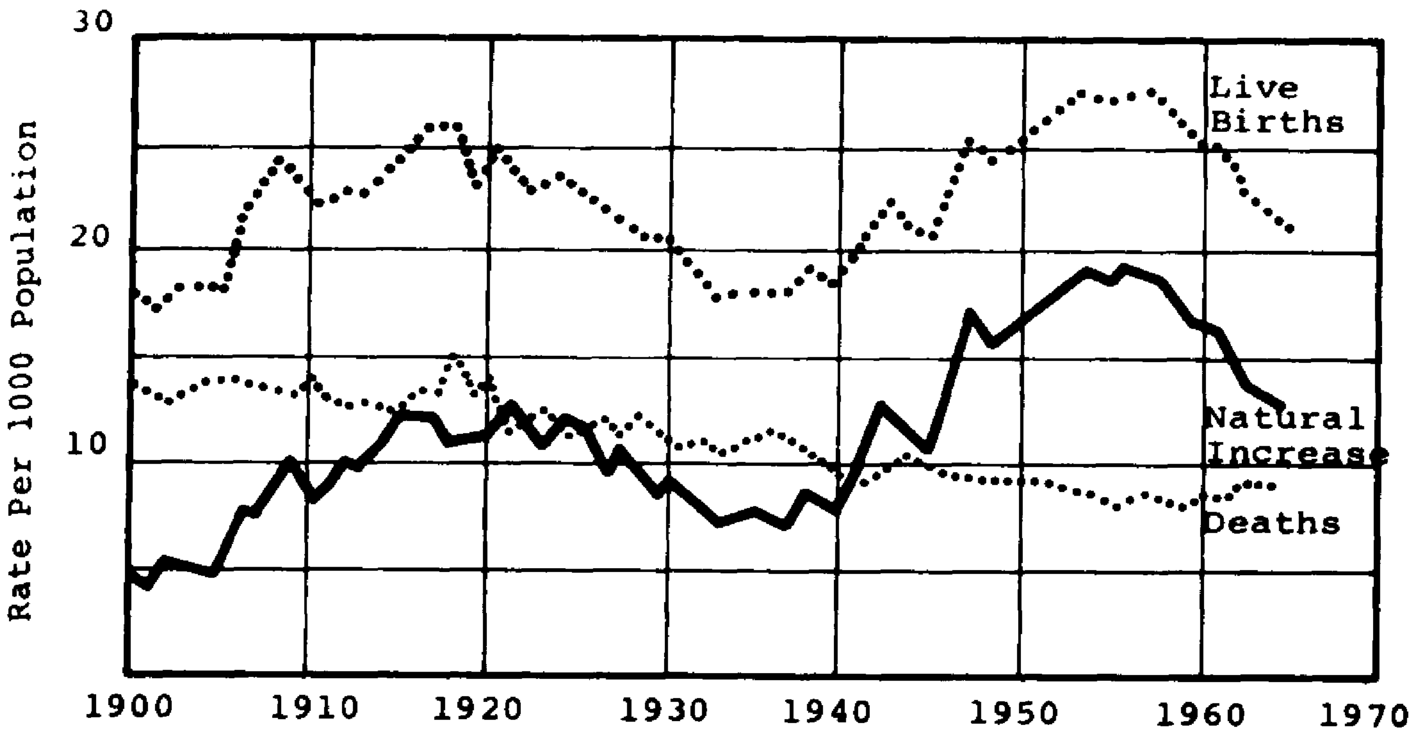

Figure 5. Michigan Demographic Rates: Live Births, Deaths, Natural Increase 1900-1964[a]

[a]R. Raja Indra, Michigan Population Handbook 1965 (Lansing: Michigan Department of Public Health, 1965), p. xix.

industrial state which has made it a major source of employment. The large increase from migration between 1910 and 1930 is attributed to the growth of the automotive industry during this period.[1] This is illustrated by the realization that, until the depression, there had been a steadily increasing number of migrants into the state. The post-depression

[1]William Haber, Allen Spivey, and Martin Warshaw (eds), Michigan in the 1970's: An Economic Forecast (Ann Arbor: Bureau of Business Research, Graduate School of Business Administration, The University of Michigan, 1965), p. 120.

period registered a 331 per cent increase in migration over the previous period, considerably less than the most recent pre-depression period. Since 1950 the number of in-migrants has decreased drastically, and the 1960 to 1963 period showed an estimated loss in population as a result of out-migration.

The reversal of the trend toward in-migration has probably been the result of two forces. First, with the growth of the service economy, employment is becoming less tied to the manufacturing base which represents Michigan's dominant industry. As a result, potential in-migrants are able to secure work in other locations. The second reason is somewhat related to the first. The growth of the amenity resources as a factor of population growth has affected migration to Michigan. With the increasing importance of non-manufacturing industries, especially the service industries, employment has become less tied to specific geographic areas which could provide employment in the manufacturing industries. Climate and other aspects of pleasant living conditions have exerted an increasing influence on the choice of residences.[1] As a result, it is probable that Michigan has lost large numbers of potential migrants to such states as Arizona, California, and Florida, the states which have profited most from this source of migration.

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[1]Edward L. Ullman, "Amenities as a Factor in Regional Growth," The Geographical Review, Vol. XLIV, No. 1 (January, 1964), pp. 119-132.

Spatial Patterns of Growth

The incidence of the overall population increase in Michigan has not been uniform throughout the state. Largely as a result of changing economic conditions the redistribution of the population in the state has been considerable.

The population and per cent of state total for the top 15 counties in population in the state for 1960 are listed in Appendix Table 2. It is apparent that the population is becoming increasingly concentrated in these counties. In the year 2000 these counties are expected to have 80 per cent of the population of the state.

Not only has the growth not been uniform throughout the state, but 26 counties actually had less population in 1960 than they had at an earlier, more prosperous, period. These counties are all in either the Upper Peninsula or in the northern part of the Lower Peninsula, are largely rural, and have relied largely on agriculture, mining, and forestry as means of employment. With the decline of this segment of the economy many of the former residents have moved elsewhere and immigrants have been few.

This loss of population has been a result of net out-migration. Figure 6 indicates counties which experienced out-migration during the 1940 to 1960 period. These counties are largely concentrated north of the Bay City-Muskegon line which has traditionally been used to separate the industrial southern part of the state from the northern part of the

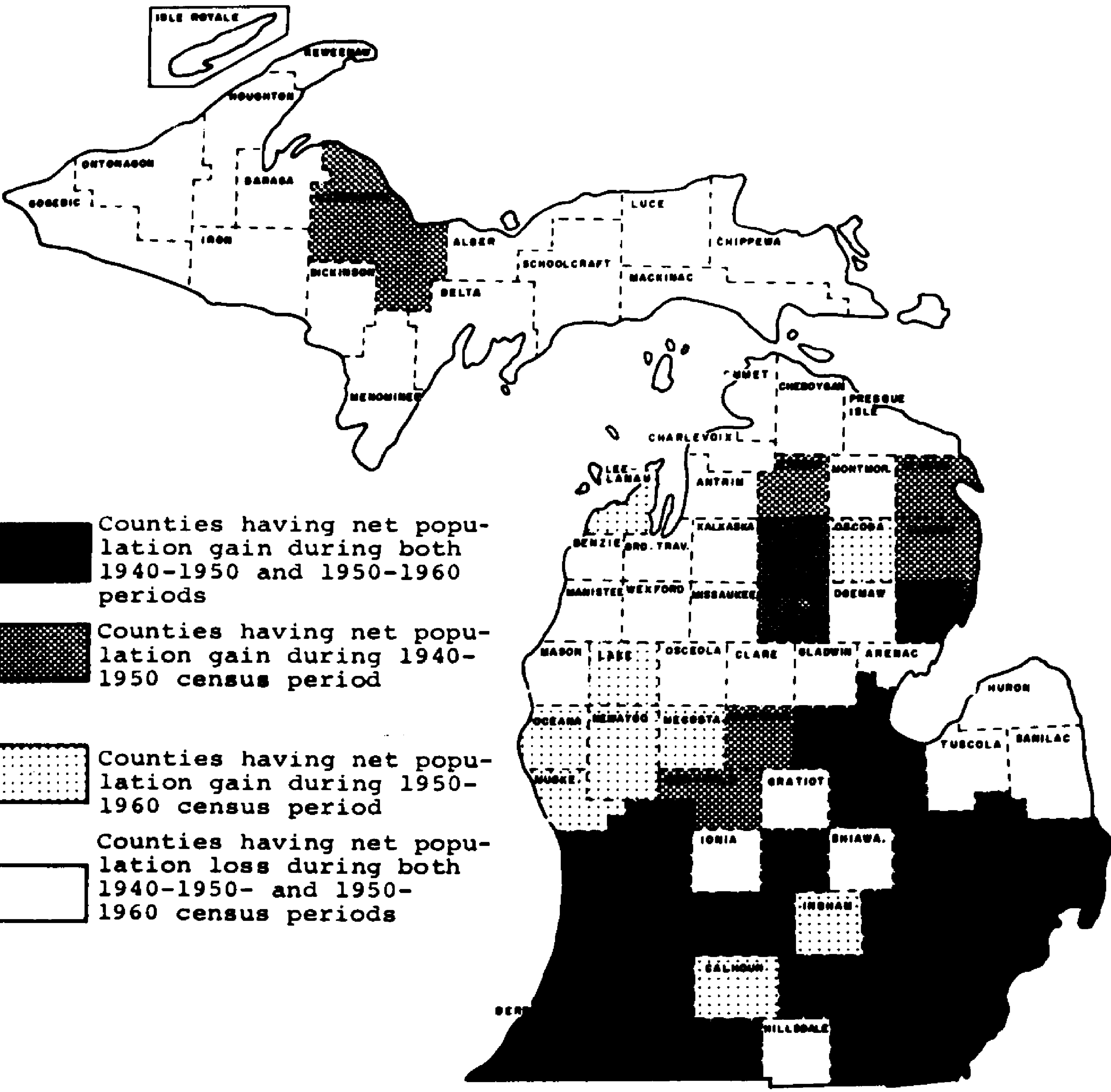

Figure 6. Population Loss[a]

[a]Compiled from U.S. Bureau of the Census, <u>U.S. Census of Population: 1940, 1950, 1960</u>. Vol. I, Characteristics of the Population. Part 24, Michigan (Washington: U.S. Government Printing Office, 1963).

state which has a preponderance of extractive economic activities.

At the opposite end of the continuum there are 29 counties which not only had a larger population in 1960 than ever before, but have never experienced a population loss from one census period to another. These counties are all in the southern part of the state and have large portions of their population engaged in manufacturing. In 1960 these 29 counties accounted for 81 per cent of the total state population.

The concentration of population in the seven planning regions selected for this study has not been uniform. The population and per cent of the state total for each region in 1940, 1950, and 1960 are indicated in Table 4.

Changes in Population Characteristics

In any discussion of the population of a state there are a number of characteristics of the population which are important and which could be mentioned. However, when the object of examining population trends is to gain an understanding of the probable water needs at some future time the list of important characteristics is considerably reduced.

In addition to the total population, two characteristics have been chosen as being of greatest importance in affecting the level of water needs in the state. These characteristics are: (1) income levels, (2) urban-rural

Table 4

Regional Population Concentration[a]

Region	1940 Population[b]	1940 Per Cent[c]	1950 Population[b]	1950 Per Cent[c]	1960 Population[b]	1960 Per Cent[c]	1980 Population[b]	1980 Per Cent[c]	2000 Population[b]	2000 Per Cent[c]
I	2,697.1	51.3	3,440.3	54.0	4,291.5	54.9	5,513.7	55.9	7,537.6	57.4
IIA	1,282.1	24.4	1,552.3	24.4	1,902.4	24.5	2,383.6	24.1	3,059.7	23.3
IIB	221.2	4.2	237.6	3.7	248.8	3.2	273.4	2.8	317.7	2.4
IIIA	566.0	10.8	653.6	10.3	828.4	10.5	1,094.5	11.1	1,462.8	11.1
IIIB	166.2	3.2	185.8	2.9	228.2	2.9	280.3	2.8	367.0	2.8
IV	126.9	2.4	119.2	1.9	119.9	1.5	117.4	1.2	130.4	1.0
V	196.7	3.7	183.1	2.8	186.1	2.4	205.2	2.1	248.9	1.9

[a]Donald E. Bailey, Preliminary Population Projections for Small Areas in Michigan. (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, 1966).

[b]Thousands

[c]Per cent of state total

proportions. To a great extent these two characteristics are related, yet they are sufficiently different to warrant a separate discussion of each.

Income Levels

Depending on the scale of the study, there are a number of different characteristics other than income and urban-rural proportions which could be important. At the municipal level the square feet of lawn, number of washing machines, etc. would be important characteristics. At a much more general scale income levels may be considered as a proxy for the more detailed characteristics. After all, it is the income level which permits the purchase of objects which require the use of water (large lawns, washers, etc.).

The average per capita income level in Michigan has been rising each decade since at least 1935. Table 9 indicates the per capita income level for Michigan for several years since 1940. Of more importance to the spatial patterns of water use in the state, however, are the different income levels among the several counties. Figure 7 shows the pattern of buying income in the state for 1968. The income levels are considerably higher in the southern part of the state than in the northern. This same general pattern has been present for the 1940, 1950, and 1960 census years.

Urban-Rural Proportions

As a general rule, urban populations generally use

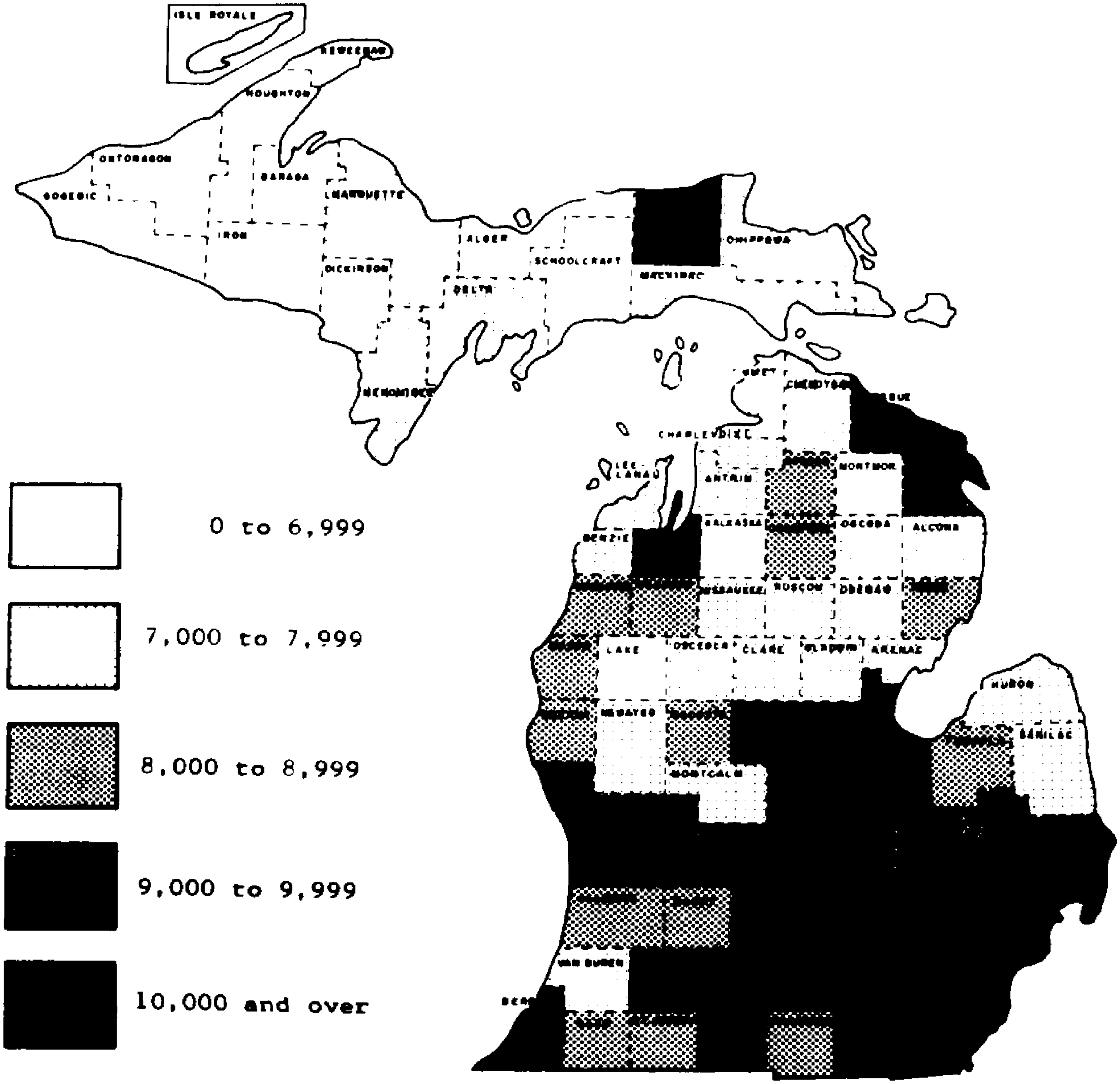

Figure 7. Effective Buying Income Per Household, 1968[a]

[a]"1969 Survey of Buying Power," Sales Management, Vol. 102, No. 12 (July 10, 1969), pp. D88-D95.

more water per person than do rural people. This is true for a number of reasons. Urban areas usually have higher incomes which give them greater access to objects which use water. A greater proportion of people who live in urban areas have lawns which are watered periodically. Generally maintenance work in cities (street washing, etc.) consumes large amounts of water. In 1965 it was estimated that per capita domestic, municipal, and commercial water use in urban areas was over three times as great as for rural areas.[1]

The population of Michigan is rapidly becoming urbanized. The number of residents who were classified as urban and rural each decade since 1850 is illustrated in Table 5. It can be seen that until the early 1900's the number of rural residents have been greater than the urban residents. Since 1920, however, the urban population has been constantly larger. Since 1840 the urban population as a per cent of the total has increased steadily except for the 1930 to 1940 period.

Population Projections

The projection of the population of an area is fraught with uncertainty. One is almost sure that any projections which are made will contain a certain amount of error; ideally this error will be kept to a minimum.

The hazards of making estimates of future populations

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[1]Water Resources Council, The Nation's Water Resources, p. 4-1-2.

Table 5

Michigan Urban and Rural Population[a]

	Population[b]		Per Cent	
Year	Urban	Rural	Urban	Rural
1960	5,739.1	2,084.1	73.4	26.6
1950	4,503.1	1,868.7	70.7	29.3
1940	3,454.9	1,801.2	65.7	34.3
1930	3,302.1	1,540.3	68.2	31.8
1920	2,241.6	1,426.9	61.1	38.9
1910	1,327.0	1,483.1	47.2	52.8
1900	952.3	1,468.7	39.3	60.7
1890	730.3	1,363.6	34.9	65.1
1880	405.4	1,231.5	24.8	75.2
1870	238.0	946.1	20.1	79.9
1860	99.7	649.4	13.3	86.7
1850	29.0	368.6	7.3	92.7

[a]Compiled from U.S. Bureau of the Census, U.S. Census of Population: 1850-1960. Characteristics of the Population, Michigan (Washington: U.S. Government Printing Office).

[b]Thousands

is best exemplified by examining projections which have been made by different sources for the same area. It is safe to say that all of them strived to provide the forecast with the greatest amount of accuracy. However, it is apparent that there are considerable differences among the several projections which have been made for Michigan. Some of the more common of these are listed in Appendix Table 3.

The population projections adopted for use in this study are based upon the work done by Dr. David Goldberg, Population Studies Center, University of Michigan (see footnote, Appendix Table 3) with modifications made by the State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce.[1] The work of the Resource Planning Division was to extend these projections to the year 2000.

The results of this projection for each of the seven planning regions are presented in Table 4. The most important information revealed by this data is the relative population changes among regions. Each of the seven regions except one is expected to experience an absolute increase in population between 1960 and 1980, and between 1980 and 2000. The big difference is in the share of the state total. Five of the seven regions are expected to have a declining share of the state's population. Only Regions I and IIIA are expected to receive a greater proportion of the total state population. Population estimates for 1980 and 2000 for the top 15 counties in 1960 are presented in Appendix Table 2.

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[1]Donald E. Bailey, Preliminary Population Projections for Small Areas in Michigan (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, 1966).

CHAPTER IV

DETERMINATION OF DOMESTIC, MUNICIPAL, AND COMMERCIAL WATER WITHDRAWALS

Introduction

The amount of water withdrawn for domestic, municipal, and commercial purposes is a function of the per capita withdrawal rates for each activity and the level of each of these activities in the region. It is possible to develop a relatively accurate predictive model of this type of water use by examining separately the various components of withdrawal and then applying withdrawal rate factors to forecasted future levels of each activity. However, the precise data which would be required for this approach is staggering and is completely beyond the resources of this thesis.[1]

For this research it was necessary to use a modified approach in estimating future levels of withdrawal. This approach involved two processes: (1) the development of a water withdrawal rate per level of activity represented by a combination of domestic, municipal, and commercial uses, (2) the

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[1]The most detailed model encountered for forecasting municipal water needs was developed by Hittman Associates, Inc., "Main I" A System of Computerized Models for Calculating and Evaluating Municipal Water Requirements (Columbia, Maryland, 1968).

application of this withdrawal rate to the expected future level of activity, in this case population totals.

This type of an approach necessitates two basic assumptions. First, for the category domestic, municipal, and commercial use there is a characteristic rate of water withdrawal per level of activity. For this category of use the level of activity is measured by the number of people who are potential water users. Consequently, the amount of water withdrawal is measured on a per capita basis.

Realizing that there will be considerable variation in water withdrawal rates among individuals and even among different parts of the state, the second assumption is that the rate of per capita water withdrawal multiplied times the total population, will reasonably approximate the total water withdrawals.

Possible Approaches

The technique which one uses is often a function of two factors, the resources with which one has to work and the purpose of the research. The combination of these two will often determine the approach which is used. After a review of the techniques used in other states in the estimation of their water needs two possible approaches were considered for use in this study. These were modeling and the application of per capita withdrawal rates to projected levels of population.

Modeling

The first possible approach which was considered was the development of a model which would incorporate as many explanatory variables as possible in order to predict the magnitude of domestic, municipal, and commercial water withdrawals. When sufficient data are present, and when properly conceived, this type of approach will probably produce the most realistic estimation of future water withdrawals.[1]

This type of an approach involves placing actual inputs (or those factors responsible for domestic, municipal, and commercial water withdrawals) into a representation of the entire system of withdrawals. The resulting output would approximate the amount of water withdrawal which could be expected under conditions exhibited by the input factors. In essence, one would be reproducing, in symbolic form, the characteristics of this type of water withdrawal. By knowing the characteristics of these explanatory variables at some time in the future it is possible to estimate future levels of withdrawal.

The main advantage to this approach is that it most closely approximates the real world. If properly developed such an approach would consider "all" the component parts in each situation. A second advantage is its sensitivity. By

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[1]One of the most comprehensive models which has been examined to date has been the one developed by Hittman Associates (see page 56). This model has been designed to include industrial water use but could be modified to exclude this category.

changing the values of the inputs to more closely approximate the real world the model can be "tuned" to a greater degree of accuracy. The third advantage follows closely the second. This involves the amount of detail which can be presented. This is entirely up to the researcher, but in the more complex models a great deal of detail can be achieved.

The major disadvantage involves the amount of data which are required in using this approach. Ideally every force which operates to influence water withdrawals should be incorporated into the model. Obviously this is impossible. The researcher must usually be satisfied with a more general representation of the real situation. And in the use of this approach for estimating future levels of water withdrawals one is also faced with the difficulty of forecasting the future levels of those variables which will be used in forecasting the end product. Thus the estimate of water withdrawal, itself a very tenuous undertaking, is based upon variables which are themselves estimates and subject to all the weaknesses of estimates.

Per Capita Withdrawal Rates

The second approach is a less sophisticated one, and involves the application of domestic, municipal, and commercial water withdrawal rates to estimates of population at some future time. This approach does not attempt to assess the influence of individual variables on withdrawal rates, but considers them to be inherent in the water use coefficients (or the per capita withdrawal rates). It is possible, however, to adjust for changing conditions by assuming an increase (or decrease) in per capita withdrawal rates to compensate for conditions which may change over time. To the extent that this compensatory change is accurate, future levels of withdrawal can be relatively accurate.

The chief advantage of this approach is in the data requirements. The only type of information necessary is that pertaining to withdrawal rates and estimates of future population levels. Thus, for a study which is being conducted on a limited budget, or one in which results are needed quickly, this approach is an appropriate one to use.

The main disadvantage with this approach is that it does not identify what factors are instrumental in causing changes in withdrawal rates. If the purpose of the study is more to estimate future levels of withdrawal rather than to completely explain the system then this is not a major disadvantage. However, to the extent that it reduces the reliability of the estimate it is a limiting factor.

Data Availability and Deficiencies

The data requirements for each of the two approaches are different, although certain elements are necessary for each. The availability of data of the type required may be the most important factor determining which approach will be used.

Per Capita Withdrawal Rates

Basic to both approaches is an accurate determination of per capita water withdrawal rates. Since the object of inquiry is domestic, municipal, and commercial water withdrawals, per capita rates used must represent only this type of use and not include any industrial use.

The only data readily available for non-industrial withdrawals for Michigan in particular is from the Michigan Department of Public Health. These water withdrawal figures apply only to water pumped by municipal systems and do not include information on per capita withdrawals by those who have their own wells or in some other manner acquire water from non-municipal sources.

The Department of Public Health is responsible for the municipal water systems in the state, and periodically collects data on the amount of water pumped by these systems. The most recent data available are for 1965. At that time approximately 76 per cent of the population in Michigan received water from municipal systems. The Department of Public Health has separated the total water pumped into two categories, industrial and non-industrial. The category "non-industrial" is a very broad one and encompasses a variety of different uses. Included within this category would be the domestic, municipal, and commercial uses which are the focus of this chapter.

The principle disadvantage with the data from the

Department of Public Health involves the reliability. These data are reported by individual municipal systems, and the quality of the reports vary considerably among systems. In the larger systems the accuracy of the data are thought to be quite high. In the smaller systems, however, the records are generally less reliable.[1] Data on per capita non-industrial water withdrawals can vary greatly if a water system fails to accurately differentiate between industrial and non-industrial uses. With inadequate staffs and without the more refined methods of data processing the validity of the data from the smaller municipal systems is questionable. Since the data reported by the Department of Public Health are for a county it includes both large and small systems. The records for individual systems are hidden within the county figures and can not be extracted.

In addition to the quality of the records there is almost always some water pumpage which is unaccounted for. This is generally a result of mechanical malfunctions somewhere in the water system or, again, from inadequate record keeping. The following clipping from the Lansing (Michigan) State Journal indicates a specific example of the problem mentioned above.

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[1]Telephone conversation with William A. Kelly, Michigan Department of Public Health, June, 1969.

Where's Our Water?

Missing: 20 million gallons of water. Meridian Township has lost track of it.

When the annual report of the public works department was submitted at the township board meeting this week, one of the trustees questioned the large amount of water "lost" in an area of the township which buys its supply from East Lansing.

Figures showed 117,355,000 gallons were purchased from the city and 96,875,000 gallons sold to customers, a difference of 20,480,000 or 17.45 per cent.

A normal water loss should not exceed 10 million gallons or about eight to ten per cent, said Gaylord Smith, public works superintendent.

He said three known water leaks in the area last year were not large enough to account for 20 million gallons even when combined with normal loss from fire department and road commission use.

"The loss could possibly be in the difference of when East Lansing read its meters and when we read ours," Smith said. "It is possible that we will show an excess instead of a loss the next time the water meters are read."

It is possible, he said, that there could be an undetected underground leak.

"The only thing we can do is to keep on checking until the difference is accounted for," Smith said, "right now we just don't know what happened."

An evaluation of the Department of Public Health data reveals a very wide range in the per capita withdrawal rates. The range of water withdrawal coefficients can be seen in Appendix Table 6.

The median coefficient was approximately 36,000 gallons per capita per year, while the mode coefficient was in the 35,000 to 36,000 block. Of the total counties used in the analysis (75),[1] 76 per cent had a range of between 20,000 gallons and 50,000 gallons per capita per year.

There was, however, a considerable range overall, from a low of 7,058 gallons per capita per year to 103,636 gallons per capita per year. A certain amount of difference among counties can be expected because of differences in the factors responsible for water withdrawals, water losses, etc. However, it was felt that a range of 7,058 to 103,636 was probably the result of inaccuracies in the reporting system.

An alternative source of data on water withdrawal rates for domestic, municipal, and commercial uses is revealed by the recent report by the Water Resources Council (see footnote 1, page 23). In this report data were presented on national non-industrial withdrawals. This data is summarized in Appendix Table 4. Water withdrawn from public systems is composed of domestic uses (household), public uses (municipal), and commercial uses. Individual systems are essentially rural domestic systems. While these data are for the nation as a whole it is possible to modify them so that they represent more accurately the Michigan situation.

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[1]The remaining eight counties either had data which was missing (two counties) or the data of more than one county were grouped together (six counties).

Independent Variables

There are essentially two method of acquiring data on explanatory variables to incorporate into a predictive model for water withdrawals. The first of these is through the use of an instrument such as a questionnaire or personal interview. Such an approach could involve simultaneously collecting information about the dependent variable (the amount of water withdrawal) and the independent variables (the explanatory factors).

The main disadvantage of this approach for an area the size of Michigan is the cost. With approximately 8,645,200 people in the state the cost of sampling a large enough segment of the population to be meaningful would be very prohibitive and beyond the resources of this study which is investigating industrial and agricultural withdrawals in addition to withdrawals for domestic, municipal, and commercial purposes.

The second method is to utilize existing data. The type of information needed is often available from various state agencies as well as from published census material. While much less costly to acquire, these types of data suffer from two weaknesses. First, the exact type of data needed are not always the type available. It is often possible to "make do" with inappropriate data, but the research generally suffers. The second weakness is that the time periods in which these data are collected do not always coincide with each other, nor do they always coincide with the data on per capita water withdrawal rates. Again, it is possible to utilize data from two different periods but the results will not accurately represent the real situation in any year. And the greater the period of time between the data collection dates the greater will be the discrepencies in the results.

Population Estimates

Accurate estimates of future population levels are necessary for forecasting domestic, municipal, and commercial water withdrawals. This aspect of data requirements has been covered in Chapter III.

Examination of Alternative Approaches

In order to achieve the best possible result both the modeling and per capita withdrawal rate approaches were investigated.

Method I: The Model

The method used to estimate annual per capita domestic, municipal, and commercial water withdrawal rates by relating them to several explanatory variables was the least squares regression technique. The function of regression is to evaluate changes in a dependent variable (in this case annual per capita withdrawal rates) with changes in the independent (explanatory) variables.

The dependent variable, annual per capita domestic, municipal, and commercial water withdrawal was determined by utilizing the 1965 Department of Public Health data on municipal water systems. The variable was generated by subtracting the industrial withdrawal from the total withdrawal, and by dividing this figure by the number of people served by municipal systems (also available for 1965 from the Department of Public Health). This information was available for the 75 counties with complete records.

A listing of the independent variables used in the regression analysis, the source of the data, and the simple correlation coefficient of each of the dependent variables is presented in Appendix Table 5. Correlation coefficients refer to the efficiency of the regression equation in estimating the dependent variable and are determined by the deviation of the actual values of the dependent variable from the predicted value of the dependent variable which is represented by the regression line.

When only one independent variable is considered the results are a simple correlation and a simple regression. When more than one variable are used the results are a multiple correlation and a multiple regression. When all of the independent variables are included the multiple correlation coefficient is .64 which means that approximately 41 per cent of the variation in per capita water withdrawal was explained by the independent variables.

There are a number of factors which could account for this relatively low explanatory power of the model. It is felt, however, that the most significant reason is inadequacies in the available data. Many of these have already been discussed. However, there are other data characteristics which may be important.

The aggregate nature of the data, both dependent and independent variables, is undoubtedly partially responsible. When aggregated, as on the county basis, the data represent merely a mean figure for that variable in that county and do not reveal information about individual situations. If water withdrawal information on individual households could be compared with corresponding data on size of family, income, home value, etc. it is very possible that a greater amount of explanation could be achieved than if the mean figures for counties are used.

One significant factor could not be included in the analysis. These are data on the pricing policies of water. The extent of metering and the water rates differ among water systems. Some systems are not metered and charge a flat rate regardless of the water used. Even for the systems which do meter their water, the actual charges vary considerably, thus providing for differences in the efficiency of water use. The inclusion of this important variable would have an important influence on the results of the model.

Method II: Per Capita Withdrawal Rates

As a result of the relatively low amount of explanation afforded by the model it was decided to try the second technique, that of applying the annual per capita withdrawal figures for non-industrial use, which were supplied by the Michigan Department of Public Health, to the projected population for 1980 and 2000.

It was not possible to apply these data directly to estimates of future population, however. Before this could be done a number of intermediate steps were necessary: (1) the establishment of a more reliable per capita withdrawal rate from municipal systems for each county in 1965, (2) estimating the corresponding withdrawal rates for those not served from municipal systems, (3) estimating the per cent of population served by municipal systems in 1980 and 2000, (4) accounting for increases in per capita withdrawal rates to 1980 and 2000, from both municipal sources and non-municipal sources.

Per Capita Withdrawal Rates, Municipal Systems

Mention was made earlier of the wide range of per capita withdrawal rates reported by the separate municipal water systems to the Department of Public Health. A discussion with officials of that department resulted in the decision not to use coefficients that were on the extreme ends, high or low, of the range. It was decided to eliminate those coefficients which were more than twice as large as the median coefficient (36,000 gallons per capita per year), and to assign to these counties the median coefficient. This adjustment applied to nine counties.

In addition to the counties to which the above discussion applies there were two for which the Department of Public Health did not have information. For these counties the median coefficient was used.

There were two groups of counties (three counties each) for which the data were reported as an aggregate. The coefficient which applied to the group was considered to be representative of each county in the group.

A listing of the counties, their corresponding coefficients, and the derivation of the coefficient are presented in Appendix Table 6.

Because of the large discrepencies among county withdrawal coefficients a test on the sensitivity of factors other than numbers of people was run. A correlation was made using the total amount of water withdrawn as the dependent variable and the number of people served as the independent variable. It was expected that because of the large differences in the per capita withdrawal rates there would be a very low correlation. The opposite was true, however. The correlation in this case was only slightly less than 1.00, a perfect correlation. A scatter diagram of this relationship is presented in Figure 8. This means that the number of people served accounted for over 99 per cent of the water withdrawn from municipal systems for non-industrial uses. This merely indicates that while changes in the per capita withdrawal rates are important in determining total

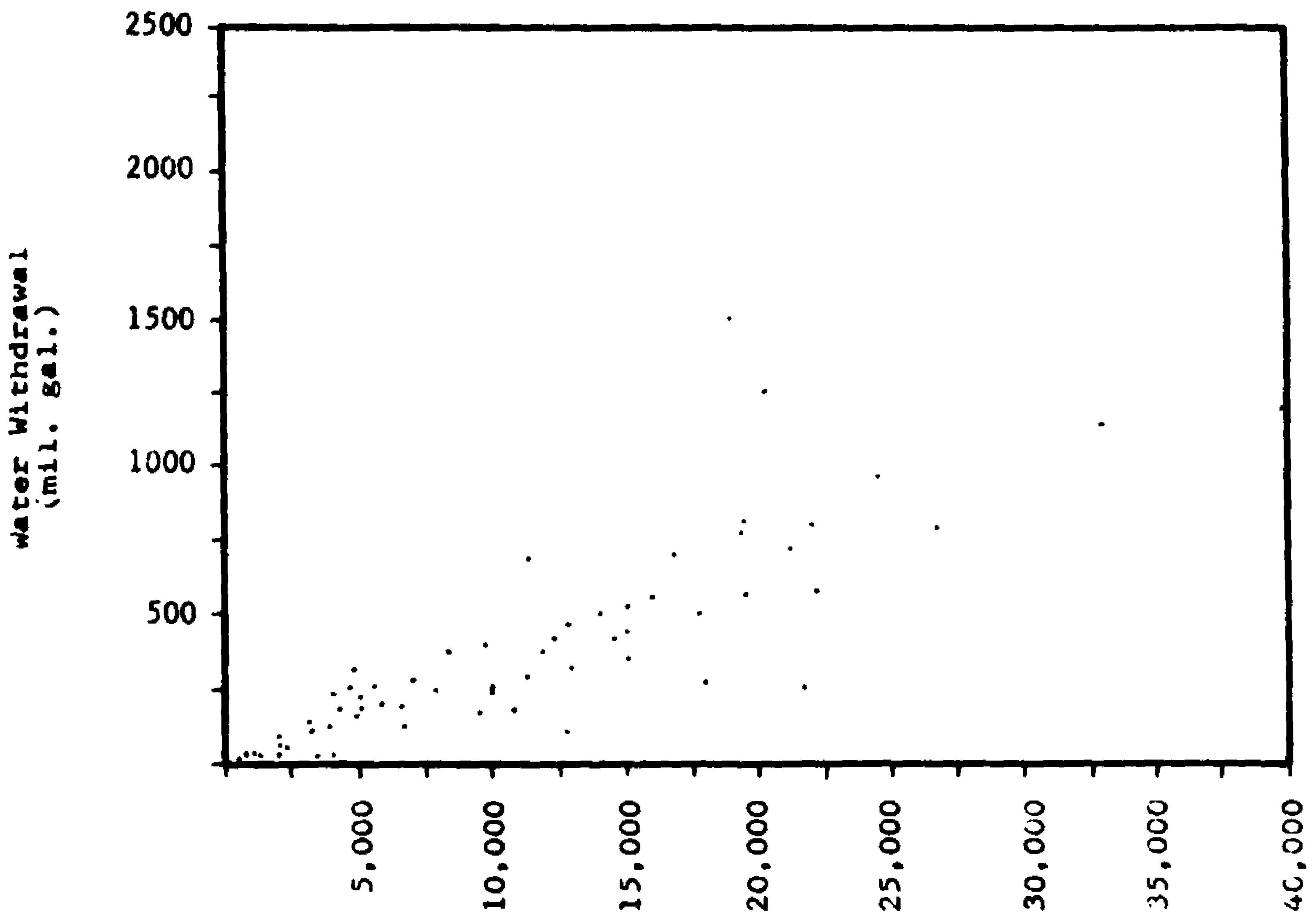

Figure 8. Relationship Between Population Served and Total Withdrawals[a]

[a]Unpublished data from the Michigan Department of Public Health, Lansing, Michigan.

withdrawals, the importance is hidden by the sheer numbers of people when the concern is with the spatial distribution of the withdrawals.

Since the ultimate purpose is to estimate the total water withdrawals on a regional basis rather than for individual counties withdrawal coefficients were developed for each region for 1965. These coefficients were computed by multiplying the county withdrawal coefficients as reported in Appendix Table 6 times the number of people served by municipal in that county, totaling the resulting withdrawal figures and the population served for each region, and dividing the population served into the total withdrawal for the annual regional per capita withdrawal rate. The results of these calculations are presented in Table 7.

Per Capita Withdrawal Rates, Non-Municipal Sources

The principle factor prohibiting the complete utilization of the per capita withdrawal rates based upon data from municipal water sources is that not everyone in the state is served by such a source. In 1965 approximately 76 per cent of the state's population received water from a municipal system. Hidden within this 76 per cent are quite a range of participation rates, from roughly eight per cent in Alcona County to virtually total participation in Wayne County.

The application of the per capita withdrawal rates from municipal systems to the total population would not matter if it were not for the fact that the rates of withdrawal appear to be considerably different. Again, the most recent information on this aspect of water use is from the 1968 report of the Water Resources Council.[1] According to the national data, in 1965 per capita withdrawal rates for individuals receiving water from individual systems were approximately 42 per cent of the withdrawal rates for individuals served by municipal systems. This is projected to increase to 51 per cent in 1980 and 57 per cent in the year 2000.

Since the estimation of future withdrawals are considerably strengthened by considering separately those who receive water from municipal systems and those who have their own private source of water, and because the source of data on the Michigan situation which would allow differentiation is extremely limited, the only alternative is to utilize the relationships found in the national data. Thus a withdrawal rate for each region for those individuals not using water from a municipal source was determined by reducing the withdrawal rate from municipal sources for 1965 by 57.85 per cent to correspond to the national difference between municipal and non-municipal withdrawals. This data is also presented in Table 7.

Population Served, Municipal and Non-Municipal Systems

If separate water withdrawal rates are to be used for those who withdraw water from municipal systems and those who

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[1]Water Resources Council, The Nation's Water Resources, p. 4-1-2.

do not then there must be some indication of the numbers who are in each category. From all indications the per cent of the population which utilizes water from municipal systems is expected to increase at least to 2000. If these trends continue it appears that the population served by municipal systems will approach the total population.

From all indications there will be an increasingly larger proportion of the population which receives water from municipal sources. It is probable that, not only will most of future increases in demand for water for domestic, municipal, and commercial purposes come from municipal systems, but that significant numbers of people who in 1965 were receiving water from their own wells will begin receiving water from public systems. The Water Resources Council based their projections of national water use on the assumption that "the Nation's population growth will occur in areas served by public distribution systems. This assumption is based upon the continuing expansion of municipal systems and the establishment of new public systems."[1]

It appears that this trend is developing in Michigan. Data obtained from the Department of Public Health on the numbers of people in each county who were receiving water from municipal systems in 1940, 1950, 1960, and 1965 are summarized in Table 6. These county data have been compiled into the seven planning regions. For the 25 year period there was a

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[1] Ibid., p. 4-1-3.

Table 6

Regional Service from Municipal Systems[ab]

Region	1940	1950	1960	1965	1980	2000
Region I						
Municipal Systems	2,421.0	2,970.4	3,748.5	4,010.5	5,147.1	7,320.4
Per Cent	89.8	86.3	87.4	89.4	93.4	97.1
Non-Municipal	276.1	469.8	543.0	476.3	366.6	217.2
Per Cent	10.2	13.7	12.7	10.6	6.7	2.9
Region IIA						
Municipal Systems	748.2	858.2	1,074.1	1,246.8	1,743.9	2,619.3
Per Cent	58.4	55.3	55.9	61.8	73.2	85.6
Non-Municipal	533.9	694.1	846.3	770.9	639.6	440.4
Per Cent	41.6	44.7	44.1	38.2	26.8	14.4
Region IIB						
Municipal Systems	93.5	101.9	105.2	116.7	148.7	220.5
Per Cent	42.3	42.9	42.3	45.2	54.4	69.4
Non-Municipal	127.7	135.7	143.7	141.2	124.7	97.2
Per Cent	57.7	57.1	57.3	54.8	45.6	30.6
Region IIIA						
Municipal Systems	349.6	400.1	519.4	552.1	794.1	1,228.6
Per Cent	61.8	61.2	62.7	61.9	72.6	84.0
Non-Municipal	216.4	253.5	309.0	340.3	300.4	234.1
Per Cent	38.2	38.8	37.3	38.1	27.5	16.0

Table 6--Continued

Region	1940	1950	1960	1965	1980	2000
Region IIIB						
Municipal Systems	77.6	91.6	119.4	130.0	185.0	292.7
Per Cent	46.7	49.3	52.3	54.6	66.0	79.8
Non-Municipal	88.6	94.2	108.9	108.0	95.3	74.3
Per Cent	53.3	50.7	47.7	45.4	34.0	20.5
Region IV						
Municipal Systems	72.8	77.4	77.4	70.2	90.3	115.4
Per Cent	57.4	64.9	64.6	68.7	76.9	88.5
Non-Municipal	54.1	41.8	42.5	36.6	27.2	15.0
Per Cent	42.6	35.1	35.4	31.3	23.1	11.5
Region V						
Municipal Systems	115.7	109.9	117.1	126.2	149.2	206.4
Per Cent	58.8	60.0	63.0	66.2	72.7	83.0
Non-Municipal	81.0	73.2	68.9	64.3	56.0	42.4
Per Cent	41.2	40.0	37.1	33.8	27.3	17.1

[a]1940, 1950, 1960, and 1965 from unpublished data supplied by the Michigan Department of Public Health (Lansing). 1980 and 2000 estimates made by author.

[b]Thousands

constant increase in numbers of people served by municipal systems for each of the regions with the exception of the 1940 to 1950 period in Region V of the Upper Peninsula. The 1950 to 1960 period in Region IV, also in the Upper Peninsula, showed only a moderate increase.

For this same period the population served by other than municipal systems exhibited a different pattern. All of the Lower Peninsula showed an overall increase during both the 1940-1950 and 1950-1960 periods. The Upper Peninsula, on the otherhand, indicated that, with the exception of the slight increase during the 1950-1960 period in Region IV, there was a marked decrease in both the absolute numbers of people and per cent of total which were served by other than municipal systems.

With the exception of Region IIA the 1960-1965 period exhibits a continued decrease in the importance of non-municipal water sources, both in absolute numbers of people served and in per cent of the total.

The numbers of people expected to be served by municipal systems and by individual systems in 1980 and 2000 were estimated by assuming that the 1960-1965 rate of decrease in those served by individual systems would continue at the same rate to 1980 and 2000. The resulting population figure for each region was then subtracted from the total expected population in 1980 and 2000 for that region to give the population served by municipal systems.

It was further assumed that the 1960-1965 increase in non-municipal withdrawals exhibited by Region IIIA was an anomaly and would not continue. For this region it was assumed that there would be neither an increase or decrease in population served by individual systems. The results indicate a constantly increasing proportion of the total population served by municipal systems.

The resulting estimates for 1980 and 2000 are also presented in Table 6. It is realized that they lack a great deal of precision. However, it is believed that, while far from scientific, the estimates are the best that could be made at the present time and certainly represent an improvement over either assuming no change in the 1965 situation or ascribing non-municipal users the same rate of withdrawal as those using municipal water.

The estimates for 1980 and 2000 are essentially in agreement with the estimates made to 2015 by the Department of Public Health. These estimates were made for nine regions within the state and thus did not coincide with the planning regions chosen for this study. However, there was sufficient similarity among the regions so that they could be used as guidelines. These estimates were made by a graphical extrapolation of past trends, with compensation made for the expected decrease in non-municipal withdrawals. In order to facilitate a comparison among the several regions the Department of Public Health data are summarized in Appendix Table 7 and Appendix Figure 1 for municipal water service in Michigan.

Increases in Withdrawal Rates

Although adequate data were not available on the Michigan situation it is probably true that there has been a gradual increase in the per capita rate of water withdrawal in the state as there has been for the nation as a whole. It is obvious, therefore, that if reliable estimates of per capita withdrawal rates are to be made for 1980 and 2000 the probable increase in per capita withdrawals must be taken into consideration.

Since the data were not available for Michigan it was necessary to make use of national figures.[1] It was fortunate that in the category of domestic, municipal, and commercial water use the Michigan situation very closely approximated that of the nation. The Department of Public Health reported that for the state of Michigan as a whole the average per capita daily withdrawal for all water procured from a municipal source (including industrial withdrawals) was 159 gallons in 1965; for the nation this figure was 157 gallons.[2] The daily per capita withdrawal from municipal systems for

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[1]Computed from data reported in Water Resources Council, The Nation's Water Resources.

[2]The exact composition of this total was different between Michigan and the nation, however. For the nation as a whole approximately 23 per cent of the total withdrawals from municipal systems were for industrial purposes. Because of the importance of manufacturing in Michigan withdrawals by industry accounted for almost 29 per cent of the total withdrawals.

non-industrial use in Michigan was 103 gallons for 1965; for the nation this figure was 121 gallons.

Because of the similarity between total withdrawal rates from municipal systems, the increase in per capita domestic, municipal, and commercial withdrawal rates for Michigan was assumed to be proportional to the increase for the same categories for the nation. The rates of increase which were used are presented in Appendix Table 8.

When these rates of increase are multiplied times the 1965 municipal and non-municipal withdrawal coefficients presented in Table 7 the resulting figures represent withdrawal coefficients for 1980 and 2000. These coefficients are also presented in Table 7. When they are multiplied times the numbers of people expected to receive water from municipal and non-municipal sources in 1980 and 2000 estimates are produced for total domestic, municipal, and commercial withdrawals. These estimates are presented in Chapter IX.

Table 7

Regional Non-Industrial Withdrawal Coefficients

	Municipal			Non-Municipal		
Region	1965	1980	2000	1965	1980	2000
I	37,810	38,434	39,062	15,937	18,124	22,312
IIA	37,590	38,210	38,834	15,848	18,022	22,187
IIB	36,920	37,529	38,142	15,562	17,697	21,787
IIIA	45,700	46,454	47,213	19,263	21,906	26,968
IIIB	31,460	31,979	32,501	13,760	15,079	18,564
IV	35,540	36,126	36,716	14,980	17,035	20,972
V	40,770	41,443	42,119	17,185	19,680	24,059

CHAPTER V

FACTORS CONTRIBUTING TO MANUFACTURING WATER WITHDRAWALS

Introduction

Just as biological life can not exist without adequate amounts of water, so industrial life also can not exist without sufficient water resources. This observation has led a University of Chicago scientist to suggest that the enormous water resources available in the Great Lakes region will cause industry to gravitate to the area in such numbers that there will be an urban belt 20 miles wide from Milwaukee to Buffalo which will be the largest industrial area in the world.[1] While such a possibility is probably exaggerated it does point up the importance of water resources to the industrial development of an area, and the corresponding large water needs of industry.

Two factors are of major significance in influencing the total amount and spatial location of water withdrawals for manufacturing. The nature of water use in manufacturing processes is one of these. The second factor is the level of

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[1] Earl H. Ruble, "Industrial Water Requirements," Journal of the American Water Works Association, Vol. 57, No. 7 (July, 1965), p. 831.

manufacturing employment, which in Michigan is the most important factor in determining the magnitude of manufacturing water withdrawals.

Water intake for manufacturing purposes in Michigan has been increasing for several decades and is expected to continue to increase, although at a slower rate, at least to the year 2000. While most areas of the state will continue to be able to meet the demands for water for manufacturing purposes there is a clearly recognizable pattern to this demand, one which is expected to change spatially between the latter part of the 1960's and 2000.

The purpose of this chapter is to examine the factors contributing to water withdrawals for manufacturing purposes in Michigan. This will include a summary of the types of uses made of water in manufacturing and the characteristics of this use, and an analysis of the trends in manufacturing which have been evident. Included within this section will be a comparison of past trends with estimates of manufacturing employment for 1980 and 2000. These estimates are presented before the methods used in their calculation because they are a logical extension of the past manufacturing trends.

Nature of Water Use in Manufacturing

The manner in which water is used in the manufacturing process is quite important in determining the total amount of water withdrawn. Water is used for different purposes and in different amounts among the several types of manufacturing in the state. And directly related to the subject of water use is the growing tendency toward water conservation on the part of manufacturing establishments.

Concentration of Withdrawals

One of the most striking characteristics of water withdrawals for manufacturing is the concentration in a relatively few industries. In the national survey of manufacturing water use which was taken in 1964, and which analyzed the water use characteristics of 8,925 manufacturing firms in the United States which had a water intake of 20 million gallons or more per year, it was found that three per cent of the firms accounted for 97 per cent of all water withdrawn for manufacturing purposes.[1] This is largely the result of differences in the size of firms, but an important part is a result of differences in the demand for water among different types of firms.

This difference in the water withdrawal needs for different types of manufacturing activities can be clearly seen when the water withdrawals per employee among the 21 two-digit SIC categories are compared.[2] Table 13,(page 153) indicates

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[1] U.S. Bureau of the Census, Census of Manufacturers: 1963. Subject Statistics: Water Use in Manufacturing. (Washington: U.S. Government Printing Office, 1966), p. 3.

[2] The Technical Committee on Industrial Classification, Office of Statistical Standards, U.S. Bureau of the Budget has devised a common means of classifying manufacturing types. The following list is at the two-digit level. For a more complete description see Standard Industrial Classification Manual (Washington: U.S. Government Printing Office, 1967).

the amount of water withdrawals per employee for each category which were developed for this study. It can be seen that there is a large range between those types of manufacturing whose processes require them to withdraw very little water per employee, and those "wet" industries which require large amounts of water. Of the 21 two-digit categories, paper and allied products, chemicals and allied products, petroleum and coal products, stone, clay, and glass products, and primary metals had significantly greater withdrawal rates per employee. In 1968 these five manufacturing types accounted for only approximately 17 per cent of the state total, and are expected to remain at approximately 17 per cent at least to the year 2000. This will include an absolute increase of about 16,000 employees but very little change in the relative proportion of total employment.

19	Ordnance and accessories
20	Food and kindred products
21	Tobacco manufactures
22	Textile mill products
23	Apparel and related products
24	Lumber and wood products
25	Furniture and fixtures
26	Paper and allied products
27	Printing and publishing
28	Chemicals and allied products
29	Petroleum and coal products
30	Rubber and plastics products
31	Leather and leather products
32	Stone, clay, and glass products
33	Primary metal products
34	Fabricated metal products
35	Machinery, except electrical
36	Electrical machinery
37	Transportation equipment
38	Instruments and related products
39	Miscellaneous manufacturing

Types of Use

The uses which are made of the water which is withdrawn for manufacturing purposes are many and varied, and differ considerably among the different manufacturing types. Plants which manufacture essentially the same products may have vastly different withdrawal rates because of the age of the plant or equipment, availability and cost of water, degree of automation, or a number of other factors.

In Water Use in Manufacturing, the Bureau of the Census has divided water intake into four categories: (1) process use - includes all water that comes in direct contact with materials or products, (2) cooling and condensing in company owned steam electric generating plants - includes water used in the production of thermal electric power by the manufacturing establishment itself, (3) other cooling and condensing - includes water used in processing equipment in which water is separated from the process materials or product, (4) boiler feedwater, sanitary, and other - involves water use in the production of direct power other than electric power, water used in maintaining sanitary conditions in the establishment, and all remaining uses.[1]

Water Conservation

Practices designed to conserve water used in manufacturing establishments can have a great impact on the water

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[1]U.S. Bureau of the Census, Water Use in Manufacturing, p. 3.

intake per unit of production or per employee. As the demands for water increase, and as water becomes more expensive, there is a tendency to make increasingly greater use of the water brought into the plant. According to one sanitary engineer who is concerned with water use in industry, "It appears that per unit of production the water requirements of industry are being drastically reduced as a result of technological changes and conservation practices...even greater reductions will be achieved when economic considerations and other incentives arise to justify further curtailment of water use."[1]

The steel industry provides a good example of what can be done by industry in conserving water. During the 1950 to 1960 period the steel industry increased its water intake by 23.9 per cent. However, in this same decade, production increased 48.6 per cent, approximately twice as great as the increase in water intake.[2]

Examples from specific plants illustrate this even more vividly. At the Fontana, California plant of Kaiser Steel water is used approximately 40 times before being lost through steam or evaporation or being discharged.[3] This rate of use was approximately 1/65th of the national intake rate for steel

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[1]Edward J. Cleary, "Some New Facts for Forecasting Industrial Water Needs," Public Works, Vol. 92, No. 11 (November, 1961), p. 78.

[2]Richard D. Hoak, "Water Resources and the Steel Industry," Iron and Steel Engineer, Vol. 41, No. 7 (May, 1964), p. 88.

Ruble, "Industrial Water Requirements," p. 832.

plants. In the Provo, Utah plant of United States Steel, water intake is only one tenth of the water requirements.[1]

Often industry may obtain process and reuse water at a cheaper price than water from the original source would cost. In 1955 Amarillo, Texas could supply the city's oil refineries with water at a cost of 13.6 cents per thousand gallons. The cost of reusing water in the refineries varied between 13.3 and 6.9 cents per thousand gallons.[2]

The following is a list of practices which have been suggested to curtail water intake in the steel industry. Most or all of them may be used to advantage by other industries in reducing their water intake.[3]

Install meters
Regulate pressure
Thermostatic controls
Automatic valves
Sanitary fixtures
Heat exchanges
Insulation
Leak surveys
Centralized control
Recirculate cooling water
Reuse water
Recondition waste water

One of the most effective means of conserving water has

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[1]Hoak, "Water Resources and the Steel Industry," p. 88.

[2]Ray L. Derby, "Water Use in Industry," Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 83, No. IR2 (September, 1967), p. 1364-7.

[3]Hoak, "Water Resources and the Steel Industry," pp. 89-90.

been through recirculation. Between 1954 and 1964 manufacturers were able to increase production 43 per cent while water withdrawals increased only 23 per cent. It is estimated that the average recirculation rate in 2000 will be two or three times that of 1964.[1]

This increase in recirculation has not been uniform in all types of manufacturing. Measures of water recirculation for 1959 and 1964 for the major water using manufacturing types are presented in Appendix Table 18.

Manufacturing Activity in Michigan

The total amount of water used for manufacturing purposes in any region is a function of the size, structure, and aerial distribution of manufacturing activity.[2] Changes in the size and structure will change the total amount of water required in an area. Unless the trend toward water conservation is increased several fold, water needed for manufacturing will increase as the degree of manufacturing activity increases.

It is probably the magnitude of manufacturing activity which has the most dramatic affect on the amount of water

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[1]K.L. Kollar and Robert Brewer, "Water Requirements for Manufacturing," unpublished material from Water Industries and Engineering Services Division, Business and Defense Services Administration, U.S. Department of Commerce, Washington, D.C., May, 1968, p. 1.

[2]Morgan D. Thomas, "A Regional Model for Projecting Industrial Water Consumption," Papers of the Michigan Academy of Science, Arts, and Letters, Vol. XLIII (1957), pp. 252-258.

needed for manufacturing. The magnitude of manufacturing activity may be measured by numbers of employees or value of output (two common measures used in water needs studies). Because of the possible substitution of capital equipment for labor, the value of output is probably the best measure of manufacturing activity. However, because of the difficulties in acquiring data on value of output at the sub-state level (especially when this is further stratified by type of manufacturing) the number of employees is most often used as an indication of the magnitude of manufacturing activity in an area, especially in water needs studies.

In addition to size, differences in the type of manufacturing activity will result in considerably different requirements for water. For the 21 two-digit SIC categories for manufacturing the most water demanding category uses approximately 1,690 times as much water per employee than does the least water demanding category.

When these conditions of size and structure are compounded by a spatial dimension the water demanded for manufacturing becomes a very complex consideration. Manufacturing activity is certainly not distributed evenly throughout the state, neither in amount nor in type. In 1968 10 counties accounted for 76.7 per cent of the manufacturing employment in the state. By 2000 this is expected to be 77.4 per cent. Few of the manufacturing types are ubiquitous in Michigan, there being definite concentrations of certain industries in particular areas of the state. In 1968 the most concentrated type of manufacturing in Michigan was SIC 21 (Tobacco manufacturers) of which 100 per cent was concentrated in Wayne County. The most evenly distributed was SIC 20 (Food and kindred products) but even here there was considerable variation throughout the state; Wayne County accounted for 39.6 per cent of the state total, while 10 counties had no employment in SIC category 20.

Size and Structure of Total Employment

Total Employment

Accompanying the general population increase in Michigan has been an increase in total employment levels. In 1880 total employment in Michigan was estimated to be approximately 569,000.[1] The latest data available from the Michigan Employment Security Commission listed total employment in 1968 at approximately 3,243,600.

While the total amount of employment increase does have a direct bearing on the total amount of water demanded in the state, a much more important trend has been the composition of this total employment. It has been with the rapid growth of Michigan as a manufacturing state that the demand for water has increased tremendously.

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[1] Simon Kuznetz, Population Redistribution and Economic Growth, United States 1870-1950 (Philadelphia: American Philosophical Society, 1957), p. 626.

Employment Structure

Changes in the state employment situation can best be evaluated by examining very basic trends in the overall structure of the economy. Changes which take place in the major types of economic activities can have an equal, or even greater, effect on the amount of water used than total increases in employment.

From the time of the first settlers in Michigan until the beginning of the 20th century employment in Michigan was dominated by the primary industries. As Table 8 indicates, employment in agriculture, forestry, fishing, and mining in 1880 was approximately 3.5 times greater than employment in manufacturing, the next largest category. This period coincided with the "Agricultural Era" which dominated the nation as a whole from the 1600's until the late 1800's.[1]

By 1940 the employment situation had changed considerably. The national economy had left the agricultural dominent era and was not basically industrial. This change from an agricultural economy to an industrial economy was mirrored in Michigan. Referring again to Table 8, by 1940 manufacturing employment had usurped the major position which agriculture and the other extractive industries had traditionally held and was not the dominant industry in the state.

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[1]Battelle Memorial Institute, The Michigan Manpower Study: An Analysis of the Characteristics of Michigan's Labor Force in the Next 15 Years (Columbus, Ohio, 1966), p. 5-1.

Table 8

Employment Trends in Michigan [ab]

Industry	1880	1900	1940	1950	1960
Agriculture	283.5	345.3	214.0	159.9	92.1
Forestry/Fishing	1.4	1.7	2.1	2.1	1.5
Mining	9.2	29.3	15.8	15.5	15.3
Construction	38.9	61.5	73.1	118.4	125.6
MANUFACTURING	82.0	130.9	700.0	978.3	1,035.9
Transportation/ Communication	26.1	61.9	100.3	152.7	155.6
Trade/Finance	48.3	113.6	343.8	485.7	573.6
Services/Public Administration	79.3	146.8	352.3	459.6	651.2
Not Reported	.4	15.0	23.4	31.7	89.6

[a]1880 and 1900 from Simon Kuznets, Population Redistribution and Economic Growth, United States 1870-1950 (Philadelphia: American Philosophical Society, 1957), p. 626.

1940, 1950, and 1960 from U.S. census of population compiled in Leonard D. Bronder and John M. Koval, Michigan's Economic Past: Basis for Prosperity (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, 1967), pp. 43-107.

[b]Thousands

Throughout the 1950 and 1960 census years manufacturing employment continued to increase while employment in the extractive industries registered constant declines, thus widening the gap between them.[1]

This rapid industrialization of Michigan is seen more clearly when compared to other areas. Value added by manufacturing is one measure of manufacturing activity. For the

[1]It should be noted that the increase in manufacturing employment was made possible by the great increase in the productivity of agriculture, not only in Michigan but in the nation, which released employment to work in the growing manufacturing industry.

period of 1900 through 1940, the period of most rapid industrial growth in the United States, Michigan had a growth rate in value added by manufacturing almost three times that of the nation and exactly double that of the next highest state in the East North Central Region (includes Illinois, Indiana, Michigan, Ohio, and Wisconsin).[1]

There is considerable evidence to suggest that Michigan (and the nation) has now entered a new era which will see a continued increase in manufacturing employment but a decline in its relative position. This era has been dubbed the "human resources era" and is characterized less by the actual fabrication of raw materials than with the development of technology which will further remove employment from expending physical effort in the production process.

This general trend is best seen when presented visually. Trends in total employment in manufacturing and manufacturing employment as a per cent of the total employment are presented in Figure 9. The two trends which stand out most clearly are, first of all, the increase in the early 1900's of total manufacturing employment and of manufacturing employment as a per cent of the total employment. The second trend is the recent decline in manufacturing employment relative to other types of employment. Despite

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[1]Leonard D. Bronder and John M. Koval, Michigan's Economic Past: Basis for Prosperity (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, p. 7.

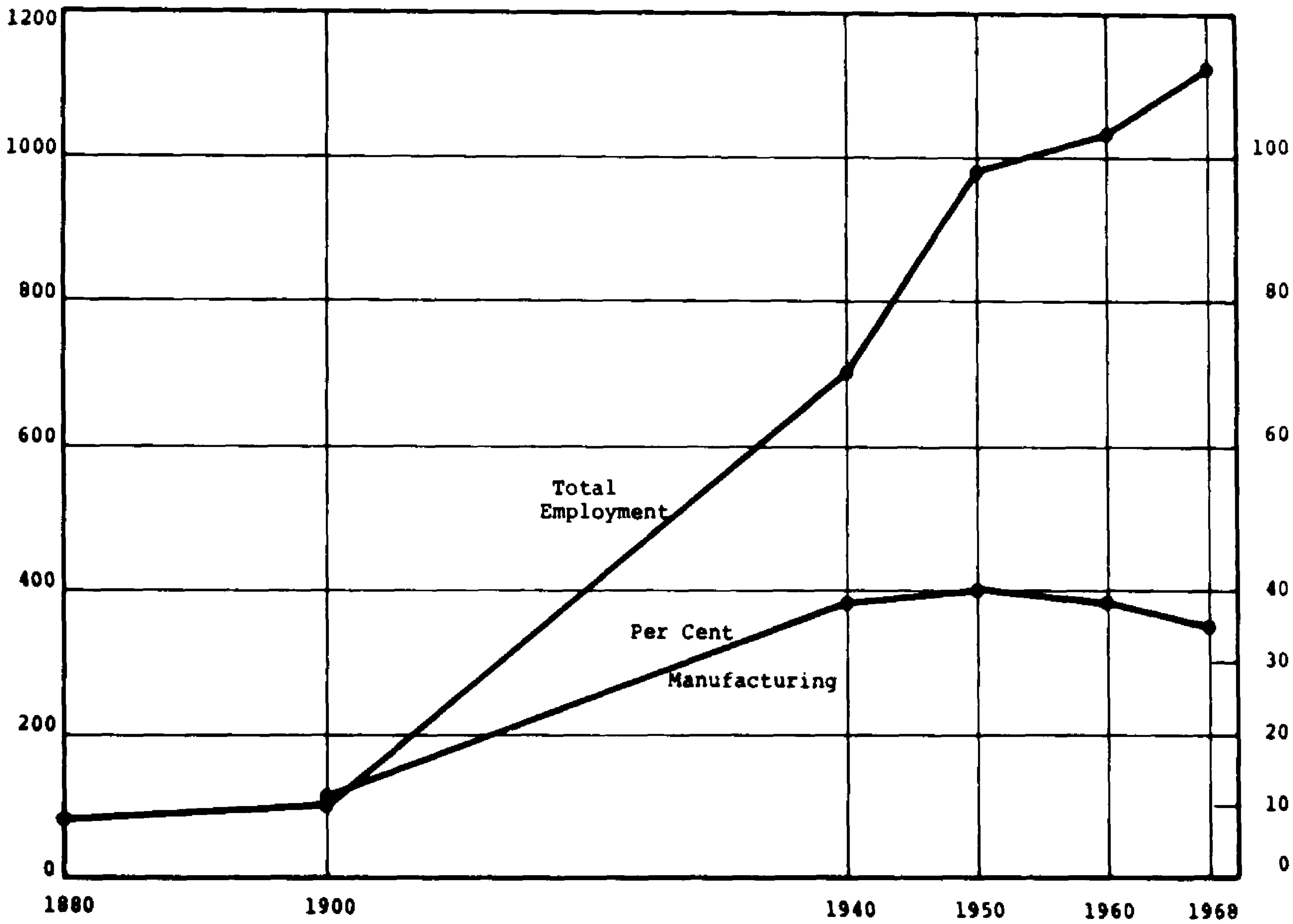

Figure 9. Total Employment and Per Cent Manufacturing[a]

[a]Data for 1880 through 1960 were taken from Simon Kuznetz, Population Redistribution and Economic Growth, United States 1870-1950 (Philadelphia: American Philosophical Society, 1957). The data for 1968 were from unpublished statistics from the Michigan Employment Security Commission, Lansing, Michigan.

continued increase in manufacturing employment, the per cent of the total employment in manufacturing has been declining since approximately 1950. Bronder and Koval have estimated that manufacturing's share of the total employment will continue to decline to 29 per cent in 1980.[1] This research has extended this rate of decline to 23 per cent in the year 2000. This has been accompanied by an increase in absolute numbers of employees. The reason why manufacturing employment can increase but have a decreasing share of the total employment is because total employment is expected to increase at a faster rate than employment in manufacturing.

Composition of Manufacturing Employment

Almost equally as important as the amount of employment to the water withdrawals for manufacturing is the composition of the employment. As mentioned earlier, there are considerable differences in the water withdrawal rates per employee among the several two-digit SIC categories. For this reason an awareness of the importance of each of the SIC categories in the state's employment structure is necessary. The proportion of the state total manufacturing employment in each of the two-digit SIC categories for 1958, 1963, 1968, and estimates for 1980 and 2000 are presented in Appendix Table 9.

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[1]Leonard D. Bronder and John M. Koval, _Michigan's Future: Its Population and Its Economy_ (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, 1967), p. 2.

As this table indicates, the bulk of manufacturing activity in Michigan has been concentrated in a few major industry types. In 1968 over 70 per cent of the manufacturing employment in Michigan was in four industries, transportation equipment, non-electrical machinery, fabricated metal products, and primary metal products. None of the remaining 17 industry types accounted for more than 100,000 employees, and none of them accounted for more than five per cent of the total manufacturing employment in the state. Combined they total less than does the transportation industry alone.

Projections are for the transportation equipment industry to further increase its dominance and to have over 36 per cent of the total state manufacturing employment by 2000. The other manufacturing types which combined with transportation equipment to total 70 per cent of the state employment in 1968 are expected to either increase only slightly, or to decline somewhat, to 1980 and 2000 so that by 2000 they will comprise only 69 per cent of the state total. This, however, is not a major change and the industrial structure of the state can be considered to remain relatively unchanged as far as the dominance by the four industries is concerned.

Regional Manufacturing Employment

When one examines a map of the manufacturing employment of Michigan it is immediately apparent that the location of manufacturing activity is not evenly distributed throughout the state. Large portions of the state account for very little of the total manufacturing employment, while almost all of the manufacturing activity is concentrated in a relatively few counties.

This distribution is most obvious when presented in a regional framework. The manufacturing employment in each of the seven planning regions (plus the per cent of the state total in each region) for 1958, 1963, 1967, and estimates for 1980 and 2000 are presented in Appendix Table 10.

Region I

The dominant position of Region I in the total state manufacturing picture is easily seen in Appendix Table 10. During the 10 year period between 1958 and 1967 Region I has averaged over 58 per cent of the state total manufacturing employment. Its rate of increase in total numbers of manufacturing employees has been comparable to most of the other regions. Between 1958 and 1963 Region I had a growth rate of 1.5 per cent per year in actual numbers of manufacturing employees. This was fourth highest among the regions of the state, a lower increase than three other regions. However, between 1963 and 1967 Region I registered a 4.2 per cent per year growth rate which was largest of all the regions.

Region I is expected to maintain its dominance in manufacturing employment in 1980 and 2000, although its position will probably be slightly lower. The region is expected to increase its total manufacturing employment .2 per cent per year between 1967 and 2000. It should have approximately 57.8 per cent of the state's manufacturing employees in 1980 and 57.6 per cent in 2000, a slight decrease from the 1958 to 1967 period.

The composition of manufacturing employment in Region I is presented in Appendix Table 11. It can be seen that the bulk of the manufacturing employment is concentrated in three categories. SIC categories 34, 35, and 37 accounted for 68.7 per cent of the total regional manufacturing employment in 1968. Although there are some minor changes expected among categories with respect to per cent of regional total, the overall situation will probably not change significantly by 2000. Fabricated metals, machinery, and transportation equipment are expected to account for 66.4 per cent of the total manufacturing employment in the year 2000.

In order to facilitate a more complete understanding of the direction of shifts in manufacturing employment, projections were made for each county and are essentially a disaggregation of the regional forecasts. Because of the detailed nature of the county forecasts less confidence is expressed in them than in the regional forecasts. Nevertheless, it is felt that they do give a relatively accurate indication of the direction of sub-regional changes in manufacturing activity. Each county's share of Region I's employment projections are presented in Appendix Table 12.

The pattern of manufacturing employment within Region I has changed much more rapidly than has Region I as a whole relative to the other regions, and considerable changes are forecasted for the future. Wayne County has dominated the region for as far back as any type of data are available, and is expected to continue to be the most important manufacturing county in the region at least to the year 2000. However, its position relative to the other counties in the region is declining.

In 1958 Wayne County had 69.3 per cent of the total manufacturing employment in Region I. Despite continued increases in manufacturing employment this had fallen to 64.8 per cent in 1963, and by 1967 Wayne County represented only 60.8 per cent of Region I's manufacturing employment. During the 1958-1963 period Wayne County increased its manufacturing employment only 1.0 per cent per year; this was the lowest of any of the counties in Region I.

The forecasted manufacturing employment for Wayne County in 1980 is 377,867. This represents a decline in the number of manufacturing employees of .25 per cent per year. A continued decrease in manufacturing employment is forecasted to 2000 for Wayne County. This is expected to be a decrease of less than .1 per cent per year, or approximately 5,500 for the 20 year period.

Three counties have profited most by the declining importance of Wayne County. Oakland County has realized the greatest absolute increase in manufacturing employment between 1958 and 1967. Employment increased by 43,630 for the period, an increase of 7.2 per cent per year. The per cent of the state total manufacturing employment represented by Oakland County increased from 9.75 per cent in 1958 to 14.54 per cent in 1967. The rapid rate of increase in Oakland County can be appreciated by comparing it with Macomb County. In 1958 Macomb County represented a larger share of the regional employment than did Oakland County by approximately 2 percentage points. This gap increased slightly by 1963. Between 1963 and 1967 Oakland County's manufacturing employment increased roughly 8.9 per cent per year while Macomb County was second only to Wayne County in the number of manufacturing employees. Oakland County is expected to increase its manufacturing employment through 2000 at a rate second only to Washtenaw County.

Macomb County has also profited considerably from Wayne County's declining relative position. Macomb County's manufacturing employment increased by 26,915 during the 1958 to 1967 period. This was the third largest increase in absolute numbers in the region as was the 4.1 per cent per year rate. Macomb County increased its relative position in the region from approximately 12 per cent in 1958 to 13.7 per cent in 1967. The forecasted increases for Macomb County will result in that county having 15.18 per cent of the regional manufacturing employment in 1980, and 16.58 per cent in 2000.

Although having a relatively smaller number of employees in manufacturing in 1958, Washtenaw County has increased at the highest rate of any of the counties in Region I (an average of 7.7 per cent per year between 1958 and 1967). If Washtenaw County grows in manufacturing employment at the rate forecasted it will have almost tripled its 1958 percentage share of the state total by 2000.

The remaining counties in Region I, with the exception of St. Clair, have all indicated a constant increase for the 1958 to 1967 period; all counties reported more manufacturing employment in 1967 than in 1958. Some of these counties have had a growth rate rivaling the larger counties (Sanilac 4.6, Livingston 4.2) but because of the small initial size have not made large contributions to the total manufacturing employment in the region. Only one county (Monroe) is expected to have a declining manufacturing employment to 2000, and this is so small (.1 per cent) that it is insignificant.

Region IIA

In terms of total manufacturing employment Region IIA has increased from 1958 to 1967, and a continued increase is projected at least until 2000. Region IIA had an annual rate of growth of 2.0 per cent between 1958 and 1963, and a 1.8 per cent per year increase between 1963 and 1967. As with all of the other regions this rate of increase is expected to be considerably less to 1980 and 2000. The expected rate of growth per year between 1967 and 1980 is expected to be .3 per cent and .2 per cent between 1980 and 2000. The growth trend of Region IIA can be seen in Appendix Table 10.

Region IIA is expected to continue to rank second among the planning regions in terms of manufacturing employment, although its relative position is expected to decrease slightly. In 1958 Region IIA had 25.27 per cent of the state manufacturing employment. After a slight rise in 1963 this decreased in 1967 to a percentage lower than in 1958. A continued, although slight, decline is expected for the region to 1980 and 2000, but it should remain well ahead of the next most important region.

The composition of manufacturing employment in Region IIA is similar to that in Region I. The structure of manufacturing employment in Region IIA is indicated in Appendix Table 11. There is not the great reliance on SIC categories 34, 35, and 37 as in Region I. These categories are still the most important in Region IIA but they represent only 47.2 per cent of the total regional employment in 1968 as opposed to the 68.7 per cent in Region I.

Five categories in Region IIA appear to be the probable beneficiaries of the declining dominance of SIC's 34, 35, and 37. Where in Region I SIC's 20, 25, 26, 36, and 38 accounted for only 9 per cent in 1967 they accounted for nearly 27 per cent in Region IIA. This is particularly important for industrial water withdrawals since SIC 26 is the 4th most demanding of water of the 21 SIC categories and SIC 20 is 8th. In terms of the total amount of water withdrawn for manufacturing in Region IIA the contribution of SIC 26 helps to compensate for lower employment totals.

Examining the region in more detail (Appendix Table 12) it can be seen that Kent, Kalamazoo, Ingham, Muskegon, and Berrien Counties have dominated the region's manufacturing employment since 1958 and are expected to continue to be the most important in 1980 and 2000. These counties had 60.6 per cent of the regional manufacturing employment in 1958. This percentage share fell slightly in 1963 but rose to 62.2 per cent in 1967. Sub-regional forecasts for Region IIA indicate that these counties will probably maintain 62 per cent of the regional manufacturing employment in both 1980 and 2000.

Within this group of counties Kent County has been the most important and has steadily increased its share of the regional manufacturing employment. Ingham County has had a continual increase in its percentage share of the regional manufacturing employment since 1963 and in 1967 displaced Kalamazoo County as the second county in that region. The other growth county in the group has been Berrien. Except for a slight decline at the 1967 period Berrien has had a continual increase in its percentage share. Muskegon and Kalamazoo Counties have experienced a general decline in their share of the total although their absolute manufacturing employment has increased.

Three other counties (Calhoun. Jackson, and Ottawa), while not among the top counties in the region, all had over

10,000 manufacturing employees in 1967, and combined they represented a substantial proportion of the regional employment. Jackson and Ottawa Counties have registered absolute increases from 1958 to 1963, and are expected to continue to do so to 1980 and 2000. Their percentage share has been increasing, although not steadily, during this period. The trend in manufacturing employment in Calhoun County, on the otherhand, has been down. Calhoun County's per cent of the regional total has been decreasing constantly from 1958 to 1967 and forecasts indicate this will continue. Absolute employment is expected to continue to decline as well.

The remaining 12 counties are small in manufacturing employment and contributed only about 18 per cent to the regional manufacturing totals in 1967.

Region IIB

Region IIB has never occupied an important position in the manufacturing schema in Michigan. Since 1958 this region has never had more than 2.0 per cent of the total state manufacturing employment. Despite its small manufacturing employment, Region IIB has been constantly increasing its manufacturing activity, both in numbers and as a per cent of the state total. Between 1958 and 1967 Region IIB had the largest rate of growth in manufacturing employment of any region. The region is expected to reach 2.0 per cent of the total state manufacturing employment by 2000. Region IIB's relative position can be seen in Appendix Table 10.

The manufacturing structure for 1968 and forecasts to 1980 and 2000 are indicated in Appendix Table 11. Regional manufacturing employment is fairly well diversified, having at least 2.0 per cent of its manufacturing employment in 15 of the categories, with no single category being of overwhelming importance. Slightly over 50 per cent of the region's manufacturing employment in 1968, however, was in a few categories. The dominance of the food processing industries in the region is undoubtedly a reflection of the region's position in the major fruit region of the state. Fabricated metals, electrical and non-electrical machinery each accounted for more than 10 per cent of the regional employment in 1968 and are estimated to continue their importance to 2000. Fortunately these industries are not large water users. Those industries which use large amounts of water (over 1,000,000 gallons per employee per year) accounted for 16.3 per cent in 1968 and by 2000 they are expected to decline slightly in importance to 15.5 per cent.

The county pattern of manufacturing employment in Region IIB is presented in Appendix Table 12. Examination of this table indicates that there does not appear to be any major reordering of the ranking of the individual counties in the region to 2000. In 1967 Grand Traverse, Manistee, Mason, and Osceola Counties accounted for almost 50 per cent of the total manufacturing employment in the state. By 2000 these counties are expected to have increased their combined share of the regional manufacturing employment by slightly less than 1.0 per cent. Most of the growth appears to be taking place in Grand Traverse and Osceola Counties, while Mason County has experienced a rising absolute employment but so slow in comparison to the regional growth that it has lost in per cent of regional total. This is expected to continue to 2000.

With the exception of three counties the remaining ones have had a rising manufacturing employment since 1958 and are expected to maintain this to 2000. The rate of increase has not been uniform, however, and the relative positions among the counties has changed. Leelanau, Newaygo, and Oceana Counties have had a declining manufacturing employment since 1958, and are expected to continue to decline.

Region IIIA

Region IIIA has consistantly been the third largest of the planning regions (see Appendix Table 10). It has increased its manufacturing employment 30,631 between 1958 and 1967 which was a growth rate of 3.1 per cent per year. This was only slightly less than the 3.4 per cent per year for Region IIB, and was well ahead of any of the other large manufacturing regions. Region IIIA had approximately 11.38 per cent of the manufacturing employment in the state in 1967. This was down somewhat from the 1963 per cent. Region IIIA is expected to continue to grow in manufacturing activity to

1980 and 2000 although, as with the other regions, at a much slower rate. Manufacturing employment is expected to increase in Region IIIA by approximately .8 per cent per year. This is only a little under the 1.0 per cent per year for Region IIB, and represents the highest rate for any region with over 100,000 manufacturing employees. The region is expected to increase its position relative to the other regions at a relatively uniform rate, increasing from 10.8 per cent in 1958 to 11.4 per cent in 1967, and forecasted increases to 12.3 per cent in 2000.

Structurally Region IIIA is dominated by the manufacturing of transportation equipment. The composition of manufacturing employment is shown in Appendix Table 11. With only 11.4 per cent of the state manufacturing in 1967, Region IIIA had approximately 20 per cent of the transportation equipment industry. When the next largest manufacturing types are included (primary metals, fabricated metals, and non-electrical machinery) it can be seen that the manufacturing structure in Region IIIA is very concentrated. These four manufacturing types constituted over 81 per cent of the manufacturing employment in Region IIIA in 1968. By 2000 it is expected that this concentration will have risen to 82.6 per cent. Of the manufacturing types, 13 have less than 1.0 per cent of the regional total each.

This manufacturing structure is very important to industrial water withdrawals in Region IIIA. SIC 33, with over

15 thousand employees expected in 2000, is a very heavy water user. Over 4,000,000 gallons of water per employee are withdrawn each year in the primary metals industry. Each employee in SIC 33 withdraws as much as 13 employees in the transportation equipment industry. This means that in the year 2000 the primary metals industry, with approximately 15,000 employees will be withdrawing about twice as much water as the transportation equipment industry with approximately 94,000 employees.

With only a few exceptions, there has been a continual increase in manufacturing employment for each county from 1958 to 1967 and continued increases are expected in each county to 1980 and 2000 (Appendix Table 12). Genesee County has been, and will probably continue to be, the major county in the region with about 60 per cent of the manufacturing employment. This per cent has stayed uniform since 1958 and is expected to continue steady until 2000. Saginaw County, the next largest, has increased its position somewhat and is expected to have about 25 per cent of the manufacturing employment in the region in 2000. Saginaw and Genesee Counties are expected to have well over 85 per cent of the regional manufacturing employment in 2000.

Bay County, the third largest county in Region IIIA, has increased its total manufacturing over the years and is expected to increase to 1980 and 2000. However, the rate of increase has been less than the region as a whole and, therefore, Bay County's per cent of the regional total is declining.

Region IIIB

Of all the regions in the Lower Peninsula, Region IIIB seems to be the weakest in manufacturing activity (Appendix Table 10). In fact, this region appears to be much like the Upper Peninsula regions. Manufacturing employment in Region IIIB has never contributed a great deal to the state total manufacturing, and it is expected to contribute even less in the future. Despite slight increases in absolute employment to 1967 the region's percentage share of the state total declined.

A very slight increase in manufacturing employment is forecasted to 1980, but as a result of the general declining importance of manufacturing throughout the state Region IIIB was forecasted to have fewer manufacturing positions in 2000 than in 1980. However, since the general assumption was made that no region would have less employment in manufacturing in 1980 or 2000 than it had previously, the 2000 employment estimate was increased by 487 to make it equal to the 1980 estimate.

The unique position of the chemical industry (SIC 28) in Region IIIB is easily seen in Appendix Table 11. In 1968 the production of chemicals accounted for 58 per cent of the manufacturing employment in the region, and 31 per cent of the employment in the chemicals industry in the state. The remaining 42 per cent of the manufacturing employment in the region is relatively scattered, no manufacturing type having over 7.0 per cent of the total.

The main factor in Region IIIB's slowly declining position in manufacturing is probably related to the lack of growth in the chemical industry. The composition of manufacturing employment for Region IIIB is indicated by Appendix Table 11. As shown, the chemical industry had a smaller proportion of the state total manufacturing employment in 1968 than in 1958. This same relative position is forecasted to continue into 1980 and 2000. The absolute employment in chemicals is expected to increase slightly to 1980 and 2000.

The importance of the chemical industry in Region IIIB assumes even greater significance when it is realized that this industry is the second largest water user of all of the 21 manufacturing categories. Therefore, primarily because of the chemical industry large amounts of water were withdrawn for manufacturing purposes in 1968 in Region IIIB and will continue to be withdrawn in 2000.

County manufacturing employment in Region IIIB is presented in Appendix Table 12. This table indicates that Midland County is the primary manufacturing county in the region. Since 1958 Midland County has had up to 66 per cent of the manufacturing employment in this 15 county region. Despite general increases in manufacturing employment (except for the forecasted 1980 to 2000 period) the rate has been low enough so that Midland County has been a declining proportion of the regional total. Continued declines are forecasted.

Midland County is the only county in the region with over 5,000 manufacturing employees; in 1967 Midland had almost 15,000. The next largest county, Alpena, had less than 3,000. Together these counties have approximately 72 per cent of the manufacturing employment in the region. However, because of declining proportion of regional total in both Midland and Alpena Counties they are estimated to have only 67 per cent in 2000.

The only other counties of any consequence in manufacturing employment are Cheboygan, Clare, and Otsego Counties. Each of these, however, had less than 5.0 per cent of the regional total in 1967.

Regions IV, V

The regions of the Upper Peninsula have never been important in manufacturing. Combined, the 15 counties in these regions accounted for only 1.11 per cent of the total state manufacturing employment in 1967 (see Appendix Table 10).

Not only does the Upper Peninsula not have a large manufacturing employment but it has declined considerably in recent years, falling from 1.6 per cent of the state total in 1958 to the 1.11 per cent in 1967. The absolute decline has been greater in Region V than in Region IV, although both regions had less manufacturing employment in 1967 than in 1958.

Projected employment figures to 1980 and 2000 indicate an even smaller amount of manufacturing activity. However, since the decision was made that the 1980 and 2000 employment would be no less than the 1967 level, both regions were stabilized at the 1967 employment totals for 1980 and 2000. This has resulted in a forecasted decline in the per cent of the state total for the Upper Peninsula, reaching 1.02 per cent in 2000.

The manufacturing structure of the Upper Peninsula is indicated in Appendix Table 11. The most important type of manufacturing is related to the timber resources of the area. In 1968 approximately 42 per cent of the manufacturing employment in the regions was in lumber and wood products, and paper and allied products. The next most important type of manufacturing activity was in the non-electrical machinery industry. This category employed 16 per cent of the manufacturing employees in 1968.

The importance of SIC 26 (paper and allied products) to the employment structure of the Upper Peninsula means that this area withdraws far more water than its small manufacturing employment would indicate. SIC 26 is the fourth heaviest user of water with a withdrawal of over 3,500,000 gallons per employee per year. The other heavy water users are not large employers in the Upper Peninsula.

The sub-regional manufacturing employment in the Upper Peninsula is listed in Appendix Table 12. In 1967 three counties accounted for about 44 per cent of the total. This relationship is expected to remain at least through the year 2000.

CHAPTER VI

DETERMINATION OF MANUFACTURING WATER WITHDRAWALS

The technique used in estimating manufacturing water withdrawals in Michigan for 1980 and 2000 involves two major steps. The first of these is the identification of manufacturing employment for each county, broken down into the 21 two-digit Standard Industrial Classification (SIC) manufacturing categories (see page 80). The second step is the application of water withdrawal coefficients, or the amount of water withdrawn annually by each employee, to these employment figures.

Estimates of Manufacturing Employment

Information Needed

There are three main types of data which are required to compute the various types of manufacturing employment in each county for 1980 and 2000. First of all, estimates of total manufacturing employment in each county are needed. Second, data are required on total state employment for each SIC category for 1980 and 2000. And third, information is needed on the proportion of each county's manufacturing employment in each SIC category at some index period in the past, and estimates for 1980 and 2000. Virtually none of these types of information were available in a form which could be used in this study and, consequently, they had to be estimated.

Data Availability

Data on manufacturing employment are available from five potential sources: (1) Census of Population, (2) Census of Manufacturers, (3) Annual Survey of Manufacturing, (4) County Business Patterns, (5) Michigan Employment Security Commission. Each of these data sources has its own advantages and disadvantages and, therefore, each was considered for use in this study.

Census of Population

The Census of population is taken every 10 years by the U.S. Bureau of the Census. Information on manufacturing employment in each county has been recorded in each census period and thus represents a relatively long period of observation. The Census of Population, however, has a number of disadvantages which preclude its use in the examination of the location of manufacturing activity.

The first disadvantage of these data is a result of the method of collection. The employment figures reported in the Census of Population are based upon the place of residence rather than the place of work. For this study the major concern is the number of people expected to work in a county in 1980 and 2000 and not how many people who lived in the county worked in manufacturing regardless of where this was. This difference may not appear to be significant. However, for counties with relatively low manufacturing employment opportunities, but which are within commuting distance of a large industrial county, the difference may be considerable.

In addition to this major deficiency there is a second one which makes it difficult to work with the Census of Population data. The Census of Population reports SIC employment as grouped data. That is, several individual two-digit SIC's are grouped together with no indication of how they can be proportionally separated. Since the water withdrawal coefficients are based upon individual two-digit categories there would be no rational basis for assigning withdrawal rates to groups of SIC categories.

Census of Manufacturers

The Census of Manufacturers, also taken by the U.S. Bureau of the Census, does not have the defects of the Census of Population. In the Census of Manufacturers employment is reported according to the place where the individual works rather than his place of residence. And the data is presented at the individual two-digit SIC level rather than as groups of two-digit SIC categories. However, the Census of Manufacturers does have two disadvantages which makes this data source less than ideal.

First of all, there is the problem of time series. The Census of Manufacturers is available in usable form for only two census periods, 1958 and 1963. The census of 1958 represented a significant change in the manner of classifying manufacturing activity over previous censuses. Industries which were placed in one category in previous censuses were often found in another in 1958. The 1958 and 1963 censuses were taken using approximately the same categories and are considered to be comparable data. For censuses taken before 1958 the difference is so great that any comparison between the two periods would incorporate so much inconsistency as to make the results invalid.

The second disadvantage of the Census of Manufacturers is the incompleteness of data due to disclosure reasons. When reporting employment for a county would result in disclosing information about individual producers this information is withheld. This does not apply to total county employment figures but only when these are broken down into the two-digit SIC categories or lower. For many counties well over half of the employment by SIC categories is withheld for reasons of disclosure.

Annual Survey of Manufacturing

The Bureau of the Census conducts annual surveys of manufacturing activity for intervening years between the Census of Manufacturers which are taken every five years.

Information is reported on manufacturing employment for selected types of manufacturing in 12 or 15 of the largest counties in the state. However, not all counties in the state are reported and even in those which are there are considerable gaps in the data.

The principle strength of the Annual Survey of Manufacturing are data on state employment in each of the two-digit SIC categories. This information is relatively complete and when used with the 1958 and 1963 Census of Manufacturers provides a reasonably long time series on state manufacturing employment by SIC category.

<u>County Business Patterns</u>

The County Business Patterns, also a publication of the U.S. Bureau of the Census, reports data only for individuals who are covered by social security. Publication has been every three years, except for two years between 1965 and 1967. The main disadvantage with this source is that it is possible that the distribution of covered employment might not be proportional to the actual distribution of manufacturing employment, thus causing some areas to be over represented while others could be under represented.

In addition to the question of validity, the County Business Patterns suffer from the same defect as the Census of Manufacturers, that of disclosure. The amount of data withheld is approximately the same for each source.

Michigan Employment Security Commission

The Michigan Employment Security Commission collects and disseminates data on employment which is covered by unemployment compensation. Every firm which employes one person in addition to the owner is required to report to the Employment Security Commission. Thus, while their coverage is not complete it may be regarded as complete without any substantial error.

Information is readily available from the Employment Security Commission on total state manufacturing employment, on employment in each of the two-digit manufacturing SIC categories, and total manufacturing employment for some counties. These are generally the larger counties or counties in which there has been substantial and persistent unemployment. These data are usually reported as grouped data, however, with the employment of two or more counties grouped together. However, no information was reported for 48 of the 83 counties in the state. While these counties are generally the ones which contribute the least to the total manufacturing employment in the state it is a major disadvantage when the purpose is to derive a complete state-wide picture of future manufacturing activity and related water withdrawals as this leaves a very large portion of the state unaccounted for.

Data on individual counties by SIC categories is generally withheld, as in the Census of Manufacturers and the County Business Patterns, for disclosure reasons. However, for the purpose of this study the researcher was able to obtain data on county employment by SIC categories for 1968. This data was relinquished with the agreement that it was not to be reported in such a manner that would violate the initial reasons for withholding it.[1]

Methodology

The estimation of manufacturing employment for each county stratified by SIC categories involves five major steps: (1) estimates of total state employment for 1980 and 2000, (2) estimates of state manufacturing employment for 1980 and 2000, (3) sub-state estimates of manufacturing employment (regional and county), (4) estimates of state manufacturing employment by SIC categories, (5) estimates of county manufacturing employment by SIC categories.

Estimates of Total State Employment

Before making estimates of state manufacturing employment it was necessary to make estimates of the total state employment expected for 1980 and 2000. Since employment in

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[1]The 1968 Michigan Employment Security Commission data on county employment by SIC categories was for one period early in 1968. These data were used for both county totals and as an indication of manufacturing structure. It was felt that this data may or may not reflect unusual conditions at the time it was gathered. For this reason, when substate (regional and county) total employment figures were needed the 1967 monthly average for the state as a whole was used by disaggregating this figure proportionally based upon the 1968 data. When referring to manufacturing structure (the manufacturing employment in each SIC category) the data are reported as 1968 since this information is reported in proportions and not in actual figures which would violate the confidence of the data.

manufacturing is the prime mover of the Michigan economy, and because estimates of manufacturing employment will be examined as a changing proportion of total employment, it was mandatory that accurate estimates of total state employment be made.

Projections of total employment were made for Michigan in 1966 to be used in another study. These projections for 1970, 1980 and 2020 are presented in Table 9.

Table 9

Total State Employment, Projections to 2020[a]

Year	Employment[b]
2020	6,876,0
1980	3,769.0
1970	3,222.0
1960	2,727.0

[a]Battelle Memorial Institute, Grand River Basin (Michigan) Comprehensive Water Resources Study Appendix O: Economic Base Study (Columbus, Ohio, 1966), p. I-15.

[b]Thousands

Data on total employment in Michigan for the last five years are presented in Table 10. These data are from the Michigan Employment Security Commission. It can be seen that the employment for 1968 (3,243,600) exceeds the Battelle estimate for 1970 (3,222,999).

Looking at the years immediately preceeding 1968,

Table 10

Total State Employment, 1964-1968[a]

Year	Employment[b]
1968	3,243.6
1967	3,208.8
1966	3,183.6
1965	3,097.8
1964	2,936.0

[a]Unpublished statistics from the Michigan Employment Security Commission, Lansing, Michigan.

[b]Thousands.

there was an increase of 25,200 employees between 1966 and 1967, and an increase of 34,800 between 1967 and 1968. Using an annual rate of increase of 30,000 the 1970 employment would be 3,303,600. This would be 2.5 per cent greater than the estimate made by Battelle for the same period.

The Michigan Office of Economic Expansion has estimated that the 1980 employment in Michigan will be approximately 3,954,890.[1] For 1980 Battelle estimates employment to be approximately 3,769,000. This is 4.9 per cent lower than the estimate of the Office of Economic Expansion.

Since the Battelle employment estimate for 1970 was approximately 2.5 per cent too low, and because the Battelle

[1]Bronder and Koval, Michigan's Future: Its Population and Its Economy, pp. 18-29.

estimate for 1980 is also lower than the 1980 estimate of the Office of Economic Expansion, it is assumed that the Office of Economic Expansion's estimate for 1980 represents more realistically the actual situation.

No estimates for total employment for 2000 could be found. However, Battelle has estimated that employment in Michigan will increase by 1.5 per cent per year between 1980 and 2020.[1] Applying this rate of increase to the 1980 employment estimate from the Office of Economic Expansion which was 3,954,890 the result is 5,326,683 in 2000.

For the purpose of this study, then, the Office of Economic Expansion's figure of 3,954,890 for 1980 and 5,236,683 for 2000 (an increase in the 1980 figure of 1.5 per cent per year for 20 years) were accepted as employment levels for the target years. Figure 10 is a graphical presentation of these data, and indicates that the estimates are realistic when compared to previous trends.

Estimates of State Manufacturing Employment

There is a paucity of information on expected future levels of manufacturing employment in Michigan. Apparently the only estimate of future manufacturing employment that has been made for Michigan as a whole was made by the Office of Economic Expansion. However, these projections extend only to 1980 and provide no data on levels of manufacturing

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[1]Battelle Memorial Institute, Grand River Basin, p. I-15.

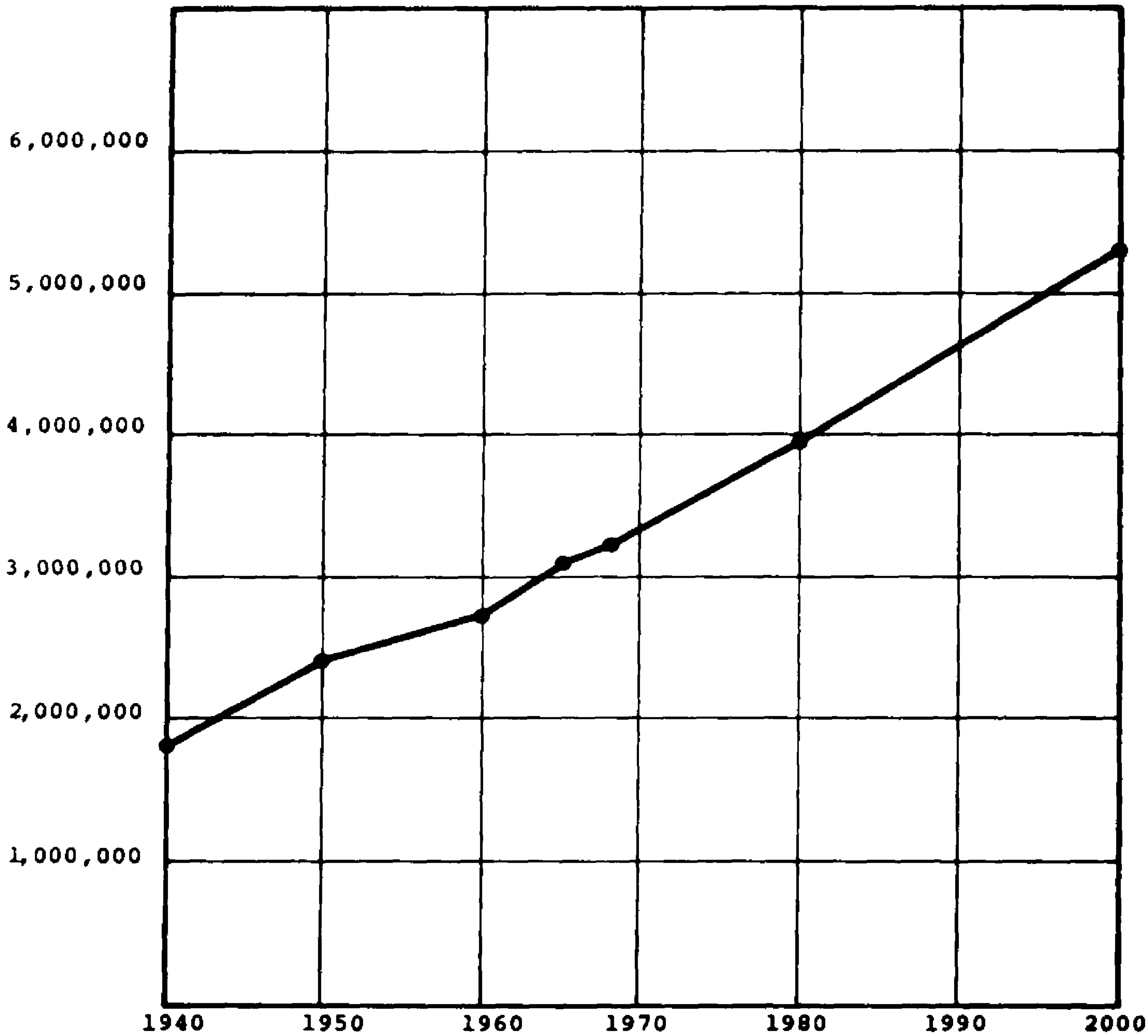

Figure 10. Total Employment[a]

[a]Data for 1940 through 1960 taken from U.S. Bureau of the Census, U.S. Census of Population: 1960. Vol. I, Characteristics of the Population. Part 24, Michigan (Washington: U.S. Government Printing Office, 1963). Projections were taken from Battelle Memorial Institute, Grand River Basin (Michigan) Comprehensive Water Resources Study Appendix O: Economic Base Study (Columbus, Ohio, 1966).

employment in the year 2000.

The initial plan was to use the estimate of total employment as a base and to estimate the proportion of the total employment made up of manufacturing employment. Several techniques were tried in an attempt to derive the 1980 and 2000 proportions. These are listed below and are followed by a short discussion of the results.

The following techniques were tried as a means of estimating the proportion of total employment made up by manufacturing employment: (1) the application of the most recent proportion to the estimates of total employment, (2) a straight line projection of the changes over the years in the proportion manufacturing employment is of total employment, (3) a straight line projection but constraining the proportion to .29 in 1980, (4) extension of the per cent change in the total employment/manufacturing employment relationship.

Technique 1

The most recent information which is available on the proportion of manufacturing employment to total employment for the state as a whole is from the Michigan Employment Security Commission and is for 1968. One approach in estimating manufacturing employment in the state for 1980 and 2000 is to assume that the proportion of manufacturing employment to total employment will remain constant, and to use the 1968 proportion, applying this to the estimates of total employment for 1980 and 2000.

Examination of the data for the 1956 to 1968 period indicates that this relationship has not remained constant over the years but has changed considerably. This data is presented in Appendix Table 13. The use of a constant proportion would not reflect these basic changes in employment structure and, therefore, was considered unsatisfactory.

Technique 2

This technique used to estimate the 1980 and 2000 manufacturing employment was to determine the proportion of the labor force engaged in manufacturing each year and to project this proportion over time. A participation rate could then be determined for 1980 and 2000 which would reflect the dynamic nature of the variable. The data used for this projection were those listed in Appendix Table 13.

This approach is essentially a time series projection where observations are taken of the participation rates each year from 1956 through 1968, and this "trend" projected on to 1980 and 2000. Such a model will assume that the conditions operating in the 1956-1968 period will continue to operate in 1980 and 2000 in approximately the same magnitude, and that no new factors will enter which will disrupt this relationship. The model for participation rate then becomes $Y=f(t)$ where Y is the participation rate and t represents time.

There will almost always be a number of factors which combine to influence the magnitude of the participation rate. These factors can be combined into an equation which normally has a greater amount of predictive power than a projection based solely on time. To be used, however, the future values of these "other factors" must be known, and this usually involves additional projections. The result is an end figure (in this case a participation rate) which is a result of a projection based upon other factors which are in turn projected.

Projections of a time series implicitly includes the effect of these other factors even if the individual effect of each can not be separated from the combined effect. Thus, while weaker than a model that incorporates discrete variables into a mathematical formula, the time series model does incorporate the indirect effect of these other variables.

The actual placing of the trend line can be accomplished by visually locating the line so that it appears to "fit" the data. However, a more precise method is available with the use of the least squares regression technique. This method assures that with any given set of data the trend line will be placed so that the errors between it and the actual values which it purports to estimate will be smaller than if the line was in any other location. This second method of fitting the trend line was the one employed.

When the initial regression was run with the proportion of the employment in manufacturing as the dependent variable and with time as the independent variable the correlation coefficient was only .48. This regression was run once more, this time with two independent variables, time and the variable "unemployment as a per cent of the total labor force." With the addition of the second variable the correlation coefficient became .87.

Since unemployment was to be included in the equation it was necessary to estimate the rate of unemployment for 1980 and 2000. Because there are so many unknowns involved in determining the rate of unemployment, the mean unemployment for the 1956 to 1968 period was considered to be the unemployment rate for both 1980 and 2000.

Utilizing this model produced a trend line which reached zero in 1990 and negative proportions after that. This is obviously unrealistic, and it was necessary to incorporate into the model criteria which would produce a more plausable estimate.

Technique 3

This technique was a modification of the previous one, differing in two important ways. First, in addition to year and unemployment, the variable "unemployment squared" was added to the model. This had the effect of lessening the degree of slope of the regression line over time as it approached zero. The second modification in the model was to constrain the 1980 estimate to a proportion that had been previously estimated by the Office of Economic Expansion; the Office of Economic Expansion has estimated that manufacturing employment in 1980 will be 29 per cent of the total employment in the state.[1] The effect of this constraint was to force the regression line through the .29 level for 1980 while continuing to utilize the 1956 through 1968 data.

Using this model to estimate the 1957-1968 proportions produced results which were very close to the actual proportions for those years. However, using this model for 2000 produced a figure of .33 for manufacturing as a proportion of total employment. This is not the expected result when the trend of the previous data and the estimate of .29 for 1980 are considered. Instead of increasing from .29 to .33 the trend should have been towards a further decrease. It also produced a "jump" in the trend line that could not be accounted for.

Projections which exhibit an abrupt change from past trends are normally the result of very strong forces. Since these forces were not evident in Michigan it was assumed that these abnormalities were a result of inadequacies in the model.

The critical value of the model appeared to be the use of the mean rate of unemployment. To test the sensitivity of this variable the estimated proportion for 2000 was computed using the highest rate of unemployment in the 1956-1968 period (13.6) and the lowest rate of unemployment ever experienced during this same period (3.5). There was some change

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[1] Bronder and Koval, <u>Michigan's Future: Its Population and Its Economy</u>, pp. 18-29.

in the proportion for 2000 but this was relatively small. Using the high unemployment rate the value of 30.5 was the indicated proportion, or 2.46 per cent lower than when the mean unemployment rate was used. When the low unemployment rate was used the value was 36.9, or 3.88 per cent higher than when the mean unemployment rate was used.

Technique 4

The per cent manufacturing employment was of total employment for the 11 year period between 1957 and 1968 is indicated in Appendix Table 13. The Michigan Office of Economic Expansion has estimated that employment in manufacturing will be 29 per cent of total employment in 1980. This 29 per cent appears to be a reasonable figure when considered in the light of the 1957 to 1968 trend, and it was accepted as the rate to be used for this research. Applying the 29 per cent rate to the estimated total employment in 1980, the result is 1,146,918.

The estimated fugure for manufacturing employment as a per cent of total employment for 2000 using Technique 4 was developed by extending the rate of decrease past the 29 per cent for 1980. Referring again to Appendix Table 13, it can be seen that there has been a sizable change in the per cent from year to year. In order to start from a base which represents a more stable condition rather than yearly fluctuations the mean per cent for the last three years was used as a base rather than the 31.6 per cent for 1968. Taking the mean of the last three years the result is 33.95.

Accepting this 33.95 rate for the 1966 to 1968 period as a more accurate rate than the actual 1968 rate, there has been a decrease of approximately 1.25 per cent per year at a compound rate of decrease to the 29 per cent estimated for 1980. At this 1.25 rate of decrease the rate would be 22.62 in 2000.

Applying this 22.62 per cent to the estimated total employment for 2000 (5,326,683) the result is 1,205,288. This figure is accepted as the total state manufacturing employment for 2000 for the purpose of this research.

These two figures, then, 1,146,918 for 1980 and 1,205,288 for 2000 are chosen as the estimated manufacturing employment levels for this study. Figure 11 indicates graphically the trend in manufacturing employment from 1940 through 1968 with the estimates for 1980 and 2000. These estimates represent a reasonable continuation of the trend in manufacturing employment since 1950, and reflect the increasing absolute importance of manufacturing employment, but the declining relative importance.

Sub-State Estimates of Manufacturing Employment

Sub-state estimates of manufacturing employment have been made for two levels of generalization. Employment estimates were first made for the seven planning regions. These were then disaggregated to the county level.

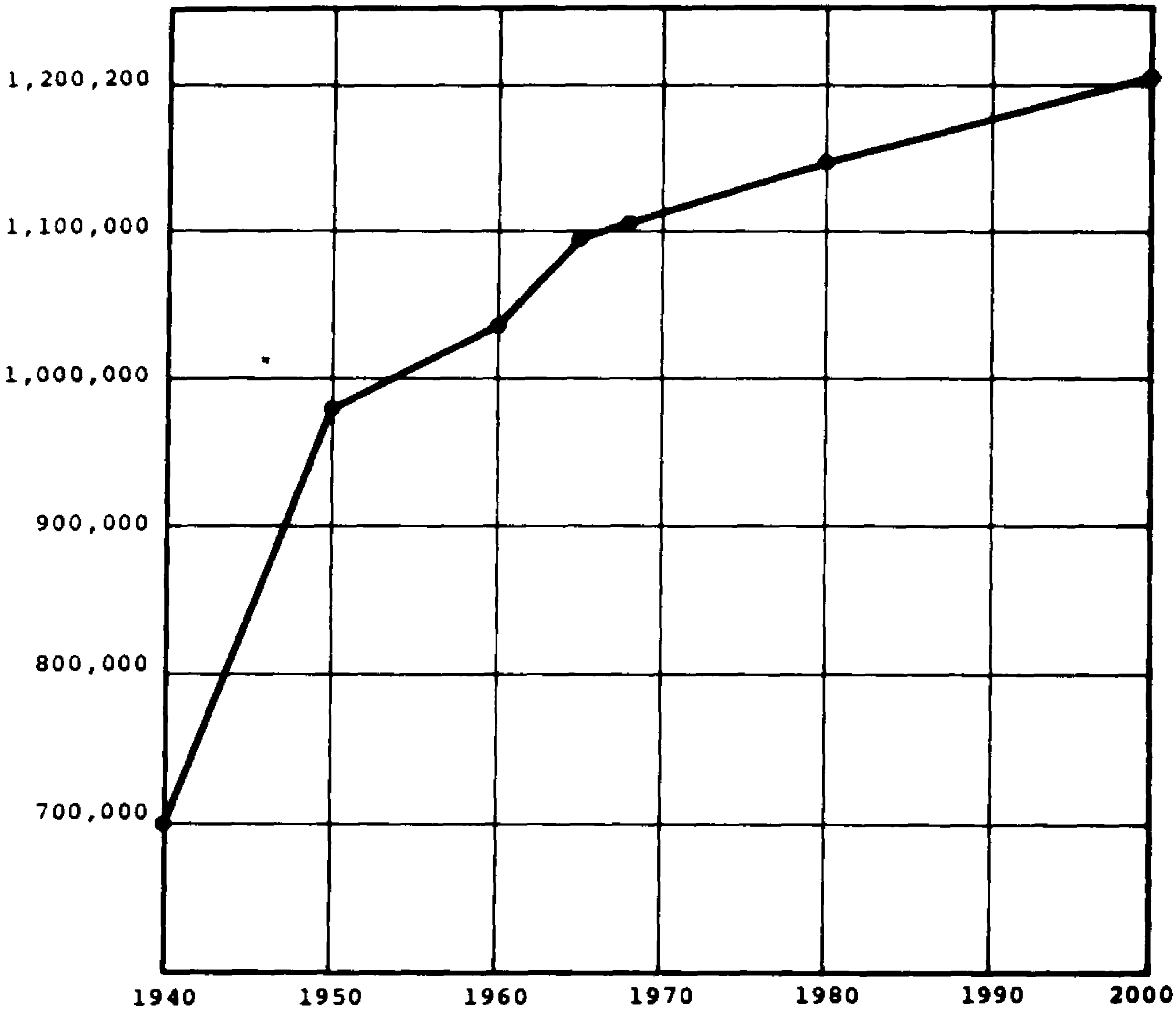

Figure 11. Manufacturing Employment[a]

[a]Data for 1940, 1950, and 1960 were taken from U.S. Bureau of the Census, U.S. Census of Population: 1960. Vol. I, Characteristics of the Population. Part 24, Michigan (Washington: U.S. Government Printing Office, 1963). Data for 1963 were taken from U.S. Bureau of the Census, Census of Manufacturers: 1963. Vol. III, Area Statistics. Part 23, Michigan (Washington: U.S. Government Printing Office, 1966). Data for 1967 were from unpublished statistics, Michigan Employment Security Commission, Lansing, Michigan. Projections for 1980 and 2000 were made by the author.

Regional Estimates

After the estimates of state manufacturing employment were made it was necessary to break this total down into the seven planning regions chosen for this study. Two different approaches were utilized in this effort, one applying to the two regions of the Upper Peninsula and one applying to the remaining five regions of the Lower Peninsula.

Upper Peninsula The contribution of the Upper Peninsula to the total state manufacturing employment has never been great. In the period between 1960 and 1967 the entire Upper Peninsula had never accounted for more than 1.56 per cent of the total manufacturing employment in the state (see Appendix Table 10).

The future of the Upper Peninsula as a contributor to the total state manufacturing employment is also expected to remain slight. The Office of Economic Expansion has estimated that the Upper Peninsula will not only fail to increase in manufacturing employment to 1980, but that it will actually lose manufacturing employment and in 1980 will account for only 1.07 per cent of the total manufacturing employment in the state.

For this reason the assumption is made that the position of the two regions in the Upper Peninsula will not change from the 1967 situation. In 1967 Region IV had approximately 7,193 employees in manufacturing, while Region V had 5,026. It is assumed that these figures will remain constant for

1980 and 2000. This assumption is based upon four reasons. First, the population of the Upper Peninsula, which has been decreasing in recent years, is projected to increase to 1980 and 2000. Second, it is believed that the efforts of the various organizations charged with the economic development of the Upper Peninsula will begin to stem the decrease in manufacturing employment. Third, the reductions in the Mackinac Bridge tolls will contribute to making the Upper Peninsula a more integral part of the total Michigan economy. Fourth, the increased attraction of the Upper Peninsula as a recreation area will contribute to maintaining its present manufacturing position.

Lower Peninsula. Projections of the manufacturing employment of the Lower Peninsula were made by doing a time series projection of the actual employment in each of the regions to 1980 and 2000, determining what per cent of the total was in each of the regions for the two years, and then applying these per cents to the already projected state manufacturing employment figures exclusive of the Upper Peninsula.

These estimates were derived by using a time series regression based upon data from the 1958 and 1963 Census of Manufacturers and the unpublished 1967 statistics from the Michigan Employment Security Commission. It is recognized that these data have three disadvantages: (1) the time span is relatively short, (2) there are only three observations, (3) the data were taken from more than one source.

The first two disadvantages reflect the general lack of available data. It is believed that the inadequacies of the sources used are less, however, than the alternate sources of data which were available for use. The third disadvantage is minimized by the fact that the coverage is virtually synonymous. The 1967 Employment Security Commission data covers all employment in firms which employ one person besides the owner. The Census of Manufacturers' data covers all full or part-time employees.

The regression equations for regional employment for 1980 and 2000 are of the form -1,003,640 + (523 x 1980) = 31,900, and -1,003,640 + (523 x 2000) = 42,360. The number -1,003,640 is a constant and 523 is the regression coefficient. Regression coefficients and constants for the regions are shown in Appendix Table 14. This same form is used in estimating county employment and SIC employment.

The results of the regression are shown in Table 11. The column "adjusted" refers to the proportional adjustments of the estimated figures so that when totaled they do not exceed the total state manufacturing employment exclusive of the 12,219 employees estimated for the Upper Peninsula.

County Estimates

Although the primary objective is to estimate water withdrawals for 1980 and 2000 in each of the seven planning

Table 11

Regional Manufacturing Employment

		Estimated		Adjusted	
Region	R	1980	2000	1980	2000
I	.94	865,094	1,198,014	662,551	694,109
IIA	.97	376,116	519,676	288,100	301,002
IIB	.99	29,507	42,727	22,581	24,695
IIIA	.99	178,985	256,205	136,618	148,414
IIIB	.91	31,900	42,360	24,849	24,849

regions estimates of manufacturing withdrawals were made for each county. This was necessitated because of the overall importance of manufacturing to the economy of Michigan.

Estimates of manufacturing employment by county is a much more tenuous procedure than the estimation of regional manufacturing employment. When working with regions abrupt changes in the employment level in one county or another will normally cancel out (increases in one county being balanced by decreases in another) thus providing a more uniform trend. At the county level, however, abrupt changes from one year to the next are directly reflected in the trend and often bias the extension of the time series. For this reason, in estimating county employment it was necessary to make adjustments to counteract this tendency.

The final estimate of county employment, the one which will be used for the final computation of manufacturing water withdrawals, is designed to reflect the nine year trend in manufacturing employment from 1958 to 1967. This trend was determined by doing a time series regression for each county. It was discovered that 20 counties out of the 83 in the state had a trend line which indicated a decreasing level of manufacturing employment. The remaining 63 counties had a positively sloping regression line which indicated an increasing level of manufacturing employment. Separate techniques were used for each group.

For the 20 counties which registered a decreasing level of manufacturing employment it was assumed that each one had already reached its lowest level of employment in 1958, 1963, or 1967 whichever one was the lowest. Employment figures were initially assumed to remain at this level to 1980 and 2000 subject to later proportional adjustment so that the total employment of all counties in a region would equal the regional employment.

The rationale for this assumption stems from the belief that those firms which are more prone to lower employment levels will register the first losses, and that subsequent losses will be fewer because the status of the remaining industries as a group will be improved and less prone to losses than before the initial losses occured. If employment changes in subsequent years are allowed to reflect the earlier losses, employment would reach zero before 2000 in nine counties.

For the 63 counties which indicated an increasing level of manufacturing employment the final employment level represents a median figure between a high and low estimate. It is felt that a final figure which represents the median position between two probable extremes will more accurately reflect the situation in 1980 and 2000.

The first estimate was made by assuming that the 1967 per cent of regional total remains unchanged to 1980 and 2000. These per cents, when applied to the regional estimates for 1980 and 2000, will represent a minimum level of employment for the 63 counties with increasing levels of manufacturing employment.

The application of a constant proportion, in itself, is often used as a means of forecasting. By assuming that future conditions will be related to a base condition by the same proportion one is almost assured of being reasonably close to the future conditions, provided the base condition has been correctly determined, unless there have been drastic changes in the interim. However, by using a constant ratio one fails to take into consideration possible changes over time.

The high estimates for the 63 counties which have experienced an increasing level of manufacturing employment is derived by the time series regression. Each county's 1980 and 2000 manufacturing employment is allowed to reach the maximum possible based upon the given data for 1958, 1963, and 1967. The regression coefficients and constants are presented in Appendix Table 15.

The final estimate for each county was then made by choosing the figure which is half way between the high estimate and the low estimate.

When these final employment estimates for counties were grouped according to regions and totaled they did not always equal the 1980 and 2000 previously estimated regional totals. These counties were then "forced" to fit the regional total. This was done by inflating or deflating them proportionally, For example, if a county accounted for five per cent of its regional total, five per cent of the difference between the projected regional total and the sum of the county estimates would be added to or subtracted from that county. When this is done for each county in the region the county totals, when summed, will equal the projected regional totals.

Estimates of State SIC Employment

The data available for use in the estimation of SIC category employment for the state was more pleantiful than in the estimation of regional and county employment. There were data for 11 years available for the period between 1958 and 1967. These data were from the 1958 and 1963 Census of Manufacturers, and from the 1959, 1960, 1961, 1962, 1964, 1965, and 1966 Annual Survey of Manufacturing which are normally taken between the regular censuses. These data are collected by the same agency, for the same purpose, and with essentially the same criteria. The only major difference being that one is a census and the other a survey. It is felt, however, that in spite of this disadvantage these are still the best data available.

The basic method used in the estimation of employment by SIC category was the extension of a time series by regression. However, because of missing data in four categories it was necessary to use two approaches.

Employment data for four categories (19, 21, 31, and 39) were not reported in the Annual Survey of Manufacturing or were missing from either the 1958 or 1963 Census of Manufacturers. These categories combined accounted for a very small proportion of the total state employment (1.6 per cent in 1968) and the lack of data is not believed to be vital to the projections. Estimates for 1980 and 2000 for these categories were made by assuming that the per cent of the total state manufacturing employment for each of the four categories in 1968 would not change before 2000. The 1968 per cent of state total was then applied to the estimated total manufacturing employment for Michigan in 1980 and 2000.

The manufacturing employment in 1980 and 2000 for each of the remaining 17 categories was projected by a time series regression. These categories were then divided into two groups based upon the strength of the trend of the data. An R^2 of .50 was arbitrarily chosen as the breaking point between those categories exhibiting a "weak trend" and those exhibiting a "strong trend." Six of the categories had a R^2 of less than .50 (SIC 25, 26, 27, 28, 29, 32). These categories accounted for 12.9 per cent of the state total in 1968.

For these categories the assumption was again made that the 1968 per cent of state total for each category would not change before 2000. These per cents were then applied to the remaining total state manufacturing employment (that remaining after subtracting out the employment in the first four categories).

For the categories with an R^2 more than .50 the number of employees for 1980 and 2000 were estimated by means of the time series regression. When summed, these category projections totaled more than the remaining employment 85.5 per cent of the state total). These categories were then "forced" to fit the remaining total employment by adjusting them proportionally as in the estimation of county employment. The derivations of the SIC estimates and the data for the regression equations are listed in Appendix Tables 16 and 17 respectively.

Estimates of County SIC Employment

Detailed and complete employment figures for each county by SIC category are not readily available. For this report the 1968 Michigan Employment Security Commission data were utilized. In addition to county totals, data were available at the two-digit SIC category level for all 83 counties. This provided an 83 by 21 matrix for the state providing detailed information on the structure of Michigan manufacturing for a very recent period.

The 1968 data on manufacturing employment serves as a point of reference for determining future cell employment for 1980 and 2000.[1] To compute these future data the 1968 cell figures are adjusted so they conform with changes expected in total county manufacturing employment and employment in the two-digit manufacturing SIC categories for 1980 and 2000.

The first step in this process is to determine the difference between the total county employment in 1968 and that expected in 1980. If the 1968 employment is less than that expected in 1980 the 1968 total must be increased. This is done proportionally based upon the percentage of the total county employment in each of the SIC categories.

For example, imagine a county which had manufacturing employment in only four of the two-digit SIC categories.

SIC	20	25	30	35
Emp	25	75	50	50

In this case the total manufacturing employment for the county would be 200. Each of the categories would also contain a certain per cent of the total.

SIC	20	25	30	35
Emp	12.5%	37.5%	25.0%	25.0%

Imagine that the manufacturing employment in the county now increased by 100. These 100 employees must be added to

[1]A cell is defined as one SIC category in one county. Each county has 21 cells and each category 83. This provides an 83 by 21 matrix of 1,743 cells.

the county totals. This is done proportionally, based upon the per cent each of the cell employment figures was of the total county employment. In the example, the following would be added to the initial cell employment figures.

SIC	20	25	30	35
Emp	13	37	25	25

This would then make the total employment in these cells for 1968 as follows.

SIC	20	25	30	35
Emp	38	112	75	75

When this process is carried through for each of the 83 counties the sum of all the cells in each county will equal the estimated county totals for 1980.

Step two is to adjust the 1968 employment in the 21 SIC categories for each county to conform to the 1980 estimates of total county manufacturing employment. The same procedure is followed as in adjusting the county totals. If the employment for the state in SIC 20 is less in 1968 than the expected employment in 1980 the employment must be adjusted to conform to the 1980 totals. This is also done proportionally. For example, if 15 per cent of the 1968 employment in SIC 20 was found in Wayne County, then 15 per cent of the increase in SIC 20 must take place in Wayne County.

After the adjustment to correct the SIC totals is made the county totals may be off. Therefore, it is again necessary to correct for the county totals, which will probably throw the SIC totals off again. This process of employment adjustment may be completed as many times as necessary, each time reducing the amount of error between totals. For this study these adjustments were made five times. The amount of error reduction with each adjustment is shown in Table 12. The greatest reduction in error occurred with the first run, and with subsequent runs the amount of error reduction became progressively smaller.

Since the important figures are those of county employment rather than of SIC employment, the last adjustment is made so that the sum of the 21 SIC categories for each county will equal the projected 1980 employment. Again, there will probably be some error remaining in the SIC totals, but this error can be tolerated at that point where it can not be tolerated in the county totals.

The same procedure would then be followed for the year 2000, again using the 1968 Employment Security Commission data as a starting point.

The result of this adjustment process would be a second and third 83 by 21 matrix of manufacturing employment (the 21 SIC categories for each of the 83 counties).

Water Use Estimate

After the estimates of manufacturing employment were made the next step was to develop estimates of annual per capita water withdrawal per employee in each of the two-digit SIC categories and to apply these to the employment estimates.

Table 12

Error Reduction

Iteration	County Totals: Cumulative Per Cent Error	County Totals: Highest Individual Per Cent Error	SIC Totals: Cumulative Per Cent Error	SIC Totals: Highest Individual Per Cent Error
		1980		
Base	758.00	29.67	128.55	35.27
5th run	6.71	1.37	.53	.43
		2000		
Base	1422.00	98.80	221.00	37.30
5th run	7.32	1.13	.21	.09

Source of Data

The most complete data on water use by manufacturing establishments has been collected by the U.S. Bureau of the Census in connection with the 1963 Census of Manufacturers. In the census water withdrawal information was asked of all firms. Those which reported using more than 20 million gallons of water per year were asked to complete a more detailed questionnaire on their water use characteristics. These findings were presented in a special report.[1]

Developing the Coefficient

The coefficients representing water withdrawal per employee were developed by dividing the number of employees into the amount of water withdrawn. The resulting coefficients represent the annual water withdrawal per employee. To accomplish this, however, necessitated two further considerations.

Determining Employment Figures

It was not possible to utilize the employment figures reported in Water Use in Manufacturing because these represent employment only in those establishments which were large water users. If the water withdrawal coefficients were based upon this employment and then ascribed to total employment it would give undue weight to the large water users and result

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[1]U.S. Bureau of the Census, Census of Manufacturers: 1963. Subject Statistics: Water Use in Manufacturing. Washington: U.S. Government Printing Office, 1966.

in an inflated total withdrawal figure.

Since the withdrawals reported in Water Use in Manufacturing represented virtually all of the water use in manufacturing in 1963 it was possible to divide the total employment for each SIC category reported in the 1963 Census of Manufacturers into the total withdrawals for each SIC category as reported in Water Use in Manufacturing. It was then possible to apply this withdrawal coefficient to total employment without fear of over representing the larger water using industries.

Levels of Generalization

While water withdrawal data were given expressly for Michigan for only 11 of the SIC categories these account for the bulk of the water withdrawals in the state. However, the remaining types of manufacturing account for some withdrawals and must be taken into consideration if a complete picture of manufacturing demands is to be had.

The withdrawal coefficients for seven of the remaining SIC categories were developed by utilizing national data. This, essentially, results in ascribing water withdrawal characteristics for the nation as a whole to the Michigan situation in particular. While this certainly results in some misrepresentation it is felt that this is less than if these categories were ignored. Water withdrawals in three categories were considered so insignificant that they were ignored even at the national scale. Thus it was impossible to develop withdrawal coefficients for these categories. The resulting coefficients are presented in Table 13.

Compensatory Effect of Labor Productivity and Water Technology

It has been recognized in a number of studies that water use in manufacturing is more directly related to levels of output than to numbers of employees. However, the difficulty of working with physical output, because of the great variety in types of output, has generally precluded the use of this measure as a basis for estimating water use.

Data on value added by manufacturing are consistent among types of products and provide a proxy for levels of output. However, value added suffers from two important defects. The level of value added is difficult to compare from one period to another because of inflation. And because of the reluctance of firms to divulge information on levels of income it is impossible to acquire information at the county level for value added by manufacturing.

To the extent that level of employment reflects levels of output employment may be used as a proxy for output. This relationship is complicated, however, by the increasing physical output per man hour as the manufacturing industry advances technologically. Increased automation has meant that the same amount of physical output can be produced by fewer employees. For example, if there were 100 employees in a base year and productivity increases three per cent per year,

Table 13

Water Withdrawal Coefficients[a]

SIC	Water Withdrawals[b]	1963 Employment	Withdrawal Coefficient
19	-	-	-
20	16	52,472	304,924 c
21	3	77,330	38,794 d
22	148	863,246	171,445 d
23	-	-	-
24	151	563,135	268,141 d
25	3	376,548	7,967 d
26	101	28,078	3,597,122 c
27	-	-	-
28	177	33,595	5,268,641 c
29	38	2,816	13,494,318 c
30	163	414,959	392,809 d
31	1	3,454	289,519 c
32	19	17,838	1,065,141 c
33	332	81,807	4,058,332 c
34	6	86,619	69,268 c
35	6	134,256	44,690 c
36	3	32,231	93,078 c
37	86	281,870	305,105 c
38	29	305,452	94,941 d
39	13	390,760	33,268 d

[a]U.S. Bureau of the Census, Census of Manufacturers: 1963. Subject Statistics: Water Use in Manufacturing (Washington: U.S. Government Printing Office, 1966).

[b]Billion gallons

[c]Based on Michigan data

[d]Based on national data

five years hence, still with 100 employees, the production will be equal to 115 employees. The Office of Business Economics, U.S. Department of Commerce has estimated that labor productivity will continue to increase at three per cent per year.[1]

Counteracting this tendency is the process of water conservation through reuse. This effort toward water economy was discussed in Chapter V. Appendix Table 18 presents data on water recirculation for 18 of the 21 two-digit SIC categories for 1959 and 1964. It can be seen that there is not a clearly demonstrated trend in water conservation in all of the SIC categories. Of the total categories presented, 11 of them demonstrated an increase in the reuse ratio between 1959 and 1964 while seven exhibited a decrease. Nor is there an established correlation between the magnitude of the coefficient and the change in the rate of reuse. It was expected that those industries which had a higher withdrawal rate per employee would have the greatest incentive to reuse water. This was not evident, however. Some of the categories with the largest withdrawal coefficients had a decrease in the rate of reuse while categories which had a low rate of withdrawal per employee often had a significant increase in the rate of reuse.

The appears to be a concensus that there will be a

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[1]Regional Economics Division, Office of Business Economics, Preliminary Report on Economic Projections for Selected Geographic Areas, 1929 to 2020, Vol. I (Washington: Water Resources Council, 1968), p. II-12.

general increase in the tendency for water reuse in the future. The Water Resources Council has estimated that manufacturing water recirculation will increase approximately 2.3 per cent per year between 1965 and 2000.[1]

For the purpose of this research these two forces are considered to balance out, and the water use coefficients will continue to be based upon numbers of employees. Since the increase in labor productivity is greater than the increase in water recirculation this will probably result in an over estimation of the water needs in 1980 and 2000. The difficulties involved in making estimates of labor productivity specifically for Michigan and in estimating recirculation for each SIC give further credence to accepting the cancellation of these forces.

Application to Employment Figures

After the water withdrawal coefficients for each SIC category were developed it was only necessary to multiply them times the number of employees estimated for that category. This was done for each SIC category in each county. When summed, these water withdrawal figures total the estimated water withdrawal for manufacturing for each county. These counties can then be organized into the seven planning regions. The resulting estimates of water withdrawals for each region and for each type of manufacturing are presented in Chapter IX.

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[1]Water Resources Council, The Nation's Water Resources, p. 4-2-4.

CHAPTER VII

WATER WITHDRAWALS FOR POWER GENERATION[1]

Importance

Tremendous quantities of electricity are required to power the modern industrial economy of Michigan and to supply energy for domestic consumption, and from all indications this will continue to be a major concern to the state. The growth of installed generating capacity in the state for the last 25 years is indicated in Figure 12. It can be seen that there have been significant increases at each five year period. These are expected to continue into the foreseeable future. In July, 1969 Michigan had approximately 10,000,000 Kw of installed capacity; by 1990 this is expected to increase to 39,300,000 Kw.

The effect of this rapidly increasing demand for electrical power will be felt in a number of ways, not the least of which is in the demand for water. At the current level of technology approximately one-half of one gallon of water is

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[1]Unless cited otherwise the material for this chapter was obtained from conversations and correspondence with D.E. Syler, Senior Engineer, Consumer Power Company, Jackson, Michigan, and from Wayne L. Wingert, "Present and Future Power Development for the State of Michigan," Paper presented at the Governor's Conference on Thermal Pollution, Traverse City, Michigan, July 18, 1969.

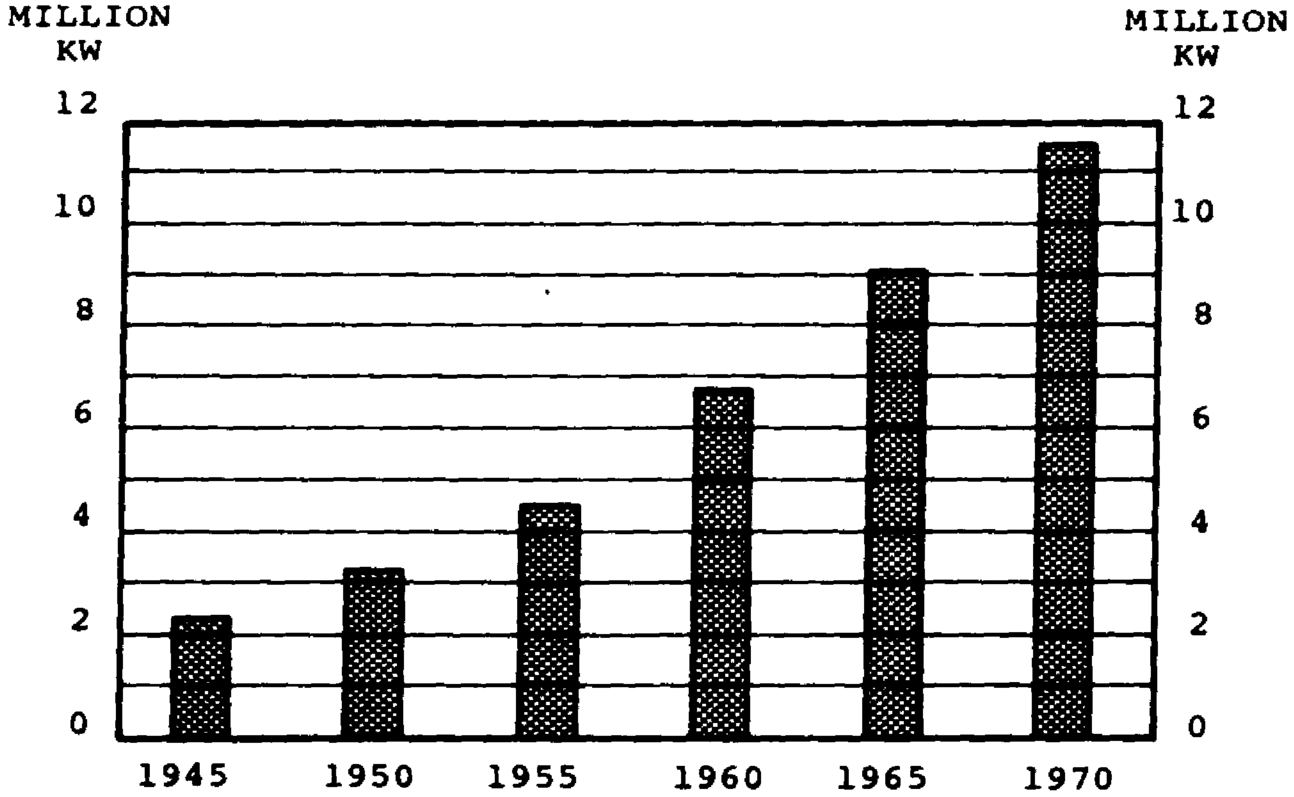

Figure 12. Installed Generating Capacity[a]

[a]Michigan Electric Power Capacity and Reliability Advisory Committee, Michigan Electric Power Capacity and Reliability 1966-1970 (Lansing, 1966), p. 17.

required for the production of each kilowatt minute of electricity.[1] At the present time this comes to about 1,656 billion gallons in 1970 and by 1990 will approach 6,507 billion gallons.

Nature of Withdrawals

The primary purpose of water used in the generation of electrical power is for cooling purposes. Very little of the water which is withdrawn for power generation (cooling) is actually consumed; reliable estimates place this at less than one tenth of one per cent. The water which is returned to the water source is unchanged in composition, the only modification being in the addition of heat. The temperature of the water is increased by 10° to 20° in the cooling process.

At the present time very little of the cooling water is recycled (cooled) and used again; most is returned as warmer water to the source. Conservationists are becoming concerned about the ecological damages which may result from the addition of warm water to the naturally cool water body, and it is possible that if these fears are real restrictions may be placed on water returns and more water will be cooled and used again. Should this happen the increased water demanded for power generation may not be as great as predicted.

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[1]This is an average figure and is a combination of nuclear and fossil fueled plants as well as plants of different ages.

Quantity Withdrawn

As stated earlier, approximately one-half of one gallon of water is required for the production of one kilowatt minute of electricity at the present time. Going on the assumption that the average 24 hour production of electricity from a plant is 63 per cent of the installed capacity, it is relatively easy to estimate the amount of withdrawals. For example, in 1990 approximately 39,300 Kw of capacity will be installed in Michigan. Therefore, (1/2) x (0.63) x (39,300,000) = 12,379,500 x (60) x (24) x (365) = 6,506,665 million gallons per year.

It should be noted that the water requirements estimated by such a method, while the best possible for such a large scale study, produce only approximate results. Mr. Syler cites four reasons for this:

1. The value of one-half of one gallon per kilowatt minute is only a "rule of thumb" figure based on an average of our present generating facilities. Future technologies may reduce this ratio.

2. With an increase in the number of hydroelectric pumped storage installations, the capacity factor of steam plants requiring cooling water would increase.

3. An increasing number of future generating plants may be internal combustion and hydroelectric pumped storage plants requiring no cooling water. Other plants may utilize a closed cycle cooling system.

4. The forecasts of future energy requirements are based upon an extrapolation from present day growth rates and could change considerably depending upon the future economic growth of the state.

Location of Withdrawals

Because of the large amounts of water required, very few of the rivers in Michigan are capable of supporting large scale electrical production. For that reason the majority of the generating capacity has been installed on the shores of the Great Lakes. Approximately 90 per cent of the installed capacity utilized water from the Great Lakes in 1969 and except for a plant in Midland County all proposed power capacity to at least 1974 will utilize Great Lakes water.

The location of major power plants in the state in 1970 is shown in Figure 13. Most of the power production takes place, as expected, in the southeastern part of the state, coinciding most closely with Region I. At the present time most of the installed capacity is fossil fueled, but increasingly the new capacity is turning to nuclear fuel.

The location of the 39,300,000 Kw of installed capacity for 1990 is not known. It is the opinion of this writer that this capacity will be installed along the shores of Lake Michigan and Lake Huron in Regions IIB and IIIB. The reasons for this belief are two. First, water of the Great Lakes are cooler in the northern parts and the problem of thermal pollution will probably not be as great. But more important is the fact that a significant proportion of this capacity may be nuclear fueled and public pressure may force the location of these plants to more sparsely settled areas of the state which certainly means outside of the southeastern part of the state.

Figure 13. Power Plant Location, 1970[a]

[a]Michigan Electric Power Capacity and Reliability Advisory Committee, Michigan Electric Power Capacity and Reliability 1966-1970 (Lansing, 1966).

CHAPTER VIII

AGRICULTURAL WATER WITHDRAWALS

Importance

Agricultural water withdrawals can be grouped into two main types, irrigation withdrawals and withdrawals required for the production of livestock. For the nation as a whole in 1965 it has been estimated that approximately 171,877 million gallons per day are withdrawn for municipal and domestic, industrial, and agricultural purposes. Of this total, agricultural withdrawals accounted for 111,259 million gallons per day, about 65 per cent of the total.[1] These figures are heavily weighted by the western states where irrigation is required for most types of agricultural production.

For the state of Michigan an almost reverse situation is presented. In 1965 it was estimated that municipal and domestic, industrial, and agricultural uses of water withdrew approximately 11,110 million gallons of water per day for the Great Lakes region. Of this total figure, however, only 154 million gallons per day, or about one per cent, were withdrawn for agricultural purposes, distributed almost equally

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[1]Water Resources Council, The Nation's Water Resources, p. 4-1.

between irrigation and livestock production.[1]

The much smaller per cent of the total withdrawal which is accounted for by agriculture in the Great Lakes area is a result of the more humid environment in which the area is located. In Michigan, average annual precipitation ranges from 26 to 44 inches[2] and is normally adequate for most of the crops commonly grown in the state. The agricultural irrigation which does occur is classified as supplementary irrigation and is used primarily to augment the natural precipitation. As a result, therefore, while the amount of irrigation water applied will vary considerably from year to year, the possibility of any agricultural production does not depend upon continuous irrigation.

Despite the fact that agricultural production in Michigan does not rely completely on irrigation as do the more arid areas of the nation, the potential for significant agricultural withdrawals is present. In 1968 there were approximately 12,670,007 acres of cropland and pasture-range in the state.[3] While only a very small per cent of this total is being irrigated at the present time, the irrigated acreage

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[1] _Ibid._, pp. 4-1-1 - 4-4-6.

[2] Lynn C. Myers and David W. Van Meer, _Michigan Statistical Abstract, 1966_ (East Lansing: Bureau of Business and Economic Research, Graduate School of Business Administration, Michigan State University, 1966), pp. 74-83.

[3] Soil Conservation Service, U.S. Department of Agriculture, _An Inventory of Michigan Soil and Water Conservation Needs_ (East Lansing: Agricultural Experiment Station, Michigan State University, 1968).

has been increasing at a very rapid rate as more and more farmers realize the potential which supplementary irrigation holds for increased production.

In addition to the water used in agriculture for irrigation, large quantities are needed for the maintenance of livestock. While the numbers of animals may be decreasing in some cases the unit withdrawal rate is not. As a result, the production of livestock will continue to place a significant demand on the state's water resources.

The purpose of this chapter, therefore, is to summarize some of the important state-wide and regional trends which may have an important influence on the amount of future water withdrawals for agricultural purposes. Because of the very rapid changes which are taking place in agriculture in Michigan any projections of future water withdrawals would serve more to indicate possible directional change and not to identify probable amcunts of withdrawals. For this reason no attempt will be made to estimate future withdrawals but merely to identify trends in those factors which may contribute to the magnitude of further withdrawals.

Land Use in Michigan

Any discussion of possible future water requirements for an area the size of the state of Michigan would be incomplete without attention being given to major changes in land use patterns. This is true for two reasons. First of all, the major types of water use which have been discussed to this point are directly affected by changes in land use throughout the state. Larger and more concentrated populations do not come about without significant alterations in land use patterns. Land which was once prime agricultural land or wooded is taken over by the higher urban and suburban land uses. And as this occurs the level of manufacturing activity normally rises causing a significant increase in water withdrawals for manufacturing purposes. For these reasons, land use changes can be viewed as indicative of changes in both the amount and composition of water withdrawals.

A second reason why it is necessary to examine land use changes is because they are directly related to water withdrawals for agricultural purposes. Changes in the extent and character of agricultural water withdrawals are reflected in changing land use patterns. As the amount of land in farms decreases, as the agricultural land under irrigation increases, and as the extent of livestock holdings decline, the amount of water used in agriculture will change, both in amount and in kind. Consequently, a discussion of agricultural water withdrawals without a discussion of the consequent land use changes would be inadequate.

This section will proceed by first examining the agricultural resource base which permits the type of agricultural production characteristic of Michigan. Attention will next be turned to the land resource history of Michigan, looking at the different periods in Michigan's development and how these have acted to alter the land use patterns. And last, the current land use pattern will be studied, giving major emphasis to how this pattern is significant to the spatial distribution of agricultural water withdrawals in the state as exhibited in the seven planning regions.

Agricultural Resource Base

The agricultural production which Michigan has realized since the middle 1800's has been possible because of the bounteous agricultural resource base which the state enjoys. As a generalization one can say that Michigan's climate, soil, and topographical characteristics permit a relatively high rate of production of a number of different types of agricultural commodities.

This is not to say that Michigan is without equal as an agricultural state; in 1964 there were 16 states which ranked higher than Michigan in value of farm products sold, one measure of agricultural importance. Nor is it meant to suggest that the state is uniform with respect to agricultural potential; in 1964 Keweenaw County, the most northerly county in the state, had less than one million dollars in farm product sales, while Huron County registered over 35.6 million dollars of farm product sales.[1]

The varied agricultural productivity exhibited is directly attributable to the agricultural resource base. In Michigan this has been composed primarily of three factors. The spatial occurrence of these factors will be briefly introduced preparatory to a discussion of overall land use changes, and changes in agricultural land use in particular, which are responsible for agricultural water use.

Climate[2]

Michigan's climate is classified as humid continental, both long and short summer. A humid continental climate is one which has an average temperature of the warmest month above 50°F and an average temperature of the coldest month below 26.6°F. The division between long and short summer is based upon the average temperature of the warmest month, above or below 71.6°F.[3] The dividing line between humid continental long and short summer climates in Michigan falls through the southern tier of counties, with 95 per cent or

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[1]U.S. Bureau of the Census, 1964 Census of Agriculture reported in K.T. Wright and D.A. Caul, Michigan's Agriculture: Its Income, Major Products, Locations, and Changes (East Lansing: Cooperative Extension Service, Michigan State University, 1967), p. 34.

[2]For a complete description of the varied character of Michigan's climate see Thomas E. Neidringhaus, "A Climatography of Michigan" (unpublished Ph.D. dissertation, Department of Geography, Michigan State University, 1964).

[3]Glenn Trewartha, An Introduction to Climate (New York: McGraw-Hill Book Co., 1954), p. 383.

of the state being of the short summer type.

As far as the agricultural potential of Michigan's climate is concerned, the two most important elements are temperature and precipitation. Other factors are important, such as the amount of sunshine, wind, and others, but their significance for agricultural production are far less than the temperature and precipitation factors.

Extremes of temperatures are not as important to Michigan agriculture as the length of time between the last killing frost in the spring and the first killing frost in the fall. This period, commonly known as the growing season, is critical because it is in this period that plant growth must take place. The average length of the growing season for the state of Michigan is shown in Figure 14. It can be seen that the longer growing seasons occur in the southern half of the Lower Peninsula. Growing seasons are generally shorter to the north and in the higher elevations. Somewhat longer growing seasons than expected occur along the shores of Lake Michigan where the prevailing winds carry moisture-laden winds from the water to the land.

In general, then, one can say that the southern half of the Lower Peninsula has temperature conditions which are best suited for agriculture and that, with exceptions resulting from proximity to large water bodies and elevation, the agricultural potential of Michigan temperature regimes decreases in the northern half of the Lower Peninsula and in

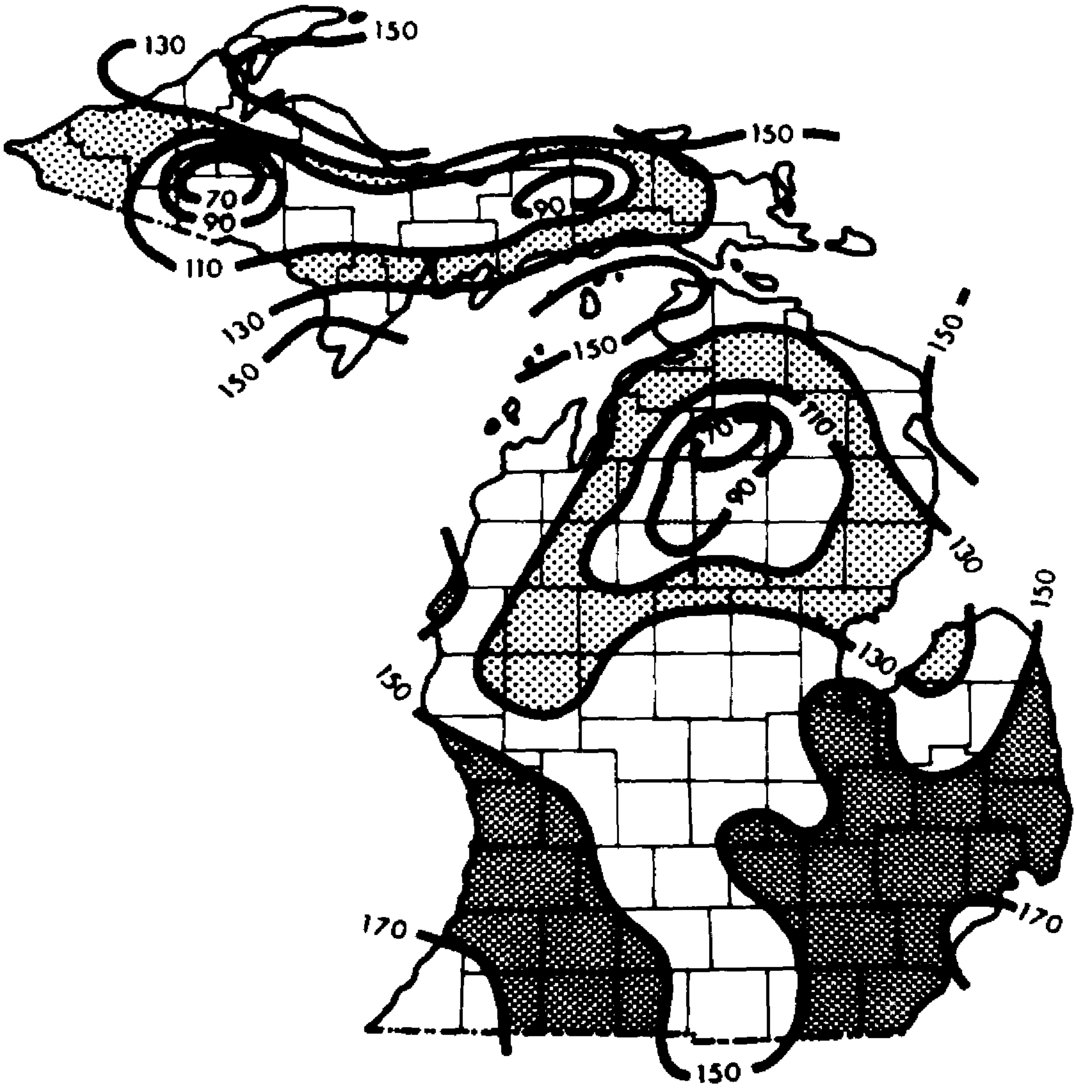

Figure 14. Length of Growing Season[a]

[a]Elton B. Hill and Russell G. Mawby, <u>Types of Farming in Michigan</u> (East Lansing: Agricultural Experiment Station, Michigan State University, 1954), p. 12.

the higher elevations of the western part of the Upper Peninsula.[1]

Precipitation totals in Michigan vary from 25 to 36 inches per year and thus are normally adequate for the type of crops which are commonly grown in the state. The distribution of the total precipitation is relatively uniform throughout the year, with a slight concentration during the spring and summer months.

While total precipitation amounts are adequate for the common Michigan crops, droughts (a period of at least two weeks during which less than 0.25 inches of rain falls in 24 hours) are a frequent occurrence during the growing season.[2] Droughts commonly occur for periods of one to three weeks but may be hidden within the monthly totals which may be normal for the year. For the farmer, however, a period of drought, even coming within a month in which precipitation totals are adequate, may be critical.

In summary, while droughts are a distinct handicap to Michigan rarely are they of such severity that they preclude any agricultural production at all; the effect is normally a reduction in the level of production. Thus, as a generalization, one can say that precipitation inadequacies pose no

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[1]There is more than a month's variation in the last freezing temperature in the spring between the southern counties and the Upper Peninsula.

[2]E.H. Kidder and R.Z. Wheaton, Supplemental Irrigation in Michigan (East Lansing: Cooperative Extension Service, Michigan State University, 1958), p. 4.

major problems for Michigan farmers throughout the state, although some areas of the state have a greater tendency for moisture deficiency than others (see Figures 2 and 3 and pages 28 and 29.

Soils[1]

It is very difficult to say anything meaningful about the soil resources of Michigan without a complete description of the soil formation process; and this is outside the scope of interest of this work. Nevertheless, a rudimentary understanding of the basic differences among the major categories of soils found in Michigan is necessary for an appreciation of the agricultural pattern exhibited in the state.

Soils are a result of the simultaneous operation of a number of factors: parent material, vegetation, climate, topography, and time. The several combinations in which these elements can occur cause there to be many different kinds of soils in Michigan, each with a somewhat different agricultural potential. The concern in this brief section will be only with the broadest classification of soils in order to explain one of the physical factors responsible for the concentration of agricultural production (and agricultural water use) in

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[1]Most of the information for this section on soils has been taken from class notes in soil science courses (soil classification and Mapping and Soil Origin and Classification) at Michigan State University. Interested readers may refer to E.P. Whiteside, I.F. Schneider, and R.L. Cook, Soils of Michigan (East Lansing: Agricultural Experiment Station and Cooperative Extension Service, Michigan State University, 1968).

the southern third of the state. As the need arises in a future section on irrigation selected aspects of soils may be discussed in greater detail.

At the great soil group level there are two categories of soils found in the state, podzols and gray-brown podzolic.[1] The division line between these two categories of soils cuts across the southern part of the Lower Peninsula, largely coinciding with the traditional Bay City-Muskegon line. The podzols are found in the northern part of the Lower and the Upper Peninsula, while the gray-brown podzolic soils are found south of the Bay City-Muskegon line.[2]

It should be recognized that both the podzol and gray-brown podzolic soils are classified as zonal (zonal soils are those which occur on well drained uplands and reflect the dominant influence of climate and vegetation). Within these broad regions there will be areas which, because of local conditions, do not conform to either podzol or gray-brown podzolic criteria.

As a rule, the soils found in the podzol area of the northern two-thirds of the state are much less fertile than

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[1]The newly developed soil classification (the Seventh Approximation) places the podzol in the spodosol class and the gray-brown podzolic in the alfisol class. Since this new classification is just starting to be used most readers will be more familiar with the older termonology.

[2]The Bay City-Muskegon line is normally considered to separate the industrial southern part of the state from the northern part of the state which has a preponderence of extensive economic activities.

those found in the southern third. For the planning regions used in this study the podzol regions coincide most closely with Regions IIB, IIIB, IV, and V. There are a number of reasons which account for the lower level of fertility. The nature of the natural vegetation is one. In the northern two-thirds of the state the natural vegetation was predominately a coniferous or mixed coniferous and deciduous forest. As the precipitation filtered through the litter from the fallen leaves and, more importantly, the needles from the coniferous trees, it produced a leaching material which tended to remove much of the nutrients from the soil. The resulting soil was commonly acidic and was usually of a lower fertility than the soils in the southern part of the state which developed under a leaf type of vegetation. The relatively sandier textured parent material found in many parts of the northern two-thirds of the state, and the generally wetter conditions (a result of lower temperatures which retards evapotranspiration) serves to accentuate the leaching action.

These conditions are lacking or are not nearly as pronounced in the southern third of the state. Here coniferous vegetation was not normally found, soils were less sandy, and the leaching less intense. Thus the fertility of the southern third of the state (largely Regions I, IIA, and IIIA) has remained higher and today supports the majority of the agricultural production in the state; in 1964 Regions I, IIA, and IIIA accounted for slightly over 82 per cent of the total farm product sales in the state (with marked concentrations in the "thumb area" and in the southeastern fruit area).[1]

Topographic Features[2]

When considered along with climate and soil conditions, topographic features do not have a major incluence on agricultural possibilities. Most of the southern third of the state has a relief which is flat to gently rolling, and poses few problems for agricultural production. Within this area there may be areas which are unusually wet and in need of drainage, and there may also be areas where local relief restricts agricultural activity; this is particularly true along the Lake Michigan shore and in prominent moraine areas. For the most part, however, topography is not a major deterrent to agricultural production in the southern third of the state.

In the northern two-thirds of the state, already restricted by a shorter growing season and generally poorer soils, there is a greater proportion of the total land area which has restricted agricultural potential because of topographic conditions. These conditions are generally hilly or rolling relief and serve to prohibit the cultivation of most row crops. This is particularly serious in parts of the

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[1] K.T. Wright and D.A. Caul, Michigan's Agriculture: Its Income, Major Products, Locations, and Changes.

[2] Information for this brief section on topography has been condensed from notes (see footnote on page 163), personal experience, and miscellaneous readings. Interested readers may refer to J.O. Veatch, Agricultural Land Classification and Land Types of Michigan (East Lansing: Agricultural Experiment Station, Michigan State University, 1941).

northern Lower Peninsula and the western half of the Upper Peninsula.

To summarize, then, the southern third of the state, relatively unincumbered either by length of growing season or soil conditions, does not exhibit topographic conditions which greatly restrict agricultural production.

Land Resource History

Upon this physical environment, represented by the critical elements of climate, soil, and landforms, Michigan has evolved from a land peopled by only Indians and an occasional fur trader to the modern industrial and agricultural state which it is today. Throughout this approximately 150 years the state has experienced a number of distinct resource development periods which represented the then current land use and economic structure of the state. This section will introduce these major periods in Michigan's development and summarize the important land use changes which have resulted.

Major Development Periods[1]

In an interesting work, Perloff and Wingo suggested that regional growth can be attributed to a region's resource

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[1]There are innumerable references to Michigan's historical development. Unless cited to the contrary source material for this section has been condensed from miscellaneous readings and from two books in particular. These are M.M. Quaife and S. Glazer, Michigan: From Primitive Wilderness to Industrial Commonwealth (New York: Prentice-Hall, Inc., 1968), and W.F. Dunbar, Michigan: A History of the Wolverine State (Grand Rapids, Michigan: William B. Eerdmans Publishing Co., 1965).

endowment which changes as the level of technology and the demand for different products changes.[1] To a great extent Michigan's development can be viewed in a like manner, progressing from a purely extractive economy to one dependent on manufacturing and tertiary activity.

Focus on Extractive Industries

For the first 300 years or so after the initial penetration by explorers of European extraction the dominant type of economic activity in the area which was to become Michigan was extractive in nature. A number of successive stages were experienced during this period, each having a place in the progression of land use changes to the pattern seen in 1970.

Fur Trading Period. The earliest type of economic activity which was carried on in Michigan was the one which had the least influence on land use. For a period of 100 years or more, and extending under the political jurisdiction of France, Britain, and the United States, pelts of beaver and other fur bearing animals provided the motivating force for the early exploration of the Michigan area. At one time or another extending over the entire state, this activity had the most minimal effect on land use.

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[1]Harvey Perloff and Lowden Wingo "Natural Resource Endowment and Regional Economic Growth," in John Friedmann and William Alonso, Regional Development and Planning (Cambridge, Massachusetts: The M.I.T. Press, 1964), pp. 215-239.

Agricultural Development in the South. With the gradual extinction of the Indian land claims land in Michigan became open to agricultural development. The direction of land clearing and settlement was from the southeast, spreading west and north. The initial focus of development centered on the southeast because the Great Lakes were the main source of entry into the Michigan area and Detroit was the main debarkation point. The importance of this focal point was so great that the price of land was determined to a great extent by distance from Detroit.

Besides access to transportation facilities, quality of agricultural land was the second most important determinant of the location of early agricultural development. The generally inferior quality of the soil in the northern two-thirds of the state was recognized at an early date and agricultural development was restricted to the southern part of the state.

This pattern of development, concentrated in the south, can be clearly seen by the dates of the establishment of the counties in the state. When Michigan achieved statehood in 1837 there were 28 organized counties. Of these, 25 were located in the southern four tiers of counties. The only northern counties to be organized were Mackinac and Chippewa in the Upper Peninsula, later divided and reduced to their present size.

Once started these agricultural developments in the southern part of the state progressed rapidly. By the latter part of the 1800's most of the timber below the Bay City-Muskegon line had been removed and the land was in agricultural production.

Development in the North. The development of the northern two-thirds of Michigan followed a dissimilar pattern from the southern third. Where in the south the initial rationale for development had, from the start, been agriculturally motivated, the development of the north was basically for timber production. One of the most romantic periods in Michigan's history, the approximately 40 years from 1860 to 1900, coincided with the most frenzied lumbering era the state (or nation) has ever experienced.

Obviously the lumber era had a tremendous affect on land use in the state. Millions of acres were cleared of merchantable timber. In some cases entire counties were denuded of white pine and other valuable species. Starting first in the Saginaw Valley area, lumbering activity spread throughout the Lower Peninsula and by the 1800's had moved across the Straits into the Upper Peninsula.

Coincident with the extraction of the timber resources of the northern two-thirds of the state was the problem of the land after the timber had been removed. Commonly known as the cutover region, large areas in Michigan (as well as in northern Wisconsin and Minnesota) were put under cultivation by farmers who were able to purchase land from timber companies who had already extracted the most valuable re-resource.[1] Thousands of acres, already cleared, appeared to await the plow. Apparently unaware of the agricultural disadvantages of the northern soils, hundreds of farmers were only too happy to oblige. As a consequence hundreds of farms and thousands of acres were placed on the agricultural roles.

It soon became apparent that these northern lands had a number of disadvantages which were not realized earlier, and that it was impossible to compete with farming areas in the southern part of the state with their longer growing seasons, better soils, and closer proximity to markets. Land abandonment on all but the better land was common. Large acreages reverted to state ownership because of non-payment of taxes. Barlowe estimates that by 1941 some 4.5 million acres had so reverted, while thousands of other acres were purchased by the federal government.[2] The agricultural production which has remained in the northern areas has been the specialty types of production in which local conditions provide selected areas with advantages in the production of particular commodities, and types of production for which a short growing season and low quality soils are not a major handicap.

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[1]By 1900 the timber industry had all but disappeared from Michigan.

[2]Raleigh Barlowe, Use of Land and Water Resources in Michigan, Report No. 52 of Project 80: Rural Michigan Now and in 1980 (East Lansing: Agricultural Experiment Station and Cooperative Extension Service, Michigan State University, 1966), p. 3.

A period of mining activity, concentrated in both iron and copper ore, began in the Upper Peninsula in the middle of the 1800's and maintained a relatively high rate of production until 1920. Since then neither copper nor iron production in Michigan has been able to compete with the higher quality ores found in the Southwest and in Minnesota, and mining has declined to a relatively insignificant activity. The actual land use changes associated with mining have not been great except in the immediate vicinity of the mines, and their relation to agricultural development and agricultural water withdrawals is insignificant.

Focus on Secondary and Tertiary Activities

Michigan is no longer a state which depends on extractive industries. While there is still some lumbering and mining which takes place, and while Michigan is still a significant agricultural producer, there are few who would classify the state as anything except industrial. This most basic change has had a very significant affect on land use patterns in the state and its affect on agricultural production in the state can not be over emphasized.

Manufacturing. The role of the automobile industry in Michigan is well known and need not be recounted here. Suffice it to say that the automobile industry has dominated the Michigan economy since the turn of the century, particularly through direct employment in the industry but also in the expansion of other industries related to the automobile industry and in the expansion of service activities supporting the industry employee.

The role of the automobile industry as a factor in water withdrawals has been covered in an earlier section. What needs to be mentioned here are the related land use changes which have influenced the agricultural withdrawals. The development of major concern has been the growth of urban and suburban populations and the consequental loss of agricultural land. The conversion of agricultural land to urban and suburban use is a common experience and there is no indication that the end is in sight. Continued decreases in agricultural land will reduce the potential for agricultural water withdrawals.

Coincident with, and indirectly related to, the growth of the manufacturing economy in Michigan has been a reduction of agricultural land use. This is in addition to the reduction as a result of urban and suburban growth, and is a result of the tremendous growth in agricultural productiveness which the United States has been able to achieve. This subject is presented here only for the sake of completeness and will be discussed more fully in a later section.

Amenities. The most recent period which Michigan has entered has been called the amenities era. The focus of attention has turned to areas of the state which can provide recreational resources. This has not been to the exclusion of areas of the state which continue to provide places of residence and employment but an addition to them. Much of the land use in the northern two-thirds of Michigan is oriented exclusively for recreational purposes. This is true of both federal and state owned land. And it is also true of much of the privately owned land.[1] Again, while a significant change in land use, the only direct relation which recreational land use has to agricultural water withdrawals is when agricultural land is withdrawn from production for recreation use.

Agricultural Land Use

As a manifestation of the major resource development periods exhibited in Michigan's history, there have been major shifts in land use patterns. The purpose of this section is to briefly examine changes in agricultural land use which have occurred in the state preparatory to examining several aspects of water use in agriculture. These major changes in agricultural land use will be considered. These are: (1) the decreasing number of farms, (2) the decreasing total acreage in farms, and (3) the increasing size of the remaining farms.

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[1]Robert L. Vertrees, "A Survey of Nonresident Landowners of Ten or More Acres in Antrim and Kalkaska Counties, Michigan," (unpublished M.A. thesis, Department of Resource Development, Michigan State University, 1967).

Decreasing Number of Farms

For the nation as a whole there are fewer farms now than there were 10 years ago, and this same trend is operating in Michigan as well. The number of farms which were in existence during the last several census periods is indicated in Table 14. It can be seen that the number of farms has declined from each census period to the next.

Table 14

Number of Farms: State Total and Regional Distribution[a]

Area	1935	1940	1945	1950	1954	1959	1964
State[b]	196.5	187.6	175.3	155.6	138.9	111.8	93.5
Region[c]							
I	17.8	18.6	18.1	18.6	18.3	18.7	18.7
IIA	37.9	37.5	37.9	38.6	39.3	40.4	40.8
IIB	12.1	12.4	11.6	11.7	11.8	10.6	10.4
IIIA	15.1	15.7	15.7	15.7	16.2	17.1	17.1
IIIB	8.9	8.5	9.1	8.7	8.7	8.4	8.5
IV	3.3	3.1	3.5	3.1	2.8	2.3	2.3
V	4.8	4.3	4.2	3.6	3.1	2.4	2.2

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1935-1964. Statistics for States and Counties, Michigan (Washington: U.S. Government Printing Office).

[b]Number of farms

[c]Per cent of state total

The number of farms expected in future years has been the subject of previous research efforts. For example, in "Project 80" an agricultural economist estimated that by 1980

Michigan would have approximately 45,000 farms.[1] This estimate was arrived at by taking a median figure between the projected 1959-64 decline in absolute numbers of farms and the projected 1959-64 percentage decline in the number of farms.[2]

It is the opinion of this researcher that the rate of decline in the future will not be as great as forecasted in "Project 80." The reason for this is that the very marginal farms which have a tendency to drop out first will do so before the less marginal farms. It is believed that we have already experienced the fastest rate of decline and that in future years the rate of decline will be less. In the future this will mean that the farms which remain in production at any one time will have a lesser tendency to drop out of production than those farms which have already dropped.

The decline in number of farms in Michigan is indicated in Table 15. This table indicates that the above discussion may be true but at least one more census period is need to give further evidence. From the 1935-40 period to

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[1]"Project 80" was a research effort by the Agricultural Experiment and Cooperative Extension Service, College of Agriculture, Michigan State University, and was designed to consider changes in rural Michigan between 1966 and 1980. To date, 16 separate reports have been published under the title "Project 80."

[2]Karl T. Wright, Economic Prospects of Farmers, Report No. 47 of Project 80: Rural Michigan Now and in 1980 (East Lansing: Agricultural Experiment Station and Cooperative Extension Service, Michigan State University, 1966), pp. 15-16.

the 1954-59 period there was an increasing rate of decline. The 1959-64 period represented a decline in the number of farms but at a slower rate of decline than during the previous periods. It is felt that this 1959-64 period represents the start of this new era.

Table 15

Loss of Farms in Michigan[a]

Period	Per Cent Decline Per Year
1959-64	3.27
1954-59	3.90
1950-54	2.68
1945-50	2.24
1940-45	1.31
1935-40	.91

[a]U.S. Bureau of the Census, Census of Agriculture: 1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office, 1967), p. 7.

The regional distribution of farms in Michigan since 1935 is shown in Table 14. An examination of this spatial distribution finds most of the farms in the southern part of the state, and a slight tendency toward an increasing concentration in this area. This change has been relatively slight, however, and the distribution is not expected to change significantly to 2000.

Land in Farms

Coincident with the decline in the number of farms has been a decline in the land in farms. Beginning immediately after World War II there started a decline in the acres of farm land which has continued to the present time. This trend is indicated in Table 16.

Table 16

Land in Farms: State Total and Regional Distribution[a]

Area	1935	1940	1945	1950	1954	1959	1964
State[b]	18.5	18.0	18.4	17.3	16.5	14.8	13.6
Region[c]							
I	16.9	20.4	17.1	16.4	16.5	17.0	17.0
IIA	36.0	43.5	35.0	35.3	35.7	37.3	37.7
IIB	14.1	17.7	14.0	14.1	13.8	12.5	11.9
IIIA	14.3	17.7	14.5	14.7	15.0	15.9	16.3
IIIB	10.9	13.0	11.2	11.2	11.1	10.7	10.6
IV	3.5	4.2	4.2	4.2	4.0	3.5	3.4
V	4.3	4.9	4.1	4.1	3.9	3.2	3.0

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1935-1964. Statistics for States and Counties, Michigan (Washington: U.S. Government Printing Office).

[b]Millions of acres

[c]Per cent of state total

The regional distribution of farm land is also presented in Table 16. Here, also, the dominance of the southern part of the state is obvious. Although there have been some changes in the regional distribution over the years this has been relatively slight except for the Upper Peninsula counties and by no means presents a clear trend.

As would be expected, the regions with the greatest proportion of the total land area in the region which is in farms are greatest in the southern regions. In 1964 Regions I, IIA, and IIA had over 71 per cent of the total land area in farms.

Farm Size

Coupled with the decreasing number of farms and total acreage in farms has been an increasing specialization and mechanization which has permitted the farmer to work ever larger units of land thus realizing economies of large scale production. Data on average farm size for the state as a whole and for the planning regions is presented in Table 17. In each instance the average size has increased over the years.

Table 17

Average Farm Size in Michigan[a]

Area	1935	1940	1945	1950	1954	1959	1964
State[b]	94	96	105	111	119	132	145
Region[b]							
I	89	88	95	97	105	116	127
IIA	91	94	102	104	112	126	138
IIB	112	115	132	138	146	163	177
IIIA	89	91	99	103	109	121	136
IIIB	125	132	144	155	166	180	196
IV	94	101	119	140	162	194	210
V	79	87	97	122	147	178	202

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1935-1964. Statistics for States and Counties, Michigan (Washington: U.S. Government Printing Office).

[b]Acres

Ironically, farms in the Upper Peninsula (Regions IV and V) are larger than those in the Lower Peninsula. This is undoubtedly because much of the farm land in the northern part of the state is used for pasture or some other use which is relatively non-intensive and which permits farmers to effectively manage larger units than if the operation was more intensive. The amount of land in farms and the amount from which crops were harvested is shown in Table 18. This data appears to substantiate the above point.

Table 18

Cropland Harvested in Michigan, 1964[a]

Area	Total Land in Farms[b]	Cropland Harvested[b]	Cropland Harvested Per Cent of Total
State	13,598,992	6,738,032	49.5
Region			
I	2,319,544	1,360,176	58.6
IIA	5,125,481	2,644,513	51.6
IIB	1,622,469	509,709	31.4
IIIA	2,219,122	1,451,219	65.4
IIIB	1,444,895	525,911	36.4
IV	456,650	122,057	26.7
V	410,831	124,447	30.3

[a]Soil Conservation Service, U.S. Department of Agriculture, Inventory of Michigan Soil and Water Conservation Needs (East Lansing: Agricultural Experiment Station, Michigan State University, 1968).

[b]Acres

Water Use in Agriculture

Water use in agriculture takes a number of forms. The use of water by the farm homestead has already been covered in a previous chapter. The remaining withdrawals which occur in agriculture are primarily those for irrigation and for the maintenance of livestock. The following two sections will deal with these two types of withdrawals.

Irrigation

Michigan is not a major irrigation state when compared to other states in the nation. However, significant water withdrawals are made for irrigation purposes and it is probable that this will continue. For this reason an understanding of the current irrigation situation in Michigan is necessary if a complete picture of water withdrawals in Michigan is to be obtained.

Importance of Irrigation in Michigan

Agricultural areas which receive, on the average, more than 20 inches of precipitation per year are considered to have sufficient moisture for growing agricultural crops without irrigation. Naturally the greatest amount of irrigation in the United States is found in the arid western states which have less than 20 inches of precipitation. However, when one examines the expansion of irrigation in recent years a major portion has been in the humid areas of the East where precipitation is normally adequate but where an occasional drought necessitates supplemental irrigation for maximum yields.

Extensive irrigation projects are a relatively new type of agricultural development in Michigan. According to the U.S. Bureau of the Census there were only 5,567 acres of cropland which were irrigated in the state in 1935,[1] the earliest year of record. It is probable, however, that irrigation in the state extends back further than 1930. The Michigan Water Resources Commission reports that in 1930 there were at least 214 irrigation systems operating in the state.[2]

The irrigated acreage in the state since 1935 is shown in Table 19. This table shows that the adoption of the practice of supplemental irrigation is largely a post World War II phenomena. There were approximately 3,000 acres irrigated in the state in 1945, a decrease of almost 50 per cent from the 1935 level. After that the growth was particularly marked. The 1950 average was almost 14,000 acres, an increase of over 300 per cent in five years. Since 1950 the irrigated acreage has almost doubled every census period except for the 1959 to 1964 period in which the increase was much less.

There have been some very real reasons for the rapid

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[1]U.S. Bureau of the Census, Census of Agriculture: 1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office, 1967), p. 7.

[2]Michigan Water Resources Commission, Water Use for Irrigation: A Survey of Water Use in Agriculture and Municipal Irrigation (Lansing, 1959), p. 1.

increase in the irrigated acreage. Listed below are some of the more important factors responsible for this trend.[1]

Table 19

Irrigated Acreage: State Total and Regional Distribution[a]

Area	1935	1940	1945	1950	1954	1959	1964
State[b]	5.6	3.0	2.9	14.0	23.5	40.2	49.0
Region[c]							
I	19.9	13.1	18.8	9.3	11.6	11.3	11.1
IIA	53.2	78.7	69.3	69.1	65.1	67.5	70.0
IIB	6.0	3.8	4.4	13.5	10.3	11.7	10.5
IIIA	20.0	3.7	6.8	2.6	8.2	5.7	5.4
IIIB	.8	.0	.1	3.0	2.2	2.1	1.4
IV	.0	.0	.6	.7	1.2	.9	.7
V	.3	.6	.0	1.9	1.4	.9	1.4

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1935-1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office).

[b]Thousands of acres

[c]Per cent of state total

1. Probably the most basic reason is the desire of farmers to eliminate weather risks in the production of farm products. This has been felt most strongly in the production of crops with a high market value potential and for which a steady supply of moisture is necessary for optimum production.

[1]Roy Huffman, Irrigation Development and Public Water Policy (New York: Ronald Press, 1953), and Max M. Tharp and C.W. Crickman, "Supplemental Irrigation in Humid Regions," in Water: 1955 Yearbook of Agriculture (Washington: U.S. Government Printing Office, 1955).

2. A second major contributor has been the reduced costs associated with the improved irrigation equipment. This is related primarily to the release of war-time developed aluminum for other than military uses. Aluminum pipe has proven to be light in weight, durable (thus requiring no special handling care), and lower priced. The development of quick-coupling devices has made sprinkling irrigation much more portable than before, allowing a minumum amount of total equipment to be used on a larger total area. And improved pumps and motors have increased the efficiency of the irrigation system.

3. The spread of information on the moisture requirements of crops and the moisture characteristics of soil has the farm operator aware of the potential which irrigation offers.

4. High product prices and resulting farm income immediately after World War II released capital for investment purposes.

5. The increase in rural electrification permitted the expansion of irrigation systems and made them much more portable thus greatly increasing their effectiveness.

Nature of Irrigation in Humid Areas

Irrigation in a humid area such as Michigan normally follows a completely different pattern than irrigation in arid lands. Although most of the following statements are addressed to irrigation in humid areas in common they apply equally well to Michigan in particular.

Need for Irrigation

The principle feature of the agricultural climate in humid areas which requires that some type of special attention be given to matters of precipitation and moisture is the frequency of short, but severe, periods of drought which occur during the growing season. These drought periods are very prevelent in Michigan; during one ten year period in Michigan there were seven periods of one to two weeks in length in which there was no rainfall registered. Few, however, extend beyond the third week.[1]

If we consider a drought to be at least a two week period in which less than 0.25 inches of rain falls during any 24 hour period then the occurrence of droughty periods are of longer duration. Kidder and Wheaton found that, for a number of locations in the central part of the Lower Peninsula, periods of drought ranging from 2 to 15 weeks were not uncommon. Records over a 20 year period indicate that a dry spell of at least a month can be expected every two years.[2]

Droughts of from one to three weeks may or may not be fatal to agricultural crops, but will normally have a deleterious affect upon the quantity and quality of yields. Four

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[1]Orson W. Israelsen, _Irrigation Principles and Practices_ (New York: John Wiley and Sons, Inc., 1950), p. 348.

[2]Kidder and Wheaton, _Supplemental Irrigation in Michigan_, p. 4.

basic measures have been suggested to counteract drought in humid areas: 1) increase the storage capacity of the soil for moisture, 2) reduce the water needs of the crops by using plants which require less water or by using farming practices which increase the efficiency of water use, 3) adjust the planting period so that the critical periods of growth will occur before the normal drought season, 4) make up the water deficiency by supplemental irrigation.[1] The latter measure has been the one to receive the greatest emphasis in Michigan as in the other humid areas of the nation.

Looking at the basic problem of uneven distribution of natural precipitation in historical perspective, there have been two basic approaches to the problem, one emphasizing the removal of excess water during periods of excessive precipitation and the other the gradual at first and then rapid adoption of irrigation measures. In chronological order the agricultural drainage programs predated the irrigation programs by several years. In the 1960 Census of Agricultural Drainage Michigan ranked third among the states in terms of land area in drainage projects.[2]

The second response to uneven distribution of natural precipitation has been through irrigation. In the humid

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[1]Huffman, Irrigation Development and Public Water Policy, p. 239.

[2]Raleigh Barlowe, Implications of Land and Water Developments in Michigan for Public Water Resource Policy (Lansing: Michigan Water Resources Commission, 1966), p. 21.

parts of the nation this has taken the form of supplemental irrigation. Supplemental irrigation is based upon the fact that even though average annual precipitation (between 25 and 36 inches in Michigan) is generally adequate for the crops which can be grown under the normal temperature conditions the available natural moisture varies considerably, both from year to year and even within any one year. Therefore, natural precipitation can not guarantee an adequate amount of moisture throughout the entire growing cycle of the crops. If this lack of moisture occurs during a critical growth period yields may be drastically reduced. For this reason it has become increasingly profitable for farmers in the humid part of the nation to add irrigation capacity to the capital improvements of the farming enterprise.

In Michigan and other humid areas this has taken the form of supplemental irrigation. Supplemental irrigation means that natural precipitation supplies the bulk of the moisture requirements for crops and any deficit is made up by the application of water through irrigation. This is a considerably different situation than that evidenced in the more arid parts of the nation where almost all types of cultivation require irrigation. In arid areas it is often natural precipitation which is supplemental and not irrigation.

Types of Irrigation

Three general methods of irrigation have been developed. These are surface, sprinkler, and subirrigation. In surface irrigation the water is conveyed to the plants by means of furrows through which the water flows and seeps into the ground where it is used by the plant. Sprinkler irrigation applies water to the crops by means of pipes and sprinklers which allow the water to fall upon the plants and soil and to then seep into the soil. In subirrigation the water table is kept sufficiently high so that the root system of the crops is kept constantly moist. In Michigan the majority of the irrigation is of the sprinkler type.

Advantages of Sprinkler Irrigation. The use of sprinkler irrigation has a number of advantages over other types of irrigation. These are summarized from a couple of sources.[1]

1. There is complete control of water at all times, permitting the irrigation of land which precludes the use of surface irrigation techniques because of possible soil erosion.

2. It is possible to apply water uniformally on all types of soils. Different textured soils have different rates of permeability and with a sprinkler system this can easily be incorporated into the irrigation scheme.

3. Marginal control of water applications is possible. If the exact water needs of the crops can be assessed with

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[1] Tyler H. Quackenbush and Dell G. Shockley, "The Use of Sprinklers for Irrigation," in Water: 1955 Yearbook of Agriculture (Washington: U.S. Government Printing Office, 1955), p. 267, and Huffman, Irrigation Development and Public Water Policy, pp. 237-238.

some accuracy these needs can be met exactly.

4. With the use of sprinkling irrigation expensive land preparation is not required. Leveling or grading may be costly or virtually impossible because of the shallowness of the soil. These problems are eliminated with irrigation done by sprinkling.

5. More land can be cropped because land which would be occupied by ditches in surface irrigation can be put into production when sprinkling is used.

6. Sprinkling irrigation permits the use of water sources of smaller quantities than does surface irrigation.

7. The application of fertilizers can be strictly controlled when applied through a sprinkler irrigation system.

8. Labor costs are substantially reduced with sprinkler irrigation. There are no ditches or ridges to be maintained, relatively inexperienced labor may be used, and irrigation can be worked into the normal scheduling of farm work so that it requires special attention only once or twice a day.

9. Potential frost damage is reduced by using sprinkler irrigation systems.

10. Less water is required than in surface irrigation. This permits either a larger amount of land to be irrigated or less cost to be incurred on a fixed quantity of land.

Disadvantages of Sprinkler Irrigation. Despite these distinct advantages there are a number of very real disadvantages to the use of sprinkler irrigation. Some of the more critical of these are listed below.[1]

1. Excessive winds may so disrupt the sprinkler patterns that certain areas receive too much water while others receive too little.

2. Water, to be used in a sprinkler system, must be free of sand and other material which may clog the jets.

3. A constant supply of water is necessary if the equipment is to be used to the maximum.

4. The initial investment in pipes, pumps, sprinkler heads, etc. is high and sufficient investment capital is necessary before a system can be installed.

5. Power requirements are relatively high and can be quite costly.

6. Very fine textured soils do not permit rapid infiltration and the fields may remain muddy for some time after the application. When the rate of application is reduced to prevent surface collection the loss by wind drift and evaporation is often excessive.

Despite these disadvantages sprinkler irrigation remains the dominant type of irrigation in Michigan; virtually

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[1] Quackenbush and Shockley, "The Use of Sprinklers for Irrigation,"p. 267, and Huffman, Irrigation Development and Public Water Policy, pp. 237-238.

100 per cent of the irrigation systems in the state are of this type.

Benefits and Costs of Supplemental Irrigation

The irrigation of agricultural crops is a rather expensive practice. Equipment purchases, installations, and operation are costly. Whether or not there will be an expansion of irrigated acreage in Michigan will depend primarily upon the question of whether or not the increased production as a result of irrigation will raise farm incomes sufficiently to cover the cost of irrigation. In this consideration there are concerns of both advantages and costs of irrigation.

Benefits. There are a number of benefits to the farming operation which have been claimed for irrigation, not all of them directly related to increasing yields through the addition of moisture. Benefits commonly cited are the following.[1]

1. Safeguards against droughts that may permanently damage or destroy agricultural crops.

2. Increased yields made possible by the addition of moisture during critical growing periods.

3. The production of higher quality products which

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[1]Tharp and Crickman, "Supplemental Irrigation in Humid Regions," pp. 256-258, and Huffman, Irrigation Development and Public Water Policy, p. 246.

can command a greater price in the market.

4. Earlier maturation which permits access to the early markets.

5. The maintenance of quality pasture conditions during dry periods.

6. An aid in the application of commercial fertilizers, insecticides, and herbicides.

7. Protection against frost damage.

8. Farmstead fire protection.

Costs. On the deficit side of the ledger there are costs which must be incurred in establishing and maintaining an irrigation system. These will vary directly with a number of factors. Some of the more important are listed below.[1]

1. The amount of land which is being irrigated.

2. The basic outlay for equipment.

3. The costs of maintenance and operation.

4. The costs involved in transferring the water from the source to the fields (normally a function of such things as nearness to the source, amount of lift required, and costs of power.

5. The type of system used.

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[1]Tharp and Crickman, Ibid.

Spatial Distribution of Irrigation in Michigan

More important for this study than the total amount of irrigation is the spatial distribution. This will be discussed under the regional framework set up for this study and under the more germane regions based upon the actual location of irrigation.

Regional Distribution

Irrigated acreage in Michigan is not distributed equally throughout the state, but is concentrated in a relatively few areas. Tabulated according to planning regions as used in this study, the distribution of irrigated acreage is presented in Table 19 (page 183). It can be seen that Region IIA has been able to maintain between 65 and 70 per cent of the total state irrigated acreage for the last 25 years. The other two dominant regions are Region I and Region IIB, each with approximately 10 per cent of the state total. The remaining regions had less than nine per cent of the state total in 1964. There does not appear to be any clearly exhibited pattern of change in any of the regions; in fact, the change has been quite erratic.

Distribution by Irrigation Districts

Tabulation by planning regions does not accurately present the complete picture of irrigated agriculture in Michigan. Certain types of crops tend to be irrigated much more than others. Since these crops tend to be grown in certain parts of the state more than in others there is a distinct concentration of irrigation in selected areas.

Irrigated Crops. According to a 1958 study conducted by the Michigan Water Resources Commission four types of crops account for the bulk of the irrigated acreage in Michigan.[1] These are: truck crops, small fruits and tree fruits, potatoes, and nurseries. These crops tend to be those which can command a relatively high price in the market and for which an adequate supply of moisture is necessary for quality production.

Certain areas of the state tend to concentrate on the production of these crops more than others. The major producing counties in the state in 1964 for each of these four types of crops are shown in Figure 15.

Irrigation Regions. A map of the major irrigated areas in the state is presented in Figure 16. This shows a very close correlation between the extent of irrigation and the acreage in the four categories of irrigated crops. Two main areas stand out on this map. The southwestern counties represent the major concentration of irrigated acreage, corresponding most closely with Region IIA of the planning regions. Irrigation in the southwest is based primarily on the production of fruits (both small fruits and tree fruits) and

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[1] Michigan Water Resources Commission, Water Use for Irrigation: A Survey of Water Use in Agriculture and Municipal Irrigation.

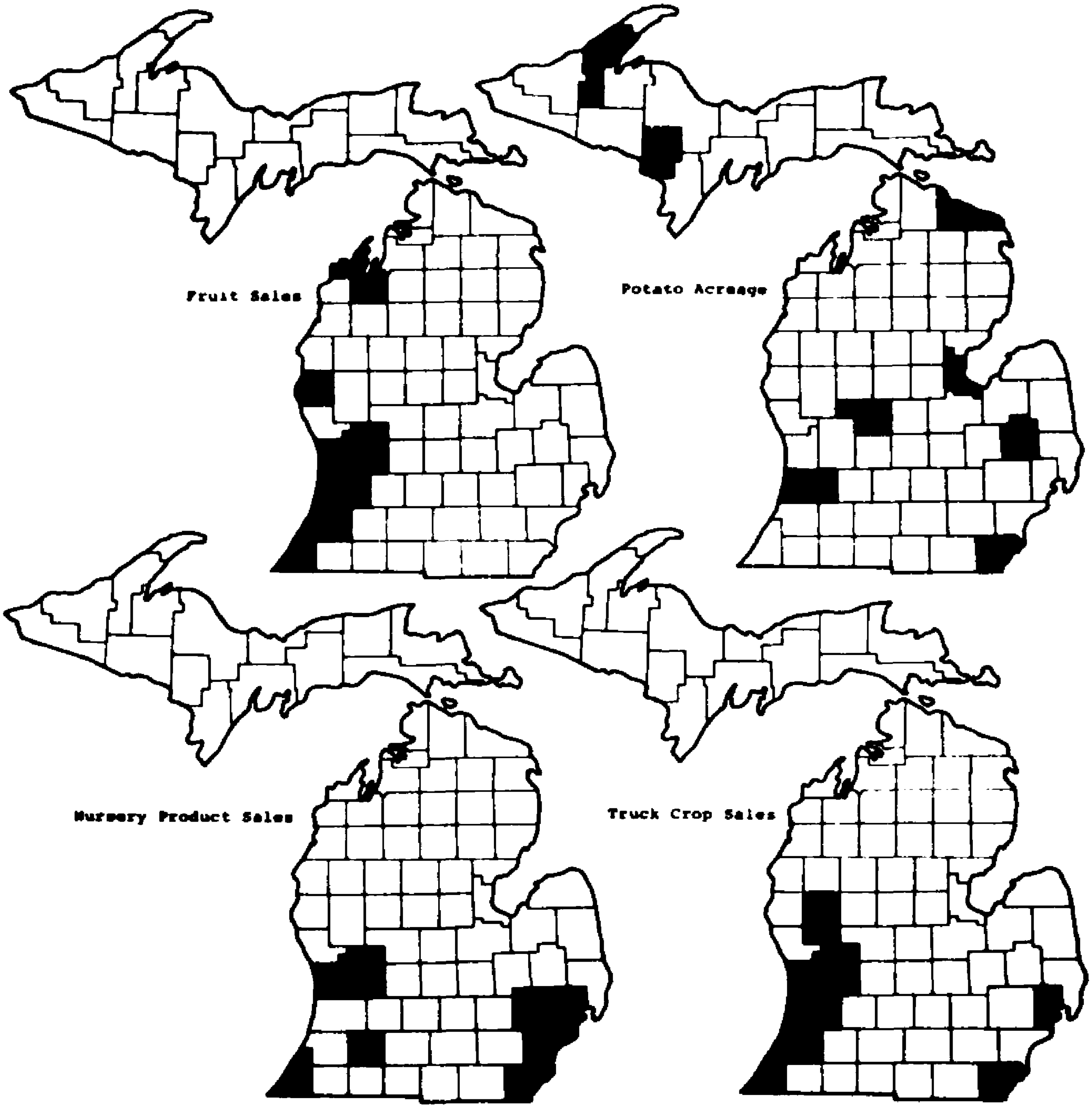

Figure 15. Major Irrigated Crops, 1964[a]

[a]K.T. Wright and D.A. Caul, Michigan's Agriculture: Its Income, Major Products, Locations, and Changes (East Lansing: Cooperative Extension Service, Michigan State University, 1967).

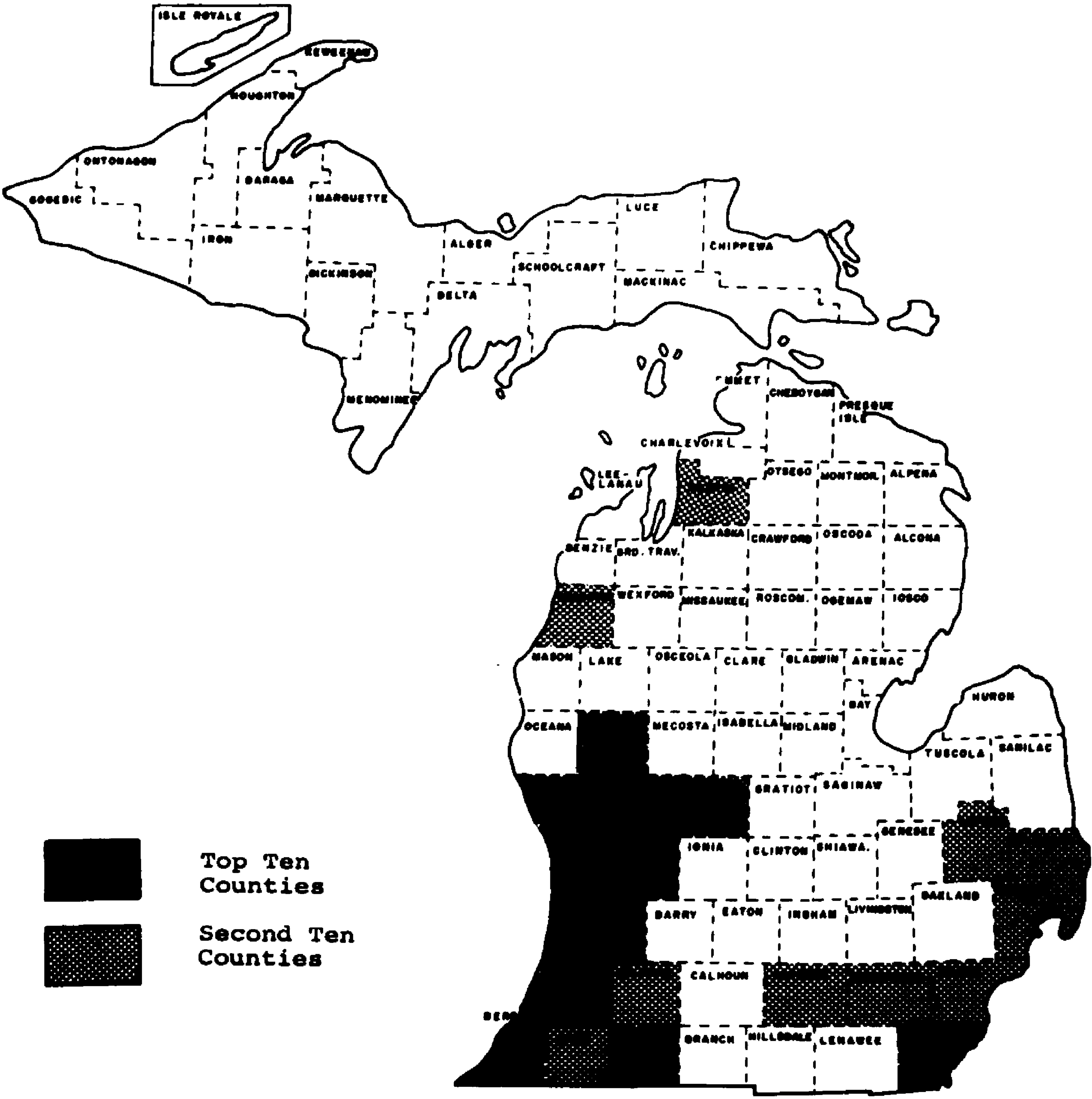

Figure 16. Irrigated Acreage, 1964[a]

[a]U.S. Bureau of the Census, Census of Agriculture: 1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office, 1967), pp. 258-265.

truck crops. A major area of irrigated potatoes is centered on Montcalm County. In the southeast the concentration of irrigation is not nearly as great; only one county is in the top ten counties based upon irrigated acreage. Truck crops, nursery products, and, to a lesser extent, potatoes are the basis for this center of irrigation.

Prospects for Future Irrigation in Michigan

The question of how much water will be needed in Michigan in future years to satisfy the demands of agricultural irrigation is the major focus of this chapter. There are so many factors which are involved that it is difficult to identify a directional trend and certainly impossible to indicate an amount of water which may be withdrawn. The purpose of this section is to identify some of the more significant factors which combined will play an important role in determining future withdrawals.

As a general rule there are five main factors which combine to determine the amount of irrigation water which will be applied to agricultural crops in any given year. These are: 1) the nature of the natural precipitation and temperature in the area, 2) the nature of the soil (such elements as slope, texture, waterholding capacity, etc.), 3) the nature and water requirements of the particular crops that are being irrigated, 4) management decisions as to the need for irrigation, the cost and availability of water, marginal returns, etc., and 5) the amount of land being irrigated.

The nature of the natural precipitation and temperature is given and is beyond the manipulation of man. That there will be periods of drought in the future is certain; the question which will determine the amount of water needed for irrigation will be the willingness of farmers to adopt the appropriate irrigation practices.

Droughts will occur on all types of soils; however, not all types of soils will receive irrigation. As suggested in an earlier chapter it is less the level of precipitation and temperature than the water in the soil which determines when irrigation is needed. Depending on a number of factors some soils, under the same precipitation and temperature conditions, will require irrigation sooner and more often than others. According to Kidder,[1] soil texture[2] is one of the most important criteria; virtually 100 per cent of the irrigated acreage in Michigan occurs on soil with a sandy, loamy sand, or sandy loam texture. It is Dr. Kidder's feeling that these three textured soils will continue to be the most heavily irrigated.[3]

It is doubtful if there will be much change in the basic water requirements of irrigated crops. The amount of

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[1] Dr. Kidder is a professor in the Department of Agricultural Engineering, Michigan State University, and is the department's expert in the field of irrigation.

[2] Soil texture refers to the relative size of the soil particles.

[3] Conversation with Dr. Kidder, July, 1969.

water necessary for optimum growth is largely determined by the physiological conditions of the plants. However, this amount of water is greater for some crops than others. For example, the average moisture use rate in inches per day for celery is 0.20 while for potatoes it is 0.30.[1] While the basic amount of water needed for the different crops will probably not change to a great extent, changes in the composition of the crops grown could have a significant effect.

Management decisions may have a very significant impact on the total water withdrawn. Ideally the application of irrigation water would be governed by the moisture content of the soil. When the moisture content dropped below a critical level a measured amount of water would be applied to bring the moisture content back to tne optimum. This ideal is seldom achieved in Michigan. Few irrigators are properly equipped or so inclined to measure changes in soil moisture content and to apply irrigation water in direct response. In actual practice water is often applied on schedule and in set amounts regardless of the soil moisture content.[2]

Probably there is a no more critical element in determining the amount of water used in agricultural irrigation

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[1]"Tentative Irrigation Guide for the Design of Sprinkler Irrigation Systems in Michigan" (College of Agriculture, Michigan State University and Soil Conservation Service, U.S. Department of Agriculture, 1954), (Mimeographed).

[2]Dr. Kidder suggests that this will probably average about eight inches per acre per year.

than the amount of land under irrigation. If one knew the amount of land under irrigation at the present time, or projections for some future date, he would be well on the way to estimating the amount of irrigation water needed. However, even the estimation of future irrigated acreage is fraught with difficulties. Aside from the problem of the rapid change in agriculture as a whole and the problems which this presents for making projections, the projection of irrigated acreage faces some problems unique to irrigation.

One of the major problems which one confronts in projecting the future of irrigation in Michigan, or in any humid area, is the incidence of drought. The adoption of irrigation practices may be accelerated considerably as a result of climate conditions. Irrigation systems are often purchased and installed based upon inadequate moisture conditions during a given year or immediately preceeding years. Once the initial investment is made in equipment these systems may be operated during periods when the natural moisture conditions, while inadequate, are not critical and would not, in themselves, cause the installation of an irrigation system. Thus there is a tendency to irrigate more acreage in subsequent years than would have been irrigated if there had not been earlier periods of drought. Therefore, in any given year, the number of irrigation systems in operation and the amount of acreage under irrigation may be related as much to natural conditions outside the realm of human manipulation as to purposely planned management practices.

A second problem which must be faced when assessing the possible future amount of irrigated acreage which may be expected in the future is the fact that with the use of portable sprinkler types of irrigation systems much larger areas of land may be potentially irrigable than is presently under irrigation. Depending on the particular year there may be several times as much land under irrigation than at other times. This will probably become more important as the irrigation systems become more portable.

There are a number of factors which may combine to restrict the future expansion of irrigation in Michigan. Two of the more important of these are related to the marginal returns which can be expected from the addition of a supplemental irrigation capacity, and the relative productivity of water used in competing purposes. Whether or not any farmer will expand his irrigation potential will depend on his assessment of the marginal returns and the cost involved in producing them. Should product prices be at a high enough level to more than compensate for the cost incurred it is very probable that the acreage under irrigation would increase. If opposite conditions prevail substantial expansion of irrigation is unlikely.

Water used in irrigation is a very consumptive use in that water is used only once and there is almost no possibility of reuse. On the otherhand, water is commonly used two or more times in the manufacturing process. This is especially important because water used for irrigation is very uneconomical when compared to industry. Even for high value crops the marginal returns per gallon of water used in agriculture can not begin to compete with the marginal return of that same gallon used in manufacturing. It has been estimated that the ratio of value added by manufacturing to value added by agriculture was about 140 to 1 for a given quantity of water used.[1]

Because of this, conflicts arising from competition between industry and agriculture for limited amounts of water will be examined carefully to insure that the benefits to be gained from allocating limited quantities of water to various uses are maximized. It is becoming increasingly clear that water resources must be plentiful to allow them to be used profitably in agriculture.

In addition, it may be necessary to restrict the amount of water withdrawn from a water source for irrigation so that the demands for water for domestic purposes, pollution abatement, etc. will remain adequate. This point has not yet been reached in Michigan, but as the competition for water becomes more intense this possibility can not be overlooked.

Despite these several hindrances to the future

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[1]Sheppard D. Powell, "Relative Economic Returns from Industrial and Agricultural Water Uses," Journal of the American Water Works Association, Vol. 48, No. 8 (August, 1956), p. 991.

expansion of irrigation in Michigan, it is undoubtedly true that the state has not yet reached the end of the growth period and that there will continue to be an expansion of irrigation; the data in Table 19 (page 183) indicates an increasing, although at a slower rate, of irrigated acreage in the state. No estimates were found of future irrigated acreage nor does this writer wish to make any; the myriad of physical, economical, and political influences would put any projection in only the realm of the possible.

As irrigated acreage does continue to expand it will probably continue to expand in the same general areas where it is now found in the greatest concentration, namely in the southwest, west central, and southeast parts of the state. It is in these parts of the state where the crops capable of producing the greatest return from irrigation have found the most favorable environment.

Livestock

In addition to water used to produce irrigated crops, the other major agricultural withdrawal is for the production and maintenance of livestock. This is a most important agricultural use of water and must be recognized in any water demand study.

The total amount of water which is used for livestock purposes is directly related to the number of animal units and the water requirements per unit.

Number of Animal Units

In terms of total number of livestock there is no clearcut increase or decrease in numbers of livestock in the state. The numbers of three major types of stock on hand in the state during several census periods are shown in Table 20. Sheep appear to be the only type of stock which exhibit any degree of consistency in trend and even here the trend is discontinuous in terms of direction of change. Of the other two, hogs show the greatest consistency in direction of change, while cattle do not appear to exhibit any degree of consistency.

In terms of other criteria than numbers of livestock the state does present a very strong directional change and this is toward a growing specialization of production with fewer farms producing larger quantities of one or a few types of stock. This is pointed out quite clearly in Table 21.

Looking at the data on number of farms in the state with any of the three types of stock, in each case there has been a decline in the number of producing farms, indicating a concentration of production in the hands of a few producers.

One might counter this point by noting that the number of total farms has been decreasing and thus one would expect that the number of farms producing any given type of stock would also be decreasing. This is true but as shown in Table 21 there has been a constant movement toward a smaller and smaller per cent of the total farms producing each type

Table 20

Number of Livestock: State Total and Regional Distribution[a]

Area	1940	1945	1950	1954	1959	1964
State[b]						
Cattle	1,541	1,955	1,696	1,839	1,610	1,725
Sheep	857	663	388	465	459	323
Hogs	586	681	690	789	968	716
Region I[c]						
Cattle	19.1	18.8	18.0	18.0	19.5	19.2
Sheep	27.0	28.9	28.9	29.2	37.7	32.9
Hogs	23.0	22.3	23.6	19.6	16.7	15.2
Region IIA[c]						
Cattle	35.0	34.9	37.0	37.1	38.5	37.9
Sheep	44.4	45.3	48.5	45.7	59.7	46.3
Hogs	46.2	49.4	51.5	56.3	62.2	65.2
Region IIB[c]						
Cattle	12.1	12.1	11.8	11.5	10.2	10.0
Sheep	4.2	3.6	4.0	6.5	7.3	5.0
Hogs	6.5	6.1	7.3	7.0	5.0	3.7
Region IIIA[c]						
Cattle	16.5	16.4	15.7	15.6	15.4	15.6
Sheep	11.0	10.5	9.0	8.2	10.2	7.1
Hogs	15.8	14.9	10.4	10.2	10.1	10.6
Region IIIB[c]						
Cattle	10.2	11.1	10.8	11.2	10.7	12.0
Sheep	12.6	10.7	8.7	9.4	11.6	8.0
Hogs	6.6	5.9	5.9	6.2	5.5	5.0
Region IV[c]						
Cattle	3.5	3.4	3.5	3.5	3.2	3.0
Sheep	.3	.3	.3	.4	.3	.1
Hogs	1.1	.9	.9	.5	.3	.2
Region V[c]						
Cattle	3.7	3.4	3.2	3.2	2.5	2.3
Sheep	.5	.6	.5	.7	.9	.6
Hogs	.7	.7	.5	.3	.2	.2

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1940-1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office).

[b]Thousands of animals

[c]Per Cent of State Total

Table 21

Livestock Specialization in Michigan[a]

Characteristic	1940	1945	1950	1954	1959	1964
			Cattle			
Farms with Cattle	148,663	136,030	114,154	96,741	67,435	54,150
Per Cent of Total	79	78	73	70	60	58
Ave. No. Per Farm	10	14	15	19	24	32
			Sheep			
Farms with Sheep	25,043	16,689	9,180	8,505	7,310	5,282
Per Cent of Total	13	10	6	6	7	6
Ave. No. Per Farm	34	40	42	55	63	61
			Hogs			
Farms with Hogs	88,768	70,303	56,023	43,256	34,257	18,266
Per Cent of Total	47	40	36	31	31	20
Ave. No. Per Farm	7	10	12	18	28	39

[a]Compiled from U.S. Bureau of the Census, Census of Agriculture: 1940-1964. Statistics for State and Counties, Michigan (Washington: U.S. Government Printing Office).

of stock. This shows that not only is production becoming more concentrated because of a fewer number of farms but that it is also becoming increasingly concentrated in the smaller number of farms which remain at each census.

One of the most outward manifestations of this growing specialization is the average number of animals per farm. This data is also presented in Table 21, and it is very clear that the number of animals per farm is increasing and will probably continue to increase into the future. It is this reason which causes the total number of livestock not to show any clear-cut decline over the years.

Spatial Distribution of Animal Units

The distribution of livestock production in Michigan is much less concentrated than is the distribution of irrigated acreage, although it still conforms to the overall agricultural picture of the state with the majority of production concentrated in the southern third.[1]

The regional distribution of the three main types of livestock for the past several census periods is shown in Table 20. It can be seen that there has been very little change in the spatial distribution of livestock production in the state over the years. Based upon this it is probable that there will be very little change in the distribution of

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[1]In 1964 over 81 per cent of the total sales from cattle, sheep, and hogs was in Regions I, IIA, and IIA which are the regions which comprise the southern third of the state.

production in the next 30 years.

A map of the sales of cattle, sheep, and hog products in Michigan in 1964 is presented in Figure 16. This further shows the concentration in the southern third of the state and also areas of concentration within that area.

Water Use in Livestock Production

Water is used in the production of livestock in a number of ways. The most obvious way in which water is used is for the body maintenance of the animal. In this use different types of animals require different amounts of water. Listed below are the water requirements for a number of livestock types.[1]

Dairy cow	3.3 gallons per pound of milk
Beef cow	10 gallons per head per day
Hogs	10 gallons per head per day
Sheep	1 gallon per head per day
Chickens	5 gallons per day per 100 birds

The above figures are only averages and will vary depending on the size of the animal, climate, and other factors.

Partly as a result of the general trend toward larger and more mechanized farming operations and partly as a means of maintaining higher sanitary standards and a better quality product, there has been a gradual adoption of new agricultural

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[1]Interview with Dr. Harlan Ritchey, Department of Animan Husbandry, Michigan State University, July, 1969.

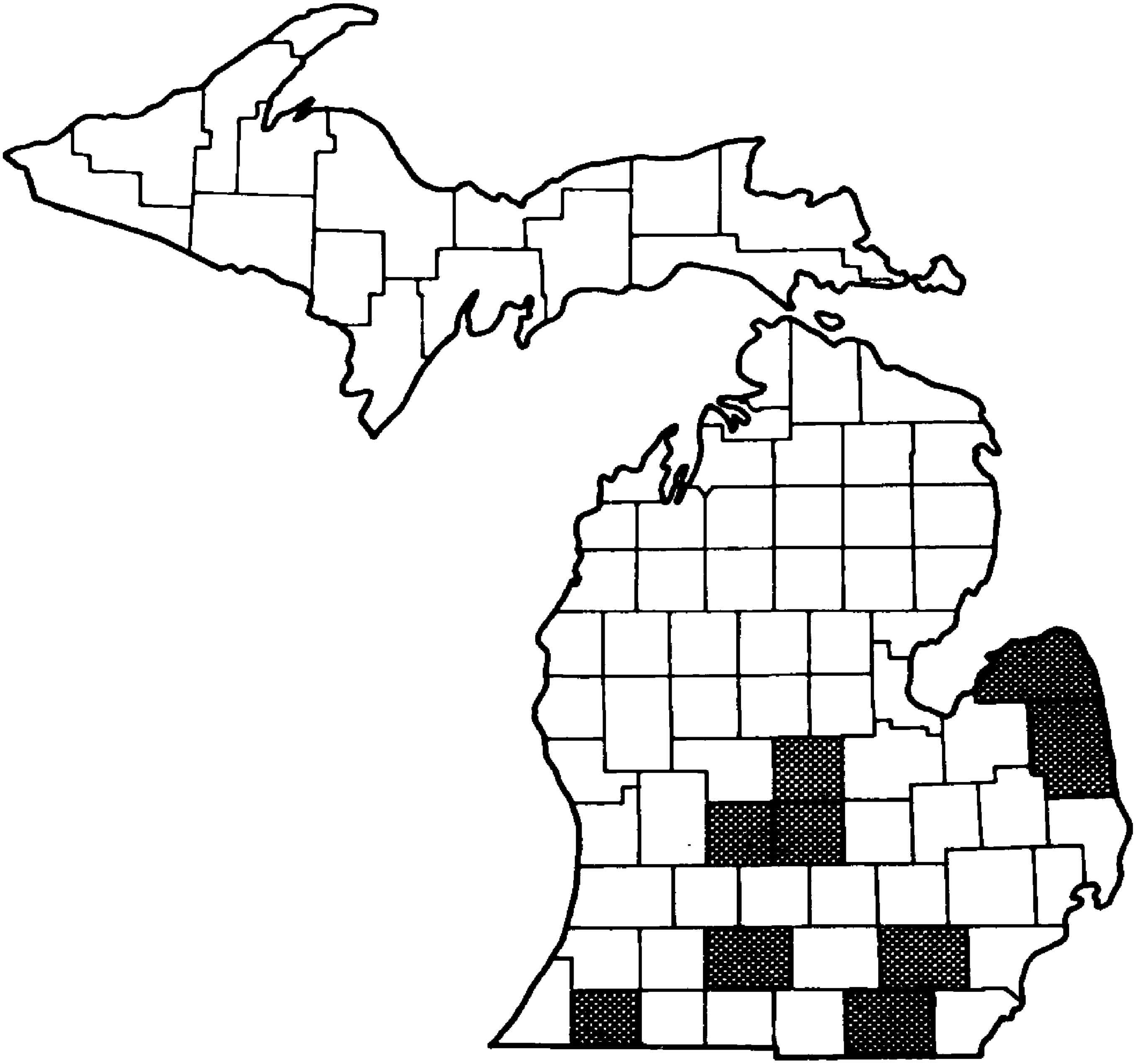

Figure 17. Major Cattle, Hog, and Sheep Producing Counties[a]

[a]K.T. Wright and D.A. Caul, Michigan's Agriculture: Its Income, Major Products, Locations, and Changes (East Lansing: Cooperative Extension Service, Michigan State University, 1967), p. 43.

equipment and processes. Many of these have resulted in a large increase in the amount of water used per livestock unit. Listed below are some of the major livestock related uses of water which might be found in Michigan today.[1] By 2000 there will undoubtedly be a number of additions to the list.

- Washing animals
- Hosing floors and ramps
- Cleaning milking equipment
- Refrigeration
- Climate control
- Liquid manure handling
- Automatic waterers
- Egg washing
- Dressing and processing

[1] C.K. Kline, "Water Systems Analysis to Meet Changing Conditions" (Agricultural Engineering Department and Cooperative Extension Service, Michigan State University, no date).

CHAPTER IX

SUMMARY, FINDINGS, AND RECOMMENDATIONS

Summary

Water availability will not be the most critical element in Michigan's future development. Although no attempt has been made to examine the water supply/demand relationships of the state, it is believed that, at least in the foreseeable future, Michigan's bounteous water resources will be sufficient to satisfy demands made upon them. This is true for water quantity only; the availability of water of a particular quality is another matter and was not an issue in this study.

While it will probably not be necessary to import water into the state the demand for water will continue to expand and will necessitate positive action on the part of the resource planners of the state if this demand is to be met in a satisfactory manner. Increased demand will most certainly necessitate the construction of new water distribution facilities. In some cases it may require that special legal, political, and economic regulations be devised to insure that future water resource action in the state proceeds in an orderly and efficient manner.

The purpose of this study is to identify what the future demands for water in Michigan may be. In this accord emphasis was placed on three aspects of expected demand.

First was the estimation of overall demand in the state. There have been a number of studies which have identified the important factors in Michigan's water demand and have rightfully concluded that these demands will increase in the future. What these studies have not done is to make a quantitative estimate of future withdrawals. Separate studies have been made for particular areas of the state, and for particular types of water uses, but none have made estimates of future water demand for the state as a whole. It is believed that this study will be a contribution to this end.

The second focus of the study was on the types of water use. Estimates of total withdrawal are useful and provide the planner with valuable information. However, much more useful are estimates which are broken down into different types of uses. Water withdrawals are made for a number of purposes. For this research four uses were considered. These were domestic, municipal, and commercial withdrawals, withdrawals for power generation, and manufacturing and agricultural withdrawals. Specifically excluded from the study were water uses for non-withdrawal purposes such as for recreation and transportation.

The third emphasis was placed on identifying the spatial occurrence of expected withdrawals. Increased amounts of water will not only be demanded in the state in the future, but will be demanded in specific areas of the state. Many times this spatial aspect of withdrawals is equally important, or more so, than the total amount of withdrawals. Citing only the total amount of withdrawal and ignoring where these withdrawals occur is analogous to saying that the river has an average depth of one foot, ignoring major holes. Consequently, this study has attempted to place the demand estimates within a spatial framework.

In some instances it was impossible to accomplish all of these goals. This was particularly true of agricultural withdrawals. The causal factors of agricultural withdrawals are identifiable but their rapidity of change places any estimates of withdrawal in the realm of the possible which certainly would not allow a great deal of confidence to be placed in them. For this reason it was necessary to be content with a discussion of directional changes in those factors responsible for agricultural withdrawals and to forego any specific estimates of withdrawals.

It was also impossible to place withdrawal estimates for power generation in a regional framework. With continued technological developments the mobility of power has increased tremendously. Thus it is now possible to transmit electrical power over relatively long distances, greatly reducing the pull to any one specific location. Therefore, estimates of water requirements for power generation were made for the state as a whole. Suggestions are made as to the general area of occurrence, but no attempt has been made to ascribe parts of the total withdrawal to specific regions.

Findings

The demands on Michigan's water resources have been large in the past and will continue to increase at least to the year 2000. The trend of water withdrawals in the state for selected uses is presented in Table 22. It is obvious that the problem of adequately meeting the state's demand for water will be increasingly important in the future.

Table 22

Summary of Michigan's Water Withdrawals[a]

Type of Use	1940	1950	1960	1980	2000
Domestic[b]	162	198	256	352	498
Manufacturing[c]	275	345	775	1,005	1,049
Power[d]	331	538	1,151	4,700	6,507[e]

[a]Billions of gallons per year.

[b]Adjusted for increased per capita consumption and for differences in municipal and non-municipal withdrawals. Includes domestic, municipal, and commercial withdrawals.

[c]Based on a per employee withdrawal rate.

[d]Computed using a withdrawal coefficient of one-half of one gallon per kilowatt minute of electricity produced.

[e]For 1990.

The following is a discussion of some of the findings in the major areas of withdrawal selected for examination in this study.

Domestic, Municipal, and Commercial Withdrawals

Water withdrawal for domestic, municipal, and commercial purposes has been a major contributor to water withdrawals in the past, and from all indications will continue to be an important use of water in the future. As technology develops, and as higher incomes give access to, larger numbers of water using devices, and as the trend toward urban and suburban living continues, the per capita withdrawal rate will increase. However, it appears that the level of population will be the most important in affecting levels of future water withdrawals in the state and among the several regions.

Estimates of water withdrawal were made by determining a per capita withdrawal coefficient and then multiplying this coefficient times the number of people expected in the state. The withdrawal coefficients were developed on a regional scale and involved a consolidation of county withdrawal rates for municipal systems. These withdrawal rates were based upon unpublished data for 1965 from the Michigan Department of Public Health with adjustments made for municipal and non-municipal systems, and for increases in the withdrawal rates over time. Existing population projections were utilized. These were projections which had been developed for state planning purposes.

The resulting estimates of regional withdrawals for domestic, municipal, and commercial purposes is presented in Table 23. It can be seen that increased withdrawals are expected to 1980 and 2000 for the state as a whole and for each of the seven planning regions. Region II will probably continue to account for the bulk of the withdrawals, approaching 58 per cent of the state total, but the dominance of Region I is expected to decline slightly. Each of the regions is expected to have an ever increasing proportion of its population served by municipal systems. In the predominately urbanized Region I this will approach 100 per cent by 2000, and will also be relatively high in the other regions as well. This will place an increasing burden on municipalities to provide adequate service.

Manufacturing Withdrawals

As one of the nation's top industrial states, Michigan has had tremendous demands placed upon its water resources by manufacturing activity. In 1963 Michigan ranked in the top ten states in terms of manufacturing employment. Between 1963 and 2000 manufacturing employment is expected to increase by over 240,000 employees. This is over 25 per cent of the 1963 totals and will be accompanied by significant increases in water demand. In 1963 Michigan accounted for somewhat over 900 billion gallons of water intake for manufacturing purposes; by 1980 this is expected to increase to 1,004.9 billion gallons and to 1,048.9 billion gallons by 2000.

Table 23

Domestic, Municipal, and Commercial Withdrawals[a]

Region	With-drawal	Per Cent of Total	Per Cent Municipal	Per Cent Non-Municipal
I				
1965	159,229.3	58.6	95.2	4.8
1980	204,469.0	58.0	96.8	3.2
2000	286,434.7	57.5	99.8	.2
IIA				
1965	59,085.0	21.7	79.3	20.7
1980	78,163.3	22.2	85.3	14.7
2000	111,490.2	22.4	91.2	8.8
IIB				
1965	6,504.8	2.4	66.2	33.8
1980	7,786.4	2.2	71.7	28.3
2000	10,527.1	2.1	79.9	20.1
IIIA				
1965	31,787.3	11.7	79.4	20.6
1980	43,467.9	12.3	84.9	15.1
2000	64,322.3	12.9	90.2	9.8
IIIB				
1965	5,574.7	2.1	73.3	26.7
1980	7,353.8	2.1	80.4	19.6
2000	10,891.3	2.2	87.3	12.7
IV				
1965	3,397.4	1.2	83.9	16.1
1980	3,723.8	1.1	87.6	12.4
2000	4,552.2	.9	93.1	6.9
V				
1965	6,248.5	2.3	82.3	17.7
1980	7,283.7	2.1	84.9	15.1
2000	9,715.2	2.0	89.5	10.5
State				
1965	271,827.0	-	88.3	11.7
1980	352,247.9	-	91.5	8.5
2000	497,933.0	-	95.7	4.3

[a]Millions of gallons

Water withdrawals for manufacturing purposes were estimated by multiplying a per employee withdrawal rate times the number of manufacturing employees expected in the state in 1980 and 2000. Because of the great diversity in manufacturing types separate withdrawal estimates were made for 18 separate manufacturing types. This resulted in a considerably more accurate estimate than if all manufacturing employees were grouped together. The basic data from which these withdrawal coefficients were developed were taken from the 1963 Census of Manufacturers report, Water Use in Manufacturing. Recognition was made of the effect of water conservation techniques (recirculation) and industrial withdrawals, but it was assumed that the compensatory effect of increased labor productivity would balance this force and the 1963 coefficients were considered to remain essentially unchanged to 1980 and 2000.

Available estimates of manufacturing employment were considered to be inadequate for this study and it was necessary to develop original estimates. These were made by disaggregating previously made estimates of total state employment, and were made for each of the 83 counties in the state. In addition, the county estimates were further stratified into 21 manufacturing types based upon unpublished Michigan Employment Security Commission data for 1968.

The results of the water withdrawal estimates for 1968 and for 1980 and 2000 are shown in Tables 24 and 25.

Table 24

Composition of Manufacturing Withdrawals by Type[a]

	1968		1980		2000	
SIC	With-drawals	Per Cent of Total	With-drawals	Per Cent of Total	With-drawals	Per Cent of Total
20	15,732.5	1.6	15,831.7	1.6	16,600.4	1.6
21	7.1	.0	7.1	.0	7.4	.0
22	594.0	.1	586.6	.1	756.1	.1
24	3,008.3	.3	3,474.0	.3	3,170.0	.3
25	176.8	.0	177.1	.0	186.3	.0
26	100,647.5	10.5	100,989.1	10.0	106,154.7	10.1
28	246,651.5	25.8	247,494.5	24.6	260,097.1	24.8
29	31,698.2	3.3	31,725.2	3.2	33,384.9	3.2
30	4,176.8	.4	10,800.6	1.1	12,064.8	1.2
31	1,221.7	.1	1,224.9	.1	1,287.8	.1
32	14,951.4	1.6	21,021.7	2.1	22,098.4	2.1
33	394,494.2	41.2	425,629.8	42.4	436,989.0	41.7
34	9,272.6	1.0	8,201.4	.8	8,586.5	.8
35	7,890.7	.8	7,312.0	.7	7,222.3	.7
36	4,357.3	.5	4,030.0	.4	4,229.7	.4
37	121,499.6	12.7	124,439.9	12.4	133,099.3	12.7
38	1,078.6	.1	1,666.8	.2	1,819.0	.2
39	329.9	.0	331.3	.0	348.2	.0

[a]Millions of gallons

Table 25

Regional Composition of Manufacturing Withdrawals[a]

Region	1967		1980		2000	
	With-drawals	Per Cent of Total	With-drawals	Per Cent of Total	With-drawals	Per Cent of Total
I	498.2	52.0	517.5	51.5	536.1	51.2
IIA	245.0	25.6	261.5	26.0	274.5	26.2
IIB	16.5	1.7	18.2	1.8	19.9	1.9
IIIA	100.0	10.4	110.8	11.0	121.5	11.6
IIIB	85.6	8.9	84.4	8.4	82.8	7.9
IV	6.6	.7	6.7	.7	7.1	.7
V	5.8	.6	5.9	.6	6.2	.6

[a]Billions of gallons

Two important points stand out. First of all, water withdrawals are highly concentrated in a relatively few industry types. In 1968 it is believed that four manufacturing types accounted for the bulk of the withdrawals. Listed in order of importance, primary metals, chemicals, transportation equipment, and the pulp and paper industry were responsible for almost 90 per cent of the withdrawals. Three of these industry types were significant water users because of the nature of the use made of the water; primary metals, chemicals, and the pulp and paper industries all had a withdrawal coefficient of over 1,000,000 gallons per employee per year. The manufacturing type with the greatest per employee withdrawal rate was the petroleum industry. But because employment in this category was so low total withdrawals were significantly less than the pulp and paper industry, the next highest category. The transportation industry was a major water user even though its per employee withdrawal coefficient was not extremely large. This was a result of the magnitude of the automotive industry in Michigan (40 per cent of the total manufacturing employment in 1968).

At the other end of the spectrum were those manufacturing types which accounted for a relatively low amount of the total withdrawals. Eleven categories account for less than one per cent of the total manufacturing withdrawal. In addition to these there were three categories whose water demands per employee were so insignificant that they were not included in the census study. These were the ordinance, apparel, and printing and publishing industries, and in 1968 accounted for only about five per cent of the state's manufacturing employment.

The distribution of withdrawals among industry types is not expected to change to any degree to 2000 (less than one per cent difference in the relative share among the 18 industries).

The regional distribution of withdrawal followed a pattern similar to that of total manufacturing. As expected, the southern part of the state dominates the manufacturing withdrawals. Region I and IIA accounted for over 77 per cent of the total (Region I itself accounts for over half of the state total). On the otherhand, three of the northern regions together accounted for only three per cent of the total state withdrawals for manufacturing.

This regional pattern of withdrawals is not expected to change significantly to 1980 and 2000. It will take particularly strong economic forces to alter the present pattern of manufacturing activity in the state and affect a relocation of water withdrawals.

Withdrawals for Power Generation

As population and manufacturing activity in Michigan continue to expand, and as modern living and industry continue to use greater numbers of technological devices, the amount of electrical energy required in the state will increase significantly. As tremendous quantities of water are required to cool the generating equipment this will mean a very large demand on the state's water resource base.

Estimates of future withdrawals for electrical power production were made by multiplying a withdrawal coefficient of one half of one gallon of water per kilowatt minute times the estimated production of electrical energy in the future. Both the withdrawal coefficient and the estimate of future power requirements were obtained from interviews and correspondence with engineers in the electrical power industry and are the most reliable estimates available.

Based upon the withdrawal coefficient of one half of one gallon of water per kilowatt minute, and an estimated production of 39 million kilowatts of installed capacity in 1990, the estimated withdrawals will be approximately 6,506,665 million gallons per year in 1990. This figure is based upon 1970 technology and future advances may alter both the withdrawal coefficient and the estimates of required power.

No attempt was made to place this withdrawal estimate within a regional framework. However, it is almost certain that most, if not all, of the new installed capacity will utilize water from the Great Lakes. It is the opinion of this writer that this will occur primarily in the northern part of the state.

Agricultural Withdrawals

When compared to the other types of withdrawals, water used for agricultural production is much less important in Michigan. Nevertheless, significant amounts of water are used in agriculture in Michigan and may possibly increase in importance in the future. The significance of total withdrawals is compounded by its spatial localization. For areas of the state where large quantities of water are demanded it matters not whether agricultural withdrawals for the state as a whole are relatively unimportant; for any one area they may be very important.

Agricultural activity is a southern Michigan phenomena. Climate and soil conditions (and to some extent topographic features) combine to form an agricultural resource base which is very limited in the northern part of the state. Consequently most of the agricultural production occurs in the southern half of the Lower Peninsula; in 1964 over 82 per cent of the value of farm products produced in Michigan came from Regions I, IIA, and IIIA, the southern three regions of the state.

Water withdrawals for agricultural production in Michigan occur for two basic reasons, for livestock maintenance and for supplemental irrigation. Irrigation in Michigan is similar to irrigation in other humid areas of the nation; natural precipitation supplies most of the needed moisture and irrigation is used to make up any deficiencies which may occur during periods of drought. In livestock production water is used in body maintenance and for other types of activities such as maintaining sanitary conditions, as an aid in feeding, and other non-essential but desirable uses.

The discussion of agricultural withdrawals differs from the previously mentioned withdrawals in that no specific estimates of withdrawals were made. The agricultural pattern in Michigan is changing so rapidly that any estimate of future withdrawals would be little better than a guess. For this reason it was decided that greater service would be provided by a summarization of trends in those activities and conditions which affect agricultural withdrawals.

The location of irrigated acreage in Michigan is concentrated in the southwest and the southeast parts of the state, with almost 70 per cent of it being found in the fruit belt of the counties in the southwest which are riparian to Lake Michigan; this area is largely coincident with Region IIA. In addition to fruits this is also an area of truck crop production which is a heavily irrigated type of production. The concentration in the southeast is largely a result of truck crops and of nursery products.

There is no one concentration of livestock production in the state outside of the concentration in the southern half of the Lower Peninsula.

Although no specific estimates of water withdrawals have been made for agriculture in Michigan a number of trends have been identified which have implications for future withdrawals. The major ones have been listed below.

1. Decreasing number of farms and land in farms throughout the state.

2. An increasing concentration of agricultural activity in the southern third of the state, especially in Regions IIA and IIIA.

3. A significant increase in the size of the farming unit and larger livestock herds.

4. Increase in irrigated acreage and an increasing concentration in Region IIA.

5. Increased tendency to make greater use of the irrigation equipment once installed, resulting in an increased application rate per acre.

6. An expanded use of water for non-essentials in the production of livestock.

These trends, and others, make it clear that agriculture in Michigan will continue to demand increasing quantities of water in the future, and that these demands will probably be relatively concentrated in a few areas.

Implications and Recommendations

The implications of this study are quite clear. Michigan will continue to require increased amounts of water to support the population and economic activity of the state. With the exception of certain areas of the state the water resource base should be adequate to satisfy the demand, but the supply/demand situation will be much more critical in some areas of the state than others.

It is the recommendation of this author that an adequately financed, three-pronged study be initiated by the Michigan Water Resources Commission to explore in depth some of the conditions presented in this study. This should be focused toward agricultural, manufacturing, and domestic, municipal, and commercial withdrawals, each type being the focus of a separate study. Typical farming units, manufacturing establishments (separated into the major SIC categories) and municipal water systems (of various size service areas) should be identified and their cooperation sought for a long range study of water withdrawals. It is felt that a ten year period should be the minimum length of time for such a study. If every attempt is made to insure that the units chosen are representative of that type of activity in the state it would be possible to make reliable generalizations to the rest of the activity.

Strict consistency should be maintained among the several areas of the state and over time. This is something very much lacking in the regional water use reports (page 10) and makes a comparison among regions of th state difficult, if not impossible.

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APPENDICES

APPENDIX TABLE 1

Sources of Michigan Population Growth[a]

Period	Population Increase	Natural Increase Per Cent	Migration Increase Per Cent	Annual Rates Births	Annual Rates Deaths
1960-1963[b]	267,000	176.7	-76.7	2.4	.9
1950-1959	1,421,500	89.5	10.5	2.7	.9
1940-1949	1,140,895	65.1	34.9	2.2	1.0
1930-1939	420,805	91.9	8.1	1.8	1.1
1920-1929	1,157,690	39.8	60.2	2.3	1.2
1910-1919	855,615	41.0	59.0	2.4	1.3
1900-1909	401,706	44.4	55.6	2.0	1.3

[a]R. Raja Indra, Michigan Population Handbook 1965 (Lansing: Michigan Department of Public Health, 1965), p. 8.

[b]Estimated

APPENDIX TABLE 2

County Population Concentration

County	1920		1940		1960		1980		2000	
	Population[b]	Per Cent[c]	Population[b]	Per Cent[c]	Population[b]	Per Cent[c]	Population[b]	Per Cent[c]	Population[b]	Per Cent[c]
Wayne	1,177.6	32.1	2,015.6	38.3	2,666.3	34.0	2,700.5	27.4	3,113.1	23.7
Oakland	90.1	2.5	254.1	4.8	690.3	8.8	1,136.4	11.5	1,678.6	12.8
Macomb	38.1	1.0	107.6	2.1	405.8	5.2	954.3	9.7	1,663.5	12.7
Genesee	125.7	3.4	227.9	4.3	374.3	4.8	554.0	5.6	790.8	6.0
Kent	183.0	5.0	246.3	4.7	363.2	4.6	459.5	4.7	592.9	4.5
Ingham	81.6	2.2	130.6	2.5	211.3	2.7	295.7	3.0	400.2	3.1
Saginaw	100.3	2.7	130.5	2.5	190.8	2.4	245.2	2.5	318.0	2.4
Washtenaw	49.5	1.3	80.8	1.5	172.4	2.2	300.4	3.0	553.7	4.2
Kalamazoo	71.2	1.9	100.1	1.9	169.7	2.2	222.1	2.3	295.4	2.3
Muskegon	62.4	1.7	94.5	1.8	150.0	1.9	171.5	1.7	210.0	1.6
Berrien	62.7	1.7	89.1	1.7	149.9	1.9	191.5	1.9	250.4	1.9
Calhoun	72.9	2.0	94.2	1.8	138.9	1.8	147.3	1.5	174.4	1.3
Jackson	72.5	2.0	93.1	1.8	132.0	1.7	141.1	1.5	175.7	1.3
St. Clair	58.0	1.6	76.2	1.5	107.2	1.4	117.1	1.2	138.2	1.1
Bay	59.5	1.9	75.0	1.4	107.0	1.4	117.3	1.2	140.3	1.1
TOTAL	2,315.1	63.1	3,815.7	72.6	6,029.0	77.1	7,757.1	78.6	10,495.3	80.0

[a]U.S. Bureau of the Census, U.S. Census of Population: 1960. Vol. I, Characteristics of the Population. Part 24, Michigan (Washington: U.S. Government Printing Office, 1963) and Donald E. Bailey, Preliminary Population Projections for Small Areas in Michigan (Lansing: State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, 1966).

[b]Thousands [c]Per cent of state total

APPENDIX TABLE 3

Comparison of Population Estimates[ab]

Source[d]	1970	1975	1980
Bureau of the Census	8,658	9,271	9,999
National Planning Association		11,615[c]	
Stanford Research Institute	9,384	10,268	11,275
Dr. David Goldberg	8,645	9,192	9,868
Michigan in the 1970's	8,891	9,494	10,204
Michigan Energy Study			10,700

[a]These estimates were compiled in State Resource Planning Division, Office of Economic Expansion, Michigan Department of Commerce, Population and Labor Force Projections for Michigan (Lansing, 1966).

[b]Thousands

[c]Estimated

[d]U.S. Bureau of the Census, Current Population Reports. Population Estimates, Series P-25, No. 301 (Washington: U.S. Government Printing Office, February 26, 1965).

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Appendix Table 4

Non-Industrial Withdrawals, United States[a][b]

	Public Systems				
Year	Domestic	Public	Commercial	Total Public	Individual Systems
2000	81	16	28	125	71
1980	77	18	28	123	58
1965	73	20	28	121	51

[a]Per Capita daily withdrawals (gallons)

[b]Water Resources Council, The Nation's Water Resources (Washington: U.S. Government Printing Office, 1968), p. 4-1-7.

Appendix Table 5

Independent Variables for Regression Model

Variable	Source[a]	R
Per cent of population which was urban, 1960	1	.11
Buying income per family, 1968	2	.09
Number of people per housing unit	3	.05
Per cent of homes in 1960 which were over $20,000 in value	3	.05
Median value of homes in 1960	3	.12
Per cent of homes heating with steam or hot water in 1960	3	.23
Per cent of homes with complete plumbing facilities in 1960	3	.01
Per cent of homes with clothes washing machines in 1960	3	.02
Per cent of homes with air conditioners in 1960	3	.05
Per cent of homes with hot and cold running water inside structure in 1960	3	.08
Per cent of homes in 1960 which were built within the last 10 years	3	.02
Number of acute care hospital beds (1968) per 1000 population (1960)	4	.20
Number of nursing home beds (1968) per 1000 population (1960)	4	.09

Appendix Table 5--Continued

Variable	Source[a]	R
Number of public school students (1968) per 1000 population (1960)	5	.02
Number of public four year college students (1968) per 1000 population (1960)	5	.09
Number of public two year college students (1968) per 1000 population (1960)	5	.33
Number of non-public college students (1968) per 1000 population (1960)	5	.07

[a]Source:

[1]U.S. Bureau of the Census, U.S. Census of Population: 1960. Vol. I, Characteristics of the Population. Part 24, Michigan (Washington: U.S. Government Printing Office, 1963).

[2]"1969 Survey of Buying Power," Sales Management, Vol. 102, No. 2 (July 10, 1969), pp. D88-D95.

[3]U.S. Bureau of the Census, U.S. Census of Housing: 1960. Vol. I, States and Small Areas. Part 5, Michigan. (Washington: U.S. Government Printing Office, 1963).

[4]Michigan Department of Public Health, Michigan State Plan, 1967-68, For Hospital and Medical Facilities Construction (Lansing, 1968).

[5]Unpublished statistics from the Michigan Department of Education, Lansing, Michigan.

Appendix Table 6

Per Capita Non-Industrial Withdrawals, 1965[a]

County	Coefficient[b]	County	Coefficient[b]
Alcona	32,000 c	Alger	35,800 c
Allegan	34,982 c	Alpena	35,974 c
Antrim	58,780 c	Arenac	28,095 c
Baraga	35,536 e	Barry	17,989 c
Bay	48,281 f	Benzie	33,333 c
Berrien	46,287 c	Branch	29,100 c
Calhoun	50,251 c	Cass	32,711 c
Charlevoix	45,541 c	Cheboygan	41,630 c
Chippewa	42,974 c	Clare	43,278 c
Clinton	27,053 c	Crawford	49,524 c
Delta	37,000 c	Dickinson	26,624 c
Eaton	39,465 c	Emmet	64,967 c
Genesee	35,500 d	Gladwin	35,692 c
Gogebic	35,500 e	Grand Traverse	62,871 c
Gratiot	29,173 c	Hillsdale	25,126 c
Houghton	35,500 e	Huron	37,244 c
Ingham	38,139 c	Ionia	40,754 c
Iosco	35,536 c	Iron	29,310 c
Isabella	24,349 c	Jackson	26,571 c
Kalamazoo	26,444 c	Kalkaska	20,526 c
Kent	38,744 c	Keweenaw	27,826 c
Lake	29,091 c	Lapeer	41,684 c
Leelanau	19,342 c	Lenawee	30,125 c
Livingston	62,174 c	Luce	46,129 c
Mackinac	57,826 c	Macomb	38,108 f
Manistee	41,709 c	Marquette	36,692 c
Mason	35,500 e	Mecosta	23,333 c
Menominee	34,561 c	Midland	48,281 f
Missaukee	27,941 c	Monroe	35,151 c
Montcalm	36,497 c	Montmorency	35,500 e
Muskegon	43,692 c	Newaygo	28,610 c
Oakland	38,108 f	Oceana	49,353 c
Ogemaw	41,538 c	Ontonagon	45,000 c
Osceola	33,333 c	Oscoda	35,500 d
Otsego	35,500 e	Ottawa	44,349 c
Presque Isle	35,500 e	Roscommon	27,777 c
Saginaw	48,281 f	St. Clair	35,500 e
St. Joseph	35,035 c	Sanilac	26,300 c
Schoolcraft	70,851 c	Shiawassee	29,997 c
Tuscola	30,256 c	Van Buren	42,631 c
Washtenaw	45,523 c	Wayne	38,108 f
Wexford	35,500 e		

Appendix Table 6--Continued

[a]Unpublished statistics from the Michigan Department of Public Health, Lansing, Michigan.

[b]Annual per capita withdrawal (gallons).

[c]Coefficient used as reported in Michigan Department of Public Health statistics.

[d]Missing data, median coefficient used

[e]Extreme data, median coefficient used

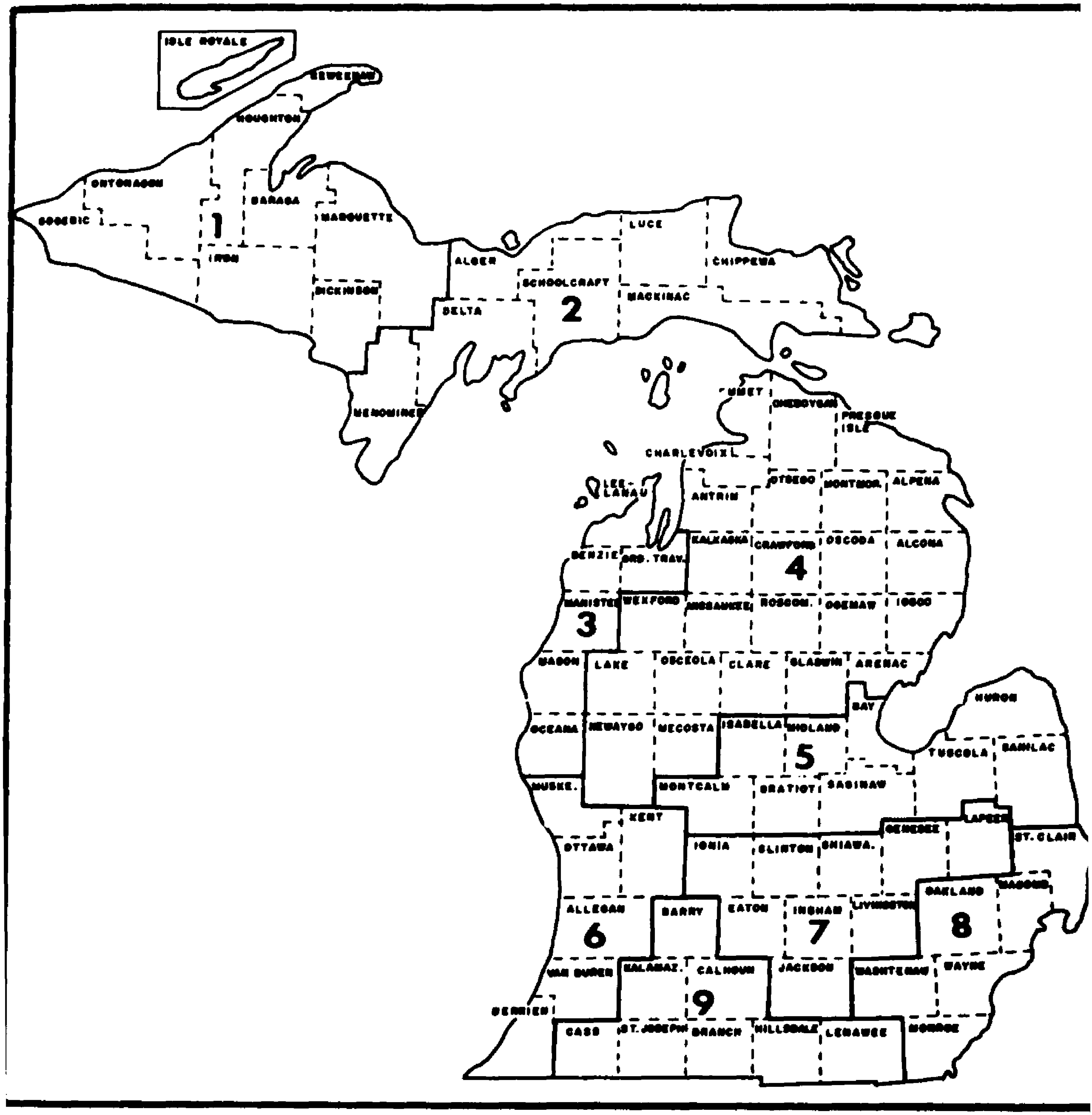
[f]Grouped data, group coefficient used

Appendix Table 7

Per Cent Served by Municipal Systems, M.D.P.H. Regions[a]

Region	1940	1960	1980	2015
1	68.2	72.0	85.2	95.0
2	42.1	53.5	52.3	88.1
3	50.1	46.1	56.9	83.8
4	36.4	37.4	61.8	92.1
5	50.8	59.0	67.6	88.5
6	62.7	60.0	71.2	89.3
7	63.1	58.1	73.1	93.8
8	91.8	89.0	92.7	97.8
9	53.4	52.4	78.9	94.5

[a]Michigan Department of Public Health, Report on Water Requirements for Municipal Use (Lansing, 1966), pp. 3-20.



Appendix Figure 1. Michigan Department of Public Health Planning Regions[a]

[a]Michigan Department of Public Health, Report on Water Requirements for Municipal Use (Lansing, 1966).

Appendix Table 8

Increase in Withdrawal Rates[ab]

Period	Public System	Individual System
1965-2000	3.31	40.00
1965-1980	1.65	13.72

[a]Computed from data reported in Water Resources Council, The Nation's Water Resources (Washington: U.S. Government Printing Office, 1968), p. 4-1-1.

[b]Per cent increase

Appendix Table 9

Manufacturing Composition, Michigan[ab]

SIC	1958	1963	1968	1980	2000
19	.4	.2	.4	.4	.4
20	7.2	6.0	4.5	4.5	4.5
21	.1	.0	.0	.0	.0
22	.3	.3	.3	.3	.4
23	1.4	1.8	1.8	2.4	2.8
24	1.4	1.4	1.0	1.1	1.0
25	2.3	2.1	1.9	1.9	1.9
26	3.4	3.2	2.4	2.4	2.4
27	3.5	3.2	2.6	2.6	2.6
28	4.4	3.8	4.1	4.1	4.1
29	.4	.3	.2	.2	.2
30	1.8	2.2	2.1	2.4	2.5
31	.6	.4	.4	.4	.4
32	2.2	2.0	1.7	1.7	1.7
33	8.5	9.3	8.5	9.1	8.9
34	9.9	9.9	11.7	10.3	10.3
35	15.6	15.3	15.5	14.3	13.4
36	3.4	3.7	4.1	3.8	3.8
37	31.6	32.1	34.9	35.6	36.2
38	1.1	1.5	1.0	1.5	1.6
39	2.1	1.3	.9	.9	.9

Appendix Table 9--Continued[ab]

[a]For Tables 9 through 12 the following conditions are applicable. The 1958 and 1963 data were taken from U.S. Bureau of the Census, Census of Manufacturers: 1958 and 1963 (Washington: U.S. Government Printing Office). The 1967/68 data were taken from unpublished statistics from the Michigan Employment Security Commission. The 1967 figures were based upon an apportionment of the 1967 monthly average for the state according to the county employment figures available for a period in 1968 (see page). Projections for 1980 and 2000 were made by the author in accordance with techniques outlined in Chapter VI.

[b]Per cent of state total.

Appendix Table 10

Regional Manufacturing Employment

Region	1958	1963	1967	1980	2000
I	513,350 58.3	551,905 57.4	644,296 58.3	662,551 57.8	694,109 57.6
IIA	222,414 25.3	245,519 25.6	278,257 25.2	288,100 25.1	301,002 25.0
IIB	14,835 1.7	18,198 1.9	20,079 1.8	22,581 2.0	24,695 2.1
IIIA	95,085 10.8	111,368 11.6	125,716 11.4	136,618 11.9	148,414 12.3
IIIB	20,040 2.3	20,830 2.2	24,043 2.2	24,849 2.2	24,849 2.1
IV	7,352 .8	6,696 .7	7,193 .7	7,193 .6	7,193 .6
V	6,947 .8	6,574 .7	5,026 .5	5,026 .4	5,026 .4

[a]24,849 absolute.
2.2 per cent of total.

Appendix Table 11

Structure of Regional Manufacturing Employment[a]

SIC	1968	1980	2000
		I	
19	.6	.6	.6
20	3.6	3.5	3.5
21	n	n	n
22	.2	.2	.2
23	2.2	3.0	3.3
24	.3	.4	.3
25	.6	.6	.6
26	1.1	1.1	1.1
27	2.4	2.4	2.4
28	3.0	3.1	3.2
29	.2	.2	.2
30	2.3	2.6	2.7
31	n	n	n
32	1.7	1.7	1.7
33	8.7	9.2	8.8
34	12.6	11.1	11.0
35	16.5	15.5	14.7
36	3.1	2.9	3.0
37	39.6	40.3	40.8
38	.7	1.2	1.3
39	.5	.6	.6
		IIA	
19	.0	.0	.0
20	6.6	6.7	6.7
21	.0	.0	.0
22	.6	.6	.8
23	1.7	2.3	2.6
24	1.2	1.5	1.3
25	5.4	5.4	5.4
26	5.5	5.5	5.5
27	3.5	3.6	3.6
28	3.3	3.4	3.5
29	.1	.1	.1
30	2.4	2.7	2.9
31	.9	.8	.8
32	2.0	2.0	2.0
33	8.6	9.4	9.3
34	11.6	10.3	10.2
35	18.2	16.5	15.3

Appendix Table 11--Continued

SIC	1968	1980	2000
36	7.3	6.6	6.5
37	17.4	18.0	18.7
38	2.1	3.1	3.2
39	1.6	1.6	1.6
		IIB	
19	.0	.0	.0
20	16.4	15.3	14.6
21	.0	.0	.0
22	n	n	n
23	2.6	3.3	3.7
24	5.2	5.8	5.3
25	3.2	3.1	3.2
26	3.1	3.0	3.0
27	3.1	3.1	3.1
28	4.0	3.8	3.8
29	.2	.2	.3
30	5.9	7.1	7.9
31	5.1	5.4	5.6
32	2.3	2.3	2.4
33	6.8	7.3	7.2
34	10.6	9.7	10.2
35	12.6	11.8	11.3
36	10.5	10.0	10.0
37	5.6	5.4	5.3
38	1.4	1.9	1.8
39	1.3	1.3	1.4
		IIIA	
19	.1	.1	.1
20	3.2	3.3	3.4
21	.0	.0	.0
22	.2	.2	.3
23	.3	.3	.4
24	.4	.4	.4
25	.7	.7	.7
26	.4	.4	.5
27	1.5	1.5	1.5
28	1.3	1.3	1.4
29	.6	.6	.6
30	.5	.6	.6
31	.3	.3	.3

Appendix Table 11--Continued

SIC	1968	1980	2000
32	.8	.8	.8
33	9.3	10.3	10.5
34	9.9	8.7	8.7
35	5.6	5.3	5.0
36	1.6	1.3	1.2
37	61.9	63.3	63.5
38	.1	.1	.1
39	.3	.3	.2
		IIIB	
19	.0	.0	.0
20	1.1	1.2	1.5
21	.0	.0	.0
22	n	n	n
23	.3	.4	.5
24	4.6	5.6	5.3
25	.3	.4	.4
26	5.2	5.5	5.6
27	2.1	2.0	2.0
28	58.2	57.0	55.5
29	.3	.3	.4
30	1.0	1.2	1.2
31	.0	.0	.0
32	4.7	4.4	4.1
33	1.4	1.6	1.7
34	5.4	5.2	6.1
35	6.8	6.6	6.6
36	1.4	1.6	2.0
37	4.3	5.0	5.7
38	n	n	n
39	3.0	2.3	1.6
		IV and V	
19	.4	.4	.4
20	8.3	7.7	7.8
21	.0	.0	.0
22	.0	.0	.0
23	2.6	2.9	3.0
24	22.6	24.8	22.0
25	7.5	7.2	7.3
26	17.5	18.3	20.1

Appendix Table 11--Continued

SIC	1968	1980	2000
27	4.7	4.3	4.3
28	.4	.4	.4
29	.0	.0	.0
30	.3	.3	.4
31	.2	.1	.1
32	2.4	2.3	2.3
33	5.5	5.4	5.3
34	.9	.8	.8
35	17.0	16.1	16.5
36	5.0	4.2	4.1
37	2.2	2.1	2.2
38	.1	.1	.1
39	2.6	2.7	2.9

[a]Per cent of total.

Letter n signifies less than one-tenth of one per cent.

Appendix Table 12

Spatial Composition of Regional Manufacturing Employment[a]

County	1958	1963	1967	1980	2000
		I			
Lenawee	10,001 2.0	10,201 1.8	13,141 2.0	13,603 2.1	14,666 2.1
Livingston	1,715 .3	2,303 .4	2,484 .4	2,795 .4	3,106 .4
Macomb	61,459 12.0	69,722 12.6	88,366 13.7	95,726 14.4	97,044 13.8
Monroe	6,151 1.2	6,837 1.2	6,864 1.1	6,875 1.0	6,825 1.0

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
Oakland	50,042	66,528	93,666	110,184	130,527
	9.8	12.1	14.5	16.6	18.5
St. Clair	7,755	9,741	9,278	9,658	10,052
	1.5	1.8	1.4	1.5	1.4
Sanilac	2,227	3,083	3,320	3,754	4,212
	.4	.6	.5	.6	.6
Washtenaw	18,009	25,827	35,214	42,089	50,228
	3.5	4.7	5.5	6.4	7.1
Wayne	355,991	357,663	391,963	377,867	377,449
	69.3	64.8	60.8	57.0	53.6
			IIA		
Allegan	3,665	3,871	4,681	4,868	5,112
	1.6	1.6	1.7	1.7	1.7
Barry	2,399	3,000	3,115	3,309	3,498
	1.1	1.2	1.1	1.1	1.2
Berrien	20,714	23,533	26,291	27,435	28,751
	9.3	9.6	9.5	9.5	9.6
Branch	2,844	3,276	3,214	3,247	3,229
	1.3	1.3	1.2	1.1	1.1
Calhoun	20,551	19,407	20,080	18,248	16,922
	9.2	7.9	7.2	6.3	5.6
Cass	2,174	2,655	3,071	3,331	3,626
	1.0	1.1	1.1	1.2	1.2
Clinton	811	914	524	483	447
	.4	.4	.2	.2	.1
Eaton	1,978	2,279	2,732	2,925	3,161
	.9	.9	1.0	1.0	1.1
Hillsdale	1,921	2,468	2,959	3,334	3,711
	.9	1.0	1.1	1.2	1.2

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
Ingham	22,910 10.3	25,188 10.3	33,578 12.1	36,510 12.7	40,147 13.3
Ionia	3,799 1.7	3,894 1.6	3,310 1.2	2,995 1.0	2,825 1.0
Jackson	14,902 6.7	16,501 6.7	19,521 7.0	20,492 7.1	21,734 7.2
Kalamazoo	25,063 11.3	25,884 10.5	29,151 10.5	28,963 10.1	29,234 9.7
Kent	44,468 20.0	50,090 20.4	58,287 21.0	61,440 21.3	65,136 21.3
Montcalm	3,452 1.6	3,966 1.6	6,282 2.3	7,260 2.5	8,418 2.8
Muskegon	23,504 10.6	25,103 10.2	25,883 9.3	25,351 8.8	24,900 8.3
Ottawa	12,012 5.4	14,512 5.9	15,748 5.7	16,771 5.8	17,788 5.9
St. Joseph	7,375 3.3	8,590 3.5	8,650 3.1	8,792 3.1	8,921 3.0
Shiawassee	4,158 1.9	5,429 2.2	6,321 2.3	7,097 2.5	7,877 2.6
Van Buren	3,714 1.7	4,959 2.0	4,859 1.7	5,249 1.8	5,565 1.8
		IIB			
Antrim	711 4.8	965 5.3	1,028 5.1	1,226 5.4	1,340 5.4
Benzie	432 2.9	483 2.7	535 2.7	581 2.6	610 2.5
Charlevoix	912 6.1	1,490 8.2	1,702 8.5	2,120 9.4	2,467 10.0

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
Emmet	656 4.4	933 5.1	846 4.2	949 4.2	1,016 4.1
Grand Traverse	2,082 14.0	2,291 12.6	3,015 15.0	3,379 15.0	3,740 15.1
Kalkaska	107 .7	126 .7	224 1.1	228 1.0	314 1.3
Lake	38 .3	41 .2	163 .8	181 .8	250 1.0
Leelanau	229 1.5	195 1.1	118 .6	114 .5	111 .4
Manistee	1,871 12.6	2,533 13.9	2,511 12.5	2,853 12.6	3,078 12.4
Mason	1,899 12.8	2,358 13.0	2,169 12.5	2,290 10.1	2,341 9.5
Mecosta	1,003 6.8	1,267 7.0	1,604 8.0	1,886 8.3	2,134 8.6
Missaukee	22 .1	27 .1	38 .2	19 .2	21 .2
Newaygo	1,826 12.3	1,758 9.7	1,814 9.0	1,733 7.7	1,654 6.7
Oceana	487 3.3	434 2.4	263 1.3	254 1.1	242 1.0
Osceola	947 6.4	1,417 7.8	2,052 10.2	2,607 11.5	3,098 12.5
Roscommon	116 .8	139 .8	188 .9	252 1.1	275 1.1
Wexford	1,497 10.1	1,741 9.6	1,809 9.0	1,909 8.4	2,002 8.1

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
		IIIA			
Bay	9,315	9,630	10,290	10,257	10,360
	9.8	8.6	8.2	7.5	7.0
Genesee	57,536	66,918	76,459	83,102	90,437
	60.5	60.1	60.8	60.8	60.9
Gratiot	2,970	3,657	3,345	3,482	3,551
	3.1	3.3	2.7	2.5	2.4
Huron	1,428	1,362	1,684	1,673	1,749
	1.5	1.2	1.3	1.2	1.2
Lapeer	1,151	1,957	1,830	2,241	2,541
	1.2	1.8	1.5	1.6	1.7
Saginaw	21,201	25,771	29,793	33,146	36,694
	22.3	23.1	23.7	24.3	24.7
Tuscola	1,484	2,073	2,315	2,717	3,082
	1.6	1.9	1.8	2.0	2.1
		IIIB			
Alcona	84	193	319	399	487
	.4	.9	1.3	1.6	2.0
Alpena	3,451	2,908	2,525	2,322	2,032
	17.3	14.0	10.5	9.3	8.2
Arenac	200	231	259	236	248
	1.0	1.1	1.1	1.0	1.0
Cheboygan	325	463	1,010	1,263	1,404
	1.6	2.2	4.2	5.1	5.7
Clare	408	672	1,073	1,334	1,551
	2.0	3.2	4.5	5.4	6.2
Crawford	294	268	799	617	416
	1.5	1.3	3.3	2.5	1.7
Gladwin	58	152	330	482	578
	.3	.7	1.4	1.9	2.3

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
Iosco	482	506	577	565	551
	2.4	2.4	2.4	2.3	2.2
Isabella	716	535	555	502	688
	3.6	2.6	2.3	2.0	2.8
Midland	13,004	13,843	14,793	14,983	14,538
	64.9	66.5	61.5	60.3	58.5
Montmorency	74	114	353	499	591
	.4	.5	1.5	2.0	2.4
Ogemaw	289	340	468	532	567
	1.4	1.6	1.9	2.1	2.3
Oscoda	80	36	92	82	78
	.4	.2	.4	.3	.3
Otsego	371	439	755	910	1,012
	1.9	2.1	3.1	3.7	4.1
Presque Isle	204	130	135	123	108
	1.0	.6	.6	.5	.4
			IV and V		
Alger	906	794	674	629	576
	6.3	6.0	5.5	5.1	4.7
Baraga	229	663	710	989	1,259
	1.6	5.0	5.8	8.1	10.3
Chippewa	775	580	247	231	211
	5.4	4.4	2.0	1.9	1.7
Delta	2,174	2,337	2,546	2,680	2,777
	15.2	17.6	20.8	21.9	22.7
Dickinson	1,951	986	1,231	1,062	993
	13.6	7.4	10.1	8.7	8.1
Gogebic	795	713	857	786	763
	5.6	5.4	7.0	6.4	6.2

Appendix Table 12--Continued

County	1958	1963	1967	1980	2000
Houghton	1,293	1,091	726	678	621
	9.0	8.2	5.9	5.5	5.1
Iron	229	608	254	364	372
	1.6	4.6	2.1	3.0	3.0
Keweenaw	115	113	100	94	86
	.8	.9	.8	.8	.7
Luce	177	203	149	139	128
	1.2	1.5	1.2	1.1	1.0
Mackinac	84	93	56	54	50
	.6	.7	.5	.4	.4
Marquette	2,223	1,761	1,111	1,035	950
	15.5	13.3	9.1	8.5	7.8
Menominee	2,573	2,345	2,830	2,770	2,757
	18.0	17.7	23.2	22.7	22.6
Ontonagon	434	656	452	445	432
	3.0	4.9	3.7	3.6	3.5
Schoolcraft	341	327	276	263	244
	2.4	2.5	2.3	2.2	2.0

[a]263 absolute.
2.2 per cent of total.

Appendix Table 13

Manufacturing Employment as a Proportion of Total Employment[a]

Year	Proportion	Year	Proportion
1968	.32	1962	.34
1967	.34	1961	.33
1966	.36	1960	.35
1965	.35	1959	.35
1964	.35	1958	.34
1963	.35	1957	.37

[a]Unpublished statistics from the Michigan Employment Security Commission, Lansing, Michigan.

Appendix Table 14

Regression Coefficients for Lower Peninsula Regions

Region	Constant	Regression Coefficient	Correlation Coefficient
I	-23,093,986	16,646	.94
IIA	-13,836,324	7,178	.97
IIB	- 1,279,273	661	.99
IIIA	- 7,465,795	3,861	.99
IIIB	- 1,003,640	523	.90

Appendix Table 15

Regression Coefficients for Counties

County	Constant	Regression Coefficient	Correlation Coefficient
Alcona	- 50,702	26	.99
Allegan	- 212,142	110	.92
Antrim	- 69,481	36	.96
Arenac	- 12,608	7	.99
Baraga	- 107,043	55	.93
Barry	- 156,781	81	.95
Bay	- 199,682	107	.97
Benzie	- 21,878	11	.99
Berrien	-1,190,072	618	.99
Branch	- 81,428	43	.83
Cass	- 192,909	100	.99
Charlevoix	- 173,148	89	.98
Cheboygan	- 144,879	74	.92
Clare	- 142,605	73	.98
Crawford	- 104,742	54	.81
Delta	- 78,069	41	.99
Eaton	- 160,410	83	.98
Emmet	- 43,381	23	.72
Genesee	-4,038,948	2,092	.99
Gladwin	- 58,217	30	.97
Gogebic	- 10,859	6	.37
Grand Traverse	- 196,024	101	.93
Gratiot	- 86,154	46	.60
Hillsdale	- 223,643	115	.99
Huron	- 50,986	28	.71
Ingham	-2,242,997	1,157	.93
Iosco	- 19,732	10	.94
Iron	- 10,962	6	.12
Jackson	- 976,213	506	.97
Kalamazoo	- 841,459	442	.92
Kalkaska	- 24,622	13	.91
Kent	-2,928,928	1,518	.98
Lake	- 26,110	13	.84
Lapeer	- 153,324	79	.82
Lenawee	- 634,131	329	.85
Livingston	- 168,118	87	.97
Macomb	-5,688,791	2,936	.96
Manistee	- 141,775	73	.88
Mason	- 61,709	32	.64
Mecosta	- 128,647	66	.99
Midland	- 373,345	197	.99
Misaukee	- 3,398	2	.96
Monroe	- 153,759	82	.91
Montcalm	- 595,976	306	.91

Appendix Table 15--Continued

County	Constant	Regression Coefficient	Correlation Coefficient
Montmorency	- 58,812	30	.90
Muskegon	- 500,309	268	.99
Oakland	-9,319,868	4,784	.98
Ogemaw	- 37,890	19	.95
Ontonagon	- 6,822	4	.14
Osceola	- 237,185	122	.99
Oscoda	- 1,732	1	.14
Otsego	- 80,881	41	.91
Ottawa	- 808,175	419	.99
Roscommon	- 15,280	8	.96
Saginaw	-1,844,833	953	.99
St. Clair	- 341,766	179	.78
St. Joseph	- 278,617	146	.91
Sanilac	- 239,480	123	.97
Shiawassee	- 467,925	241	.99
Tuscola	- 181,311	93	.98
Van Buren	- 255,397	132	.86
Washtenaw	-3,698,068	1,898	.99
Wayne	-7,179,912	3,846	.85
Wexford	- 67,494	35	.96

Appendix Table 16

Derivation of State SIC Projections

SIC	R^2	Deri-vation	SIC	R^2	Deri-ation
19		a	30	.91	c
20	.83	c	31		a
21		a	32	.44	b
22	.79	c	33	.84	c
23	.92	c	34	.74	c
24	.51	c	35	.68	c
25	.15	b	36	.52	c
26	.37	b	37	.76	c
27	.14	b	38	.60	c
28	.03	b	39		a
29	.03	b			

a Missing data, taken at 1968 proportion

b Weak trend, taken at 1968 proportion

c Strong trend, time series regression, proportional deflation

Appendix Table 17

Regression Coefficients for State SIC Employment

SIC	Constant	Regression Coefficient	Correlation Coefficient
20	2,167,209	- 1,706	.91
22	- 235,234	121	.88
23	- 2,293,174	1,176	.95
24	- 415,205	217	.71
30	- 1,861,958	958	.95
33	- 5,448,579	2,818	.91
34	- 6,571,920	3,395	.86
35	- 7,385,764	3,834	.82
36	- 2,422,061	1,251	.72
37	-24,240,613	12,503	.87
38	- 1,110,291	571	.77

Appendix Table 18

Water Recirculation[a]

SIC	1964 Total Water Intake[b]	1964 Gross Water Used[b]	1964 Reuse Ratio	1959 Total Water Intake[b]	1959 Gross Water Used[b]	1959 Reuse Ratio	Per Cent Change Reuse Ratio 1959-1964
20	16	23	1.43	12	19	1.58	- 9.49 c
21	3	19	6.33	3	44	14.66	-56.82 d
22	148	311	2.10	135	182	1.34	+56.71 d
24	151	217	1.43	140	184	1.31	+ 9.16 d
25	3	4	1.33	3	4	1.33	.00 d
26	101	243	3.19	95	244	2.56	+24.60 c
28	177	215	1.21	241	278	1.15	+ 5.21 c
29	38	79	2.07	18	38	2.11	- 1.89 c
30	163	336	2.06	127	218	1.71	+20.46 d
31	16	18	1.12	12	14	1.16	- 3.44 c
32	19	24	1.26	64	68	1.06	+18.86 c
33	332	475	1.43	257	375	1.45	- 1.37 c
34	6	10	1.66	6	7	1.16	+43.10 c
35	6	14	2.33	11	22	2.00	+16.50 c
36	3	3	1.00	2	4	2.00	-50.00 c
37	86	192	2.23	86	155	1.80	+23.88 c
38	29	76	2.62	23	60	2.60	+ .76 d
39	13	22	1.69	14	20	1.42	+19.01 d

[a]U.S. Bureau of the Census, Census of Manufacturers: 1963. Subject Statistics: Water Use in Manufacturing (Washington: U.S. Government Printing Office, 1966).

[b]Billion gallons

[c]Based on Michigan data

Based on national data