CASE HISTORIES AND COMPARATIVE COST ANALYSIS OF LAND TREATMENT OF WASTEWATER BY SMALL MUNICIPALITIES IN MICHIGAN

Thesis for the Degree of M. S.

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ABSTRACT

CASE HISTORIES AND COMPARATIVE COST ANALYSIS
OF LAND TREATMENT OF WASTEWATER BY
SMALL MUNICIPALITIES IN MICHIGAN

By

Jeffery R. Williams

Land treatment as an alternative form of wastewater treatment has become increasingly important in recent years. With the inception of Public Law 92-500, the Federal Water Pollution Control Act amends of 1972 establishes guidelines for greater improvement in the quality of wastewater treatment. These amendments state that land treatment must be considered in the initial planning stages for wastewater treatment projects, before a community can qualify for federal grant money. Land treatment is being considered as a viable means of treating wastewater, because traditional treatment processes cannot handle the increasingly complex waste load and other forms of advanced wastewater treatment systems can be expensive to build and operate, particularly for a small community which historically treated its wastes with privately owned septic tanks.

Small rural communities are somewhat of a special problem because the demands for local services such as police and fire protection, transportation, water and health care systems are becoming increasingly difficult to finance with the local tax base, let alone the cost of constructing and operating a wastewater treatment system.

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Because of this and other unique difficulties facing small communities, land treatment for advanced wastewater treatment is a viable alternative.

This study addresses several problems concerning the land treatment method. Actual operation of the institutional and physical characteristics of various types of land treatment systems has been documented. Operation and construction costs are presented for six land treatment systems in Michigan. This information is compared with operation and construction costs of several conventional treatment systems. Data on the economic and institutional characteristics of each facility was collected from state and local officials. Operation and construction cost information has been collected chiefly from local community audit reports.

A comparative cost analysis of the operation expenses of the two general categories of treatment, land and conventional, has in general shown that the land treatment systems on the whole are less expensive to operate than conventional systems. Comparisons of individual cost categories are also presented along with a statistical analysis. Salary and wage expense for conventional type treatment systems is higher than the expense incurred in the same category for the land treatment systems. The conventional systems were also more expensive in terms of operation and maintenance and overall total costs. Land treatment systems were generally more expensive in terms of their general administrative expenses. The comparison of construction costs shows that for the systems included in this study, land treatment systems required a smaller capital expenditure than the conventional treatment systems.

CASE HISTORIES AND COMPARATIVE COST ANALYSIS
OF LAND TREATMENT OF WASTEWATER BY
SMALL MUNICIPALITIES IN MICHIGAN

By

Jeffery R. Williams

A THESIS

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In memory of Vincent C. Williams

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CHAPTER 1

INTRODUCTION

The Problem

Because of the growing demand for water, particularly in the more developed and industrial areas of the world, there has developed a need for better management of water resources. The demand for water for domestic use has increased from 2.0 billion gallons per day in 1900 to 7.2 billion gallons per day in 1975. It is predicted for 1980 that U.S. industry will use 360 billion gallons per day. This will be a substantial increase over the amount used by industry in 1960, approximately 162.5 billion gallons per day [Chanlett, 1973]. Along with this rise in water use, there has been an increase in the volume of wastewater. In 1972, approximately 7 1/2 billion gallons per day of wastewater requiring treatment were produced. The waste load from municipal systems is expected to nearly quadruple over the next 50 years [Council on Environmental Quality, 1970]. The desire to control wastewater problems and attain better management of our water resources is apparent from the efforts of state and Federal government programs to insure adequate supplies and quality. In turn, these programs, legislated by the government, reflect the extremely complex decisions and actions of the nation's population through negotiations, compromises, hearings, interest group lobbying and other forms of public participation.

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Historically, there has been uncontrolled discharge of untreated or partially treated wastes directly into rivers, streams and other bodies of water. This problem has developed because unlike many resources, the waste-assimilating capacity of water and water itself has been treated in many instances as a free good. The basic mechanism of allocating or managing resources is the market. However, the market only operates well when property rights or ownership rights are specifically and clearly defined. In the case of water's waste-assimilating capacity, the property rights are not clearly specified. The problem is that the waste-assimilating capacity of water has historically been treated as a free good and has, therefore, encouraged the overuse of water for waste disposal. Thus the situation has developed where the private costs of using water as a waste dump differ from the social costs. These social costs may develop from a variety of problems including adverse effects on health, production of goods and services, esthetics and all systems dependent upon the delicate balance of the ecosystem. These problems can be hard to identify and, even still harder, is the problem of estimating their costs.

Because of the problems with the market system, the management of water resources has become a problem for the political arena to deal with. Public policy dealing with such problems has relied heavily on a regulatory approach. Administrative bodies are charged with drawing up rules of detailed behavior that specify what is allowable and what is not. Secondly, legislative approaches to many problems arising in the private sector often tend to rely heavily on subsidies for the construction of capital facilities [Kneese, 1975]. Such is the case with the programs for wastewater treatment in the United States.

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Historical Perspective on Legislation

The first federal legislation dealing with the discharge of wastes into the nation's waterways was an obscure law, the Refuse Act, passed in 1899 but rarely enforced until the early 1970s. This law prohibited the discharge of any refuse matter, except from municipal sources, into the nation's navigable waters without a permit [Kneese, 1975].

The first comprehensive federal legislation was the Water Pollution Control Act of 1948. This law left the primary responsibility for pollution control with the states, but it gave the federal government authority for investigations, research and surveys. This law's amendments of 1956 established the policy for the 1956-70 period by providing grants for construction of municipal treatment plants and a procedure for federal enforcement against individual dischargers. Additionally, the Water Quality Act of 1965 sought to strengthen the enforcement process and provide for federal approval of standards on interstate water [Kneese, 1975].

Federal involvement increased with each amendment, so that by 1971 municipal grants covered up to 55 percent of construction costs and annual appropriations were at one billion dollars [Council on Environmental Quality, 1975].

It was not until 1972, when the Federal Water Pollution Control Act was amended, that major changes started taking place at the national level. Federal grants increased to 75 percent of the eligible construction costs and Congress authorized 18 billion dollars over a three year period for the program [Council on Environmental Quality, 1975]. However, even with this legislation, in earlier years the n

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nation was not quick to act on controlling water pollution. Enforcement was slow and cumbersome and as a result, there were only three civil court actions brought against polluters before 1972 [Council on Environment Quality, 1975]. In addition to this, Congress, in 1912, decided to let the states play the major role in controlling water pollution. Basically, until the mid 60s, the authority remained with the states and many of their enforcement activities remained ineffective.

Historical Perspective on Water Quality

It is somewhat difficult to present the status and trends of water pollution in the United States before the mid 1960s. However, as of 1920, localized pollution was occurring which was causing nuisances to recreation and wildlife. By 1940, progressive deterioration of streams became a recognizable factor. The situation continued to worsen and, as of 1960, 105 million people were served by sewers discharging into streams. Even with partial treatment in some areas, stream assimilating capabilities were being overloaded [U.S. Department of Health, Education and Welfare, 1960].

By 1970, less than one third of the nation's population was served by a sewer system and adequate treatment plant. Five percent were served by sewers which discharged their wastes without any treatment. The remaining 32 percent had sewers, but inadequate treatment plants [Council on Environmental Quality, 1970].

The first systematic nationwide inventory of water quality was completed by the Environmental Protection Agency in 1974. The study analyzed trends in water quality for 22 major waterways from fı

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from 1963 to 1972. The data examined showed a mixed picture for the 22 waterways, but suggests that the impact of improving treatment for Biological Oxygen Demand, Chemical Oxygen Demand, bacteria ammonia and suspended solids is beginning to be apparent; these pollutants all showed general improvements. On the other hand, worsening trends are associated with nutrients in the forms of nitrogen and phosphorus. The parameters with the higher levels are phenols, suspended solids, and coliform bacteria [U.S. EPA, 1974].

Overview of Treatment Technology

Various methods have been developed to treat wastewater. Basically, they can be divided into two major groups; that of biological treatment and physical-chemical treatment. Biological treatment involves the natural processes of a stream's treatment processes. The processes are those of settling, anaerobic decomposition of settled and separated solids, and bio-oxidation of the nonsettling and dissolved organic material [Chanlett, 1973]. These processes are combined and accelerated in a sewage treatment plant before the effluent is discharged. They may also be supplemented by some processes such as screening, solids drying and chlorination.

Physical-chemical sewage treatment involves the use of chemical and physical processes for solids removal and stabilization of the waste. One such process is reverse osmosis. Basically, these techniques are independent of biological processes and are usually much more expensive than the biological processes.

This study concentrates on the biological treatment processes. A basic distinction is made between two types of biological treatment:

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the conventional treatment process and the land treatment process. There are further divisions under land treatment and conventional treatment. These are clarified in Chapter 3. The conventional treatment process involves mechanical and chemical acceleration of the biological treatment process in a series of tanks or units, each having a specific purpose. In this process, the sewage effluent is discharged directly from the last stage of the treatment plant to a nearby watercourse.

The land treatment process basically involves the discharge of the effluent to land instead of a watercourse. The initial wastewater can be treated in a conventional treatment plant as defined above, or in earthen ponds and lagoons.

The Problem from the Perspective of the Small Community

The land treatment process has become increasingly important in recent years, particularly to the small rural community. With the inception of Public Law 92-500, the Federal Water Pollution Control Act amendments of 1972 establish guidelines for greater improvement in the quality of wastewater treatment. These amendments state that land treatment must be considered in the initial planning stages for wastewater treatment projects, before a community can qualify for federal grant money. Land treatment is being considered as a viable means of treating wastewater, because traditional treatment processes cannot handle the increasingly complex waste load, and other forms of advanced wastewater treatment systems are too expensive to build and operate, particularly, for a small community, which historically treated its wastes with privately owned septic tanks.

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Most of the small communities in Michigan are located around lakes or along streams that have a limited capacity to assimilate biochemical oxygen demand (BOD) and nutrient loads from wastewater. Many of these municipalities are faced with a choice between conventional tertiary treatment (basically phosphorus removal) and a form of land treatment for final discharge of their domestic wastewater [Malhotra, 1975].

Small rural communities are somewhat of a special problem, because they very rarely have enough funds to finance a sewage treatment system to meet the new water quality requirements. Grant money is available from state and federal sources, but in some instances, the community cannot legally issue enough bonds to acquire the necessary funds for the remainder of the cost of construction. Special arrangements are usually made with a county authority to issue bonds in these cases. The legal authority for these arrangements is spelled out in Act 342 of the Public Acts of Michigan, 1957. A description of these acts can be found in Chapter 2.

Because of these and other unique difficulties facing small communities, land treatment for advanced wastewater treatment is a viable alternative. To summarize:

1. Operation and maintenance costs are generally believed to be less for land treatment than for conventional methods of treatment [Malhotra, 1975].

2. Operation of the system may be less complex than conventional treatment. The complexity of operation will, however, increase if agricultural operations are a component of the land treatment system.

3. Costs of construction may be lower than construction costs for conventional treatment units.

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4. Some types of land treatment have the opportunity to increase farm revenues, particularly, if most of the irrigation costs are paid by the wastewater authority.

5. Similarly, some types of land treatment operations can increase revenues, for the wastewater authority by leasing the land treatment area for forestry or farming operations or by selling agriculture and forestry products from the treatment site.

Land treatment should not be considered trouble free, however. There are also some disadvantages.

1. Usually the amount of land required for a land treatment system is substantially larger than the amount of land required for conventional treatment processes which handle a comparable volume of waste. The required land may not be available or only available at a prohibitive price in certain communities, particularly more urban ones.

2. There is also a stigma attached with the idea of returning wastes to land. Some communities may not accept land treatment as socially acceptable alternative to conventional methods of wastewater treatment.

3. Additionally, if a large amount of land is purchased from private owners in a municipality, the result is that the tax base of the community is reduced. The magnitude of this effect is dependent on the overall acreage and the value of the land.

The important thing to remember is that land treatment is also as complex as conventional treatment in terms of hydrological, chemical and biological characteristics. The system must be operated carefully and effectively or it will be just as susceptible to operating problems as other methods of treatment. It should not be considered a panacea for every community's sewage problems.

The Living Filter Concept

In land treatment systems, the soil acts as a physiochemical "filter," hence the "living filter" concept. The soil and soil biota act to filter and stabilize the organic matter contained in the wastewater effluent. Nutrients, such as nitrates and phosphates, are removed by agricultural crops and forest products or are precipitated out or absorbed in soil particles. The "purified" water may then be collected by drainage systems or allowed to recharge ground water supplies.

Research on the "living filter" concept has been collected at The Pennsylvania State University since 1963. Those, and other studies, have indicated that essentially complete removal of suspended solids, BOD, and fecal coliforms may be obtained by land irrigation of secondary effluent. Nitrogen and phosphorus removal depends on the soil and cropping characteristics, the sequence of wetting and drying periods, and the hydraulic and phosphorus loading rates [Malhotra, 1975].

While the biological, chemical and physical characteristics of land treatment systems may be well documented, there has been little work done on the social science aspects. Two previous studies have been conducted by the Department of Agricultural Economics, Michigan State University. These studies, by Christensen [1975] and Lewis [1975], identified some basic institutional issues and questions. Christensen's objectives were to (1) basically describe the land treatment concept and its application, (2) identify and evaluate alternatives for acquiring land use rights and for managing the farming operation of land treatment systems, (3) identify and estimate some of the parameters involved in the investigation of a land treatment system and the uncertainties surrounding them and lastly, (4) to specify implications of land treatment at the farm, firm and regional level.

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Lewis' study surveyed sixteen small municipalities in Michigan which use land treatment of wastewater by spray irrigation. The municipal systems were summarized according to institutional arragements, financial, agricultural and physical characteristics. Additionally, three alternative methods of institutional arragements were illustrated by case studies of communities utilizing different approaches including an area wide sewage authority, and two methods of county involvement.

The Environmental Protection Agency also published several reports in 1975 dealing with evaluation and costs of land application treatment systems. The purpose of this research was to supply enough information to aid the planner and engineer in evaluating the monetary costs and benefits of land application systems for municipal wastewater treatment. This research also developed a model to estimate the costs of land application of wastewater. To date, however, this model has not been tested with actual data from operating systems.

Statement of the Problem

This study addresses additional problems concerning the land treatment method which have not previously been studied. More specifically, the actual operation of the institutional and physical characteristics of various types of land treatment systems are documented. Operating and construction costs are presented for six land treatment systems in Michigan. This information is compared with the costs of conventional treatment methods. The various land treatment methods presented include spray irrigation, flood irrigation, ridge and furrow irrigation and seepage lagoons. Previous studies have concentrated mainly on spray irrigation characteristics.

Objectives

Specifically, the study objectives are:

1. To describe the various types of land treatment systems used by municipalities in Michigan.
2. To identify the institutional characteristics of the systems included in the study.
3. To present data on the construction, operating and maintenance costs for six land treatment systems and four conventional treatment systems which are currently operating in Michigan.
4. To give a description of the treatment technology used in each system.
5. To compare and analyze categories of cost information of land treatment systems with the conventional treatment costs.

The accomplishment of these objectives will provide useful information to communities, wastewater authorities and planners evaluating the land treatment alternative for municipal wastewater. The data on the operating costs may also be useful for evaluation of the models for estimating the costs of operation.

Procedure

This study uses six communities in Michigan to identify the representative financial, institutional and physical methodology characteristics of land treatment systems. A case study approach was used to determine the actual operating costs and institutional arrangements being used. This type of approach should indicate any particular problems communities are facing and which institutional arrangements are workable.

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Selection of the systems was conducted in conjunction with the Municipal Waste Water Division, Department of Natural Resources. Several considerations were involved in this selection.

1. Only small municipal systems were considered. These are systems treating mainly domestic and a small percentage of light industrial wastewater.

2. The system had to have been operating for a few years so enough financial information was available.

3. Operation and maintenance of the system had to be acceptable in the sense that the effluent quality was meeting approval of the regulatory agencies. In general, operation of the system was to be considered successful.

The next step was to contact community officials and the Local Audit Section, Michigan Treasury Department to collect data on the financial characteristics and operating costs of the system. Field and telephone interviews were conducted with community individuals to collect information. Information was also collected from the Construction Grants Division of the Department of Natural Resources.

Conventional treatment systems were selected as they would be comparable to the land treatment systems in terms of number of people served, type of wastes and degree of treatment. However, in most cases the land application system treatment quality should be of a higher degree. This is because the conventional systems use only phosphorus removal as a form of tertiary treatment. Land treatment should also remove additional solids and chemicals from the secondary effluent that phosphorus removal does not accomplish.

Organization

This study is organized to identify the problem, provide background information on legislation and physical features, and to present data for analysis of the financial characteristics of land treatment methods. Chapter 2 discusses the legal background for wastewater treatment in Michigan. Chapter 3 describes land treatment and conventional treatment technology, and discusses the current state of wastewater treatment in Michigan. Chapter 4 presents the case study information on the six municipal land treatment systems. Data on the conventional systems is presented in Chapter 5 and analyzed with the data on land treatment systems. Chapter 6 closes with the summary and general comments.

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CHAPTER 2

LEGAL BACKGROUND OF WASTEWATER TREATMENT IN MICHIGAN

This chapter is a summary of the current laws which give legal authority for wastewater treatment in Michigan.

Public Law 92-500

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-50, has expanded the federal role in water pollution control. It has raised the level of federal funding for construction of publicly owned wastewater treatment works, increased the amount of planning, emphasized participation by the public and established a regulatory mechanism which includes effluent limitations to meet water quality standards. It also establishes a national waste discharge permit program. Through the permit system, effluent limits are established for all point source dischargers.

The objective of the act is to "restore and maintain the chemical, physical and biological integrity of the nation's waters." Congress also specified goals to be achieved within a specific period of time. The main goal is to eliminate the discharge of pollutants into navigable waters by 1985. There is, however, an intermediate goal to reach, "wherever attainable," a water quality that "provides for the protection and propagation of fish, shellfish and wildlife" and "for recreation in and on water" by July 1, 1983.

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The achievement of the goals is based on the establishment of the effluent standards by the Environmental Protection Agency. In some cases, the EPA has decided that the standard will be a certain level of treatment. This is the case for municipal treatment plants. Municipalities must have at least secondary treatment by July 1, 1977 and have achieved "best practicable waste treatment technology . . . including reclaiming and recycling of water, and confined disposal of pollutants by July 1, 1983."

The importance of coordinated research and technical cooperation are recognized in Title I of the act. Through this, money has been appropriated for water quality surveillance, research on pollutant effects and demonstration programs to show and test improved methods of pollution control. Research on rural sewage treatment and agricultural pollution problems are also included. Section 106 includes a description of a state's responsibilities to qualify for grant monies and the conditions for grant offers.

Title II is the section which provides for federal grants for the construction of treatment systems. One of the most important points in this section includes a statement which pertains to land treatment technology. Part of Section 201 states "The administration shall encourage waste treatment management which results in the construction of revenue producing facilities providing for

(1) the recycling of potential sewage pollutants through the production of agriculture, siviculture, or aquaculture products or any combination thereof,

(2) the confined and contained disposal of pollutants not recycled,

(3) the reclamation of wastewater, and

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(4) the ultimate disposal of sludge in a manner that will not result in environmental hazards.

In other words, land treatment is to be considered as a credible alternative to conventional treatment systems and must be investigated as an alternative wastewater management technique in the procedure for application of grant money.

Overall, the purpose of Title II is "to assist in the development and implementation of waste treatment management plans and practices which will achieve the goals of the Act." Section 202 provides for up to 75 percent grants of the eligible costs for the construction of municipal sewage treatment facilities. This area spells out the conditions of receiving the federal grant, one of which is that alternative waste management techniques have been studied and evaluated for possible use. This includes land treatment alternatives.

Basically, Title III and additional sections spell out administrative procedures dealing with standards and enforcement and permits and licenses. The administrator of the EPA has the responsibility of initiating rules and action within the broad framework of the act.

Many of the administrative rules and regulations are spelled out in the Federal Register [Vol. 38, No. 39, February 28, 1973]. Some of the more important ones concerning grants are mentioned below. The maximum grant for any project is 75 percent of the eligible construction costs except those systems which are incorporated in planning area wide waste treatment systems. These may qualify for further grant considerations. Only land purchased after October 17, 1972 for use in the treatment process is eligible for federal grants.

Prior to this date, the local municipality had to assume total responsibility for the cost of land, if purchased and used in the treatment system. This change is quite significant, because certain areas where land costs were prohibitive earlier may now consider the land treatment alternative to be more viable. This is particularly true where land costs would be a high proportion of the total construction cost.

Public Law 84-660

It is important to point out that some of the systems in this study began construction in the late sixties and, as a result, were governed by the Federal Water Pollution Control Act of 1956 and its amendments in 1966, Public Law 84-660. This law included the first authorization for federal grants to assist in the construction of waste treatment works. During 1966 major amendments occurred and appropriation authorization was increased and the previous maximum dollar limitation of $250,000 on grants was dropped. The federal share became 55 percent and provisions were made for future reimbursements of state and local funds used in lieu of federal funds in construction of projects when federal money was inadequate to provide grants for all eligible projects within a state. This was true of many projects in Michigan.

Public Act 329, 1966, Michigan

Public Act 329 of the Public Acts of Michigan, 1966, as amended, is an act to prevent the discharge of untreated or inadequately treated sewage or other liquid wastes into any waters of the state; to provide financial assistance to local agencies for construction of p

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treatment works to prevent such discharge, and to abate and prevent pollution of the waters in and adjoining the state. This act established the state water pollution control fund which was created to assist local units of government in financing wastewater treatment systems. This fund was initially started by the sale of $285 million of general obligation bonds authorized by Act 76 of the Public Acts of Michigan, 1968, in 1968. This was followed by an additional credit of $50 million of clean water bonds in 1972 (see Act 159 of the Public Acts of Michigan). Payments from this fund are made to eligible recipients following the joint resolution by both houses of the legislature. A priority list of projects is compiled by the Water Resources Commission. All, or part of the list, may receive grants for a given year depending on legislative approval.

Section III of the act contains the details on the operation of the grant system. Basically, grants can only be made to projects eligible for federal grants on which construction began after June 30, 1967. Initially, the grant offer did not exceed 25 percent of the total eligible treatment system costs. Additionally the sum of state and federal grants could not exceed 90 percent of the eligible costs for federal grant participation. As of July 1, 1967 until June 30, 1971, a treatment system qualifying for a 25 percent state grant and a federal grant under P.L. 84-660 as amended, which was under construction before July 1, 1971, was eligible to receive an advance payment from the state water pollution control fund against the prospective federal share of the eligible costs. Therefore, the combined state grant, state advance of the federal share, and federal grant was not less than 55 percent of the eligible costs. (Some systems in this study fit into this category.)

As of the fiscal year 1974, new rules and regulations under P.L. 92-500 took effect and grants are now awarded under a three step process. Step I grants are for completing facility plans, Step II is for plans and specifications, and Step III grants are for construction. At the same time, the amount of grant money a municipality could receive from the state became 5 percent of eligible costs and the amount from the federal government became 14-75 percent of eligible costs.

Currently, grants to municipalities shall be awarded in descending order of priority and all projects, which have been approved for the current fiscal year, will be awarded funds. If there are not enough funds to meet the need of all projects on the current priority list, funds will be fulfilled from the next year's fund appropriation before funds are allocated to any project on the next year's priority list. Basically, the project priority list is established by assigning priority points based on various characteristics of the project and financial need of the community. Some of the characteristics are as follows:

1. Present population to be served by the project.
2. The designated use of the surface receiving waters below the wastewater discharge point. Alternatively, land disposal systems are assigned points for ground water discharge.
3. An average sewage discharge during anticipated drought flow time periods.
4. The need of effluent quality greater than secondary treatment.
5. General location of the discharge.

Points may also be awarded in consideration of the case of court ordered installation or by order and agreement of the Water Resources Commission and the Department of Public Health. However, before a grant can be made, a comprehensive long-range plan must be submitted by the local municipality to the Water Resources Commission for approval.

Public Act 159, 1969, Michigan

Public Act 159 of the Public Acts of Michigan, 1969 was an act to provide financial assistance to local agencies for the construction of collecting sewers to prevent the discharge of untreated or inadequately treated sewage or other liquid wastes into the waters of the state, etc. This act established a fund known as the State Sewer Construction Fund which was used for state grants to local municipalities for construction of collecting sewers. Grants were awarded for construction that began after June 30, 1968. The proceeds of the sale of $50 million in bonds authorized by Act 76 of the Public Acts of Michigan, 1968, were deposited in this fund.

Grants were made in an amount equal to approximately one-half that portion of the cost of construction of the collecting sewers. Various sections of the act spell out the application procedures, amounts, and limitations of the act. With the birth of Public Law 92-500, collecting sewers became grant eligible under federal law, so this act was phased out and the money from the sale of the bonds was deposited in the state Water Pollution Control Fund.

Public Act 98, 1913, Michigan

This act, as amended, outlines the responsibilities of the Michigan Department of Public Health concerning sewage treatment. It gave the State Health Commission the supervisory power over water and sewer systems in the state.

In 1973, there was some agency reorganization and as a result, the Department of Natural Resources, Wastewater Division became responsible for execution of this Act. The Department of Public Health works with the Wastewater Division and influences its decisions. Basically, the department examines plans and specifications, issues construction permits, supervises the water and sewer systems, examines and certifies operators for the plants and levies penalties for violation of the act.

The act requires each municipality file plans for sewage systems either owned or operated for the purpose of review to protect public health and issuance of construction permits. Periodic reports on the operation of the system are also required.

Public Act 245, 1929, Michigan

Act 245, 1929, as amended, created the Water Resources Commission. The commission consists of the directors of the Department of Natural Resources, Department of Public Health, Department of State Highways, Department of Agriculture and three individual (one each) representatives of conservation groups, municipalities and industrial management appointed by the governor. The commission's responsibilities are as follows:

1. Coordinating work concerning water resources with state agencies and governmental units.

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2. Acts in a court of law in the name of the people of Michigan to enforce laws relating to pollution and floodway control.

3. Set rules and standards regarding pollution and issue permits to ensure compliance with the standards.

4. Investigate the state's surface and subsurface water.

5. Conduct surveys of the state's waters and take an advisory capacity in the formation of flood control districts.

Any persons or organization must file a report with the commission if they want to use the state's water for waste disposal purposes. The Commission can accept or reject such proposals.

<u>Public Act 342, 1939, Michigan</u>

This act, as amended, is referred to as the County Public Improvement Act of 1939. It is "an act to authorize counties to establish and provide connecting water, sewer and sewage disposal improvements and services within or between cities, villages, . . . or any duly authorized established combination thereof . . ." This act is particularly important for many of the smaller communities, which have a small tax base, because it allows the county government to enter into contractual arrangements with other governmental units to help provide for acquiring funding and construction of improvements. Bonds can be secured to finance the projects by a vote of full faith and credit by the county commissioners and the cooperating unit of government. The board of commissioners also approves projects and designates a county agency to locate, acquire, construct and maintain the system. Basically, the authorized agency oversees the project and acts as the official applicant for grants.

The capital and maintenance costs must be paid back to the county during a period not to exceed forty years from sources such as connection charges, monthly rates, user assessments and property taxes.

Certain procedures must be undertaken before the local governmental unit may enter into a contact with the county. These are:

1. Public notice of the resolution authorizing any such action must be given.

2. Explanation must be given as to how the funds for repayment to the county will be collected.

3. The right of referendum must be explained.

After public notice and within 45 days, 10 percent or 15,000 whichever is less of the registered electorate, may petition a referendum. If an election is required, a simple majority is needed to ratify the contract.

Once the contract is in force, bonds may be sold in the name of the county and are exempt from taxation within the state. General obligation or revenue bonds may be issued and the maximum interest rate allowable for these bonds under the act is 10 percent. The Municipal Finance Commission must approve the bond issue.

If the local unit of government cannot meet its repayment obligations, the state treasurer may be authorized to withhold unrestricted state funds such as sales tax revenue from the local unit of government to reimburse the county.

Public Act 185, 1957, Michigan

Act 185 is an act to authorize the establishment of a department and board of public works in counties; to prescribe the powers and duties of any county subject to the provisions of the act; to authorize the issuance and payment of bonds; and to prescribe a procedure for special assessment and condemnation.

The county commissioners, by a two-thirds vote, can establish a department of public works. The county agency can be the authorized county agency in Act 342, Public Acts of Michigan 1939 as amended. This department is designed to be supervised by the board of public works consisting of 3, 5 or 7 appointed members or, alternatively, the existing board of county road commissioners may be appointed as the board. The county drain commissioner automatically becomes a member of the board.

The board of public works has several powers which are listed below:

1. The board may hire a director of public works and other qualified professionals as needed.
2. The board can acquire water, sewage or refuse systems in the county.
3. The board has power over the construction, operation and maintenance of these types of systems.
4. Lake improvements may be directed by the board.

Majority vote by the board and local government consent is needed to acquire any of the systems mentioned in item 2 above. Funds can be obtained by revenue bonds, bonds issued in anticipation of special assessments, and by advances from the county and public or private corporations. The board of public works and county commissioners must approve the bond issue.

The local municipality and county's full faith and credit must be pledged. Again, as in the act preceding this discussion, should the local government be unable to meet its financial obligations, certain state funds may be withheld from the local unit of government and directed to the county in lieu of payment. The county may order local officials to levy additional taxes in order to meet its obligations.

Chapter II of the act concerns special assessment procedures for financing. Additionally, the final chapter concerns the condemnation procedure that is to be followed, if needed, by the board of public works. Act 149 of 1911 deals with the power of eminent domain over private property for public use also.

Public Act 233, 1955, Michigan

Act 233 of the Public Acts of Michigan, 1955, provides that municipal authorities may acquire, own and operate sewage disposal and water supply systems, contract with governmental units for the system's use and issue bonds to finance the authority's activities. An area authority can be formed if the legislative bodies of two or more municipalities agree to articles of incorporation for such an area authority. There is a period of sixty days after required public notice is given of the intent to form such an authority for any objection to be filed with the local court.

The area authority has the legal authority to determine a design, construct, operate and maintain facilities under the state health commissioner, acquire and condemn property, issue bonds and to generally supervise the project.

The authority may enter into contractual agreements, not to exceed forty years, for the construction, operation and financing of sewage and water system with member municipalities. Public notice of

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any contract of this nature must be given in the participating municipalities. A general election will be required to determine if the contract will be executed if there is a challenge by petition of 10 percent of the registered voters. A simple majority is needed to execute the contract. When the contract has been confirmed, the authority may issue only revenue bonds which are backed by full faith and credit by each participating member of the authority. Funds may be raised by each member municipality to meet its allocated share of annual services and costs by special assessments, user charges, connecting fees and state funds unless they are expressly prohibited for this purpose. Should any municipality default on its financial obligation, it may pledge up to 25 percent of its sales tax money received from the state.

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CHAPTER 3

WASTEWATER TREATMENT METHODOLOGY AND THE STATE OF WASTEWATER TREATMENT IN MICHIGAN

Treatment Methodology

In municipal sewage treatment systems each home has a sewer pipe which is connected to a series of laterals, mains and interceptors which transport the wastewater to the sewage treatment plant. Once the waste has arrived at the plant it is processed by various techniques to achieve various levels of treatment quality. These levels are primary, secondary and tertiary or advanced treatment. The treatment becomes increasingly complex from one level to the next.

Primary Treatment

Primary treatment is basically the removal of settleable solids and suspended solids through the use of screens and gravitational settling tanks. Initially, as wastewater enters the centralized treatment plant there is generally some preliminary treatment to remove large objects and grit. Screens of various sizes are generally used in this process. Debris collected on the screen can be removed manually by raking, mechanically or they can be ground up by a device known as a comminutor. Next the wastewater may pass into a grit chamber where stones, cinders, sand, etc. settle out on the bottom of the chamber. This chamber is more important where the sewer system collects the runoff from streets and parking lots. The grit is usually disposed of in a land fill site.

The wastewater contains suspended solids and these are removed in the next step by a sedimentation tank. In a sedimentation tank the velocity of the wastewater flow is slowed enough to cause the suspended solids to sink to the bottom of the tank. The solids or sludge can be removed from the bottom of the tank by various mechanical means.

This type of primary sewage treatment can remove up to 70 percent of the suspended solids and cause a 40 percent reduction in BOD [McGauhey, 1968].

Secondary Treatment

Basically, secondary treatment is biological digestion of the sewage which yields a more stabilized effluent which has a lower BOD.

The two principal techniques used in the secondary stage are the trickling filter and the activated sludge process [U.S. EPA, 1976]. After primary treatment the wastewater flows to one of the processes mentioned. The trickling filter is a medium that has a large surface area, such as a bed of rocks in which aerobic and facultative organisms are allowed to grow. The wastewater can be distributed to this medium by various means. One common way is with the use of a rotating boom with sprinklers attached to it. The boom sprinkles wastewater as it rotates over a circular tank containing the slime covered rocks. As the wastewater passes over the rocks, the bacteria consume the organic matter in the sewage. The filtered water is collected at the base of the medium to be pumped on for further processing.

The other process which is used for secondary treatment, activated sludge, also makes use of bacteria. In activated sludge pr

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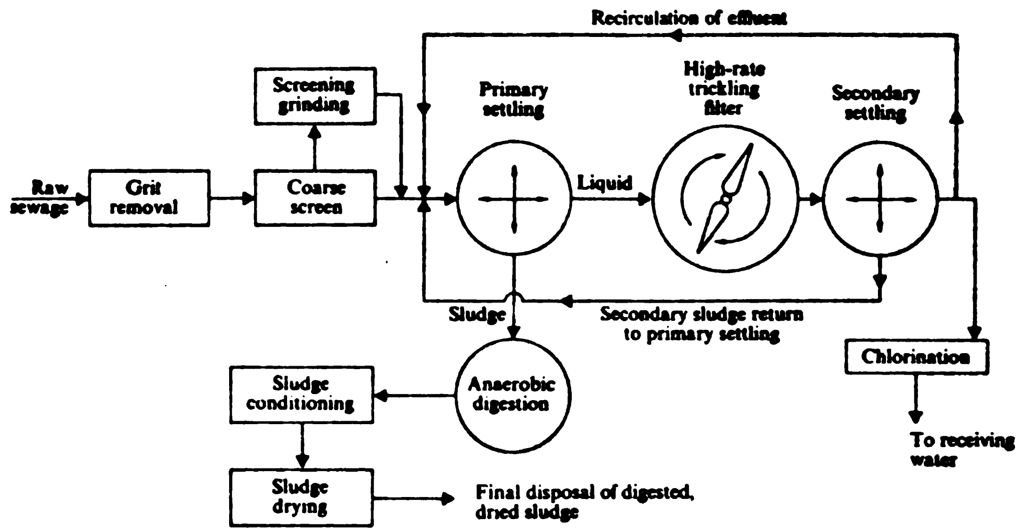
processes, flocs of many types of microorganisms growing on sludge particles, are kept in suspension in an aeration tank where air is bubbled through the mixture to provide enough oxygen required by these bacteria etc., to consume the sewage. The idea is basically the same as the trickling filter. That is, to provide bacteria colonies and oxygen to remove or consume the sewage. However, an additional step is needed to separate the solids from the water in this process. This is done in a clarifier where the solids (activated sludge) settle out and cleaner water flows out of the top of the clarifier. Part of the activated sludge is pumped back to the aeration chamber where it is kept in suspension to help provide flocs of microorganisms which keep the treatment cycle functioning.

Secondary treatment with these methods can remove approximately 80-95 percent BOD and 70-95 percent suspended solids [McGauhey, 1968].

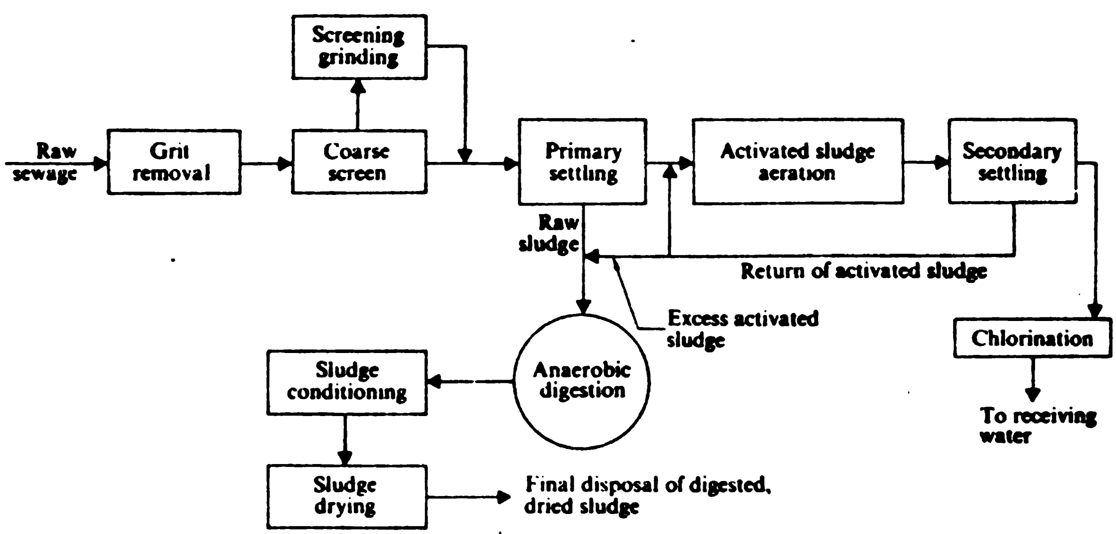
Sludge which settles from primary settling and secondary settling (if needed) is removed and further treated and conditioned for removal from the treatment site. A schematic flow diagram of the preceding process can be found on page 30.

Lagoons often called stabilization or oxidation ponds can also be used to treat sewage to the level of secondary treatment. Waste stabilization lagoons have some advantages particularly for use in small communities. The operating cost of lagoons is believed to be much less than a comparable conventional system. Additionally, the actual operation and maintainance of such a system is not as complex.

There are various types of lagoons which can be used in various combinations to achieve the level of secondary treatment. The design basically depends on the treatment objectives. Michigan requires that



Schematic flow diagram of high-rate trickling-filter sewage treatment plant.



Schematic flow diagram of an activated-sludge type of sewage treatment plant.

SOURCE: Chanlett, 1973.

FIG. 1. Schematic Flow Diagrams of the Two Principal Secondary Level Treatment Techniques: High-Rate Trickling-Filter and Activated Sludge.

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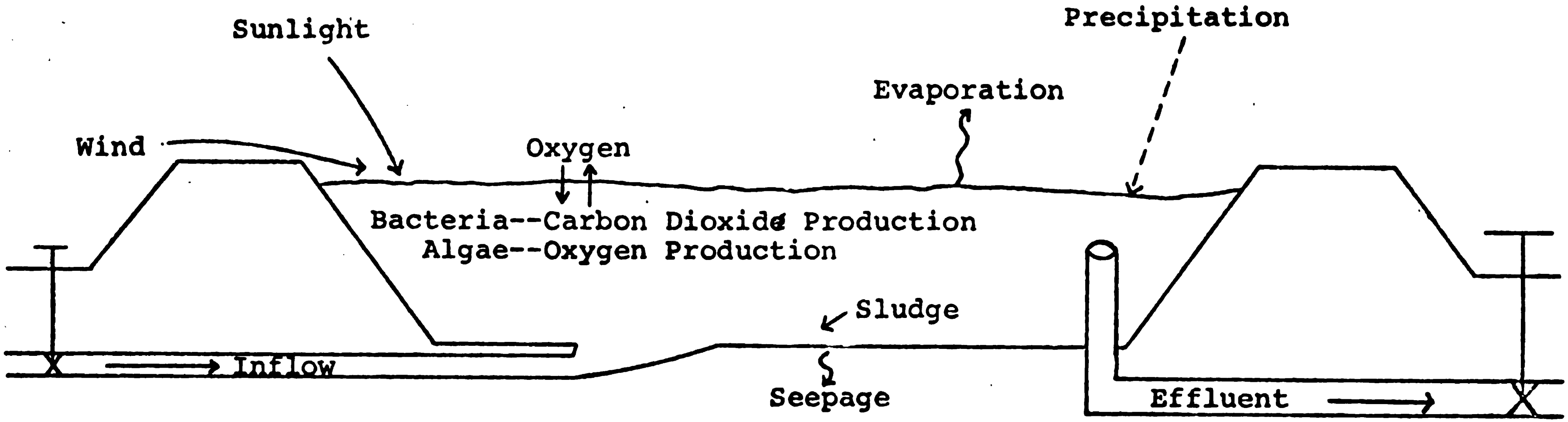
multiple cells be used and designed to be operated in series and parallel. Each subsequent pond in a series operation acts as a clarifier for the effluent from the previous pond. In a parallel operation, the raw sewage is distributed equally to each cell.

The lagoon is a pond usually three to five feet deep in which the interaction of sunlight, algae, bacteria and oxygen work to restore the quality of the water to the level of secondary treatment. See page 32 for a diagram of a waste stabilization lagoon.

A pretreatment anaerobic waste stabilization pond is essentially a digestor that requires no dissolved oxygen. In that type of pond anaerobic bacteria break down the organic waste. An aerobic waste stabilization pond is one in which aerobic bacteria break down the wastes. The algae in these ponds also help to provide the oxygen to maintain a sufficient level of oxygen in the water for the aerobic organisms. The remainder of the oxygen can be provided from the air be the natural surface mixing process. An aerobic pond may be mechanically aerated to supplement or replace the algae as a means of providing for the necessary level of dissolved oxygen. A facultative waste stabilization pond is one which there are two zones. The upper zone is aerobic and the lower zone is anaerobic. An aerated lagoon may function as a facultative waste stabilization lagoon, as well, because sludge may settle to the bottom of the pond and undergo anaerobic decomposition. Most waste stabilization ponds at present, are facultative treatment units [Gloyna, 1971]. In other words, they are similar to the biological treatment process of rivers and lakes.

With the proper use of waste stabilization ponds, it is possible to have 75-96 percent reduction in BOD, 90-99 percent reduction in



SOURCE: Schoon, 1970.

FIG. 2. Diagram of a Waste Stabilization Lagoon

suspended solids and 98-99 percent reduction in bacteria [McGauhey, 1968].

Tertiary or Advanced Waste Treatment

Tertiary treatment basically involves the removal of organic and inorganic particles not removed in previous treatment.

Because of more stringent standards and the increasing complex waste loads from both municipal and industrial waste, secondary treatment techniques alone are no longer able to meet the water quality standards for discharge. Many of the pollutants are exceedingly difficult to remove from the water and many existing primary and secondary treatment plants have to be upgraded to meet the new water quality requirements.

Basically, the techniques for advanced waste treatment include two major alternatives; physical-chemical treatment and land treatment. This study is basically concerned with the land treatment alternative as an advanced wastewater treatment method. The land treatment alternative is an extension of biological treatment.

In the land treatment method the soil acts as a "living filter." The soil is the treatment medium where many complex physical, chemical and biological processes renovate the wastewater applied to the land. The major renovation mechanisms are uptake by plant roots, precipitation, absorption, oxidation, ion exchange and filtration. These mechanisms remove such items from the wastewater as suspended solids, organic matter, nitrogen, phosphorus, heavy metals, bacteria, viruses and other dissolved solids.

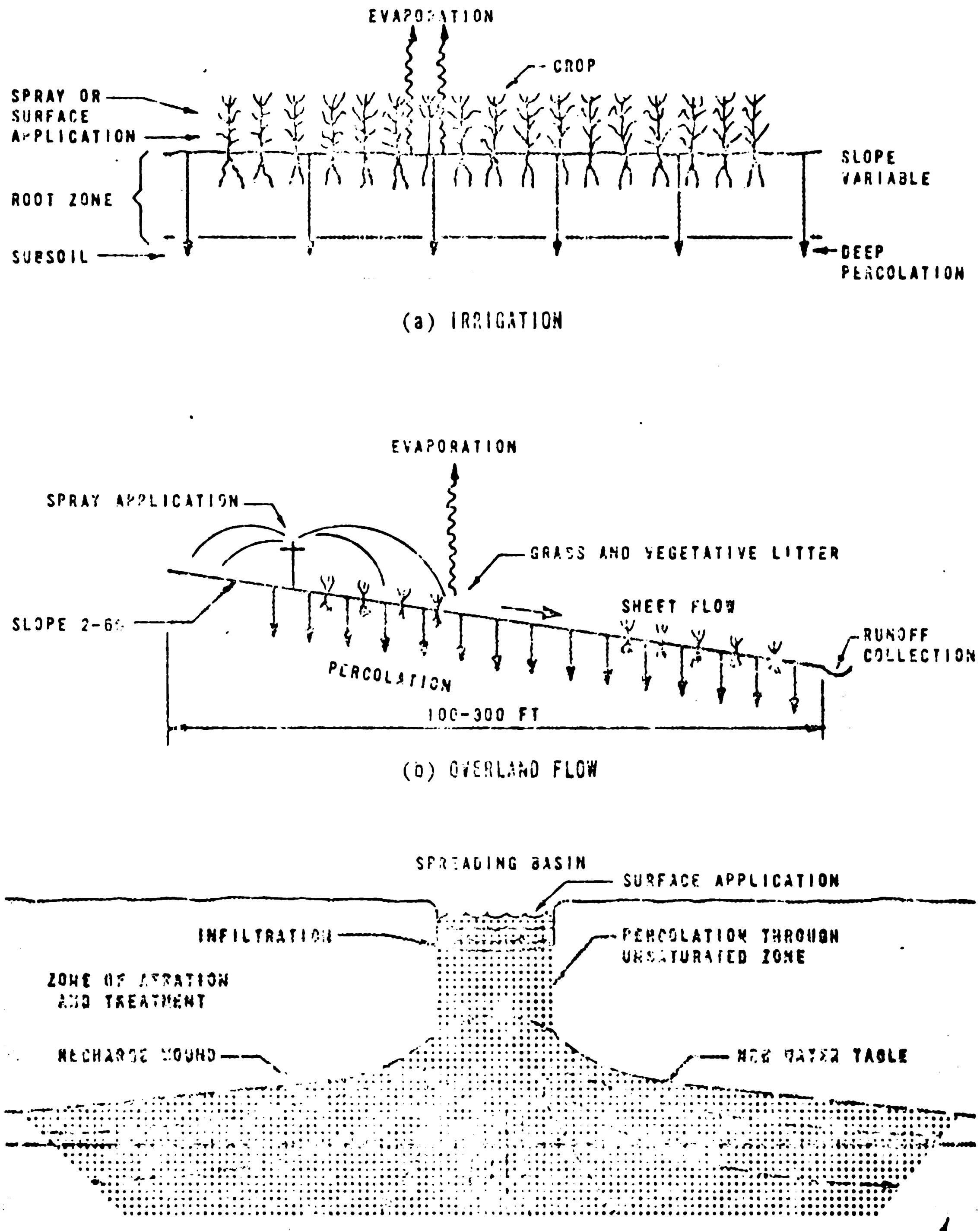
Application Techniques

Land application techniques can be classified into three basic groups; irrigation, overland flow or spray-runoff, and infiltration-percolation. See page 35 for graphic details.

Irrigation. Irrigation is the controlled discharge of effluent, by spraying or surface spreading, onto land to support plant growth. The wastewater is "lost" to plant uptake, to air by evapotranspiration, and to groundwater by percolation. Application depends upon the soil, the type of crop, the climate, and the topography. Sloping land is acceptable for irrigation provided that application rates are modified to prevent excessive erosion and runoff. Renovation of the wastewater occurs generally after passage through the first 2 to 4 feet of soil. Monitoring to determine the extent of renovation is generally not practiced; when it is practiced, however, removals are found to be on the order of 99 percent for BOD and suspended solids. Depending upon the soil type and the crop harvested, removals of nitrogen and phosphorus from the wastewater may also be quite high.

The use of irrigation as a treatment and disposal technique has been developed for municipal wastewater and a variety of industrial wastewaters, including those from the food processing industry, the pulp and paper industry, tanneries, animal feedlots, dairies, and some chemical plants. Crops grown have ranged from vegetables to grasses and cereals [Pounds, 1973]. However, crops used for human consumption without undergoing processing are not recommended.

Overland Flow. Overland flow is the controlled discharge, by spraying or other means, of effluent onto the land with a large portion of the wastewater appearing as runoff. The rate of application is



SOURCE: Pounds, 1973.

FIG. 3. Land Application Approaches

measured in inches per week, and the wastewater travels in a sheet flow down the grade or slope.

Soils suited to overland flow are clays and clay loams with limited drainability. The land for an overland flow treatment site should have a moderate slope--between 2 and 6 percent. The surface should be evenly graded with essentially no mounds or depressions. The smooth grading and ground slope make possible sheet flow of water over the ground without ponding or stagnation. Grass is usually planted to provide a habitat for the biota and to prevent erosion. As the effluent flows down the slope, a portion infiltrates into the soil, a small amount evaporates, and the remainder flows to collection channels. As the effluent flows through the grass, the suspended solids are filtered out and the organic matter is oxidized by the bacteria living in the vegetative litter.

The overland flow treatment treatment process has been developed in this country for treatment of high strength wastewater, such as that from canneries, with resultant reductions in BOD from around 800 mg/L down to as low as 2 mg/L. Reductions of suspended solids and nitrogen are also high although phosphorus reduction is reported to be on the order of 40 to 60 percent [Pounds, 1973].

Infiltration-Percolation. This method of treatment is similar to intermittent sand filtration in that application rates are measured in feet per week or gallons per day per square foot. The major portion of the wastewater enters the groundwater although there is some loss to evaporation. The spreading basins are generally dosed on an intermittent basis to maintain high infiltration rates. Soils are usually coarse textured sands, loamy sands, or sandy loams.

This process has been developed for groundwater recharge of municipal effluents, municipal wastewater disposal, and industrial wastewater treatment and disposal. The distinction between treatment and disposal for this process is quite fine. Unquestionably, industrial wastewater applied to the land for the purpose of disposal is also undergoing treatment by infiltration and percolation, whether or not monitoring for detection of renovation is being practiced [Pounds, 1973].

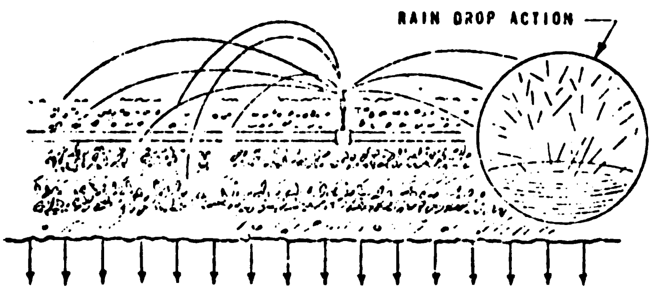
Other Treatment Approaches. There are several other approaches to the disposal of wastewater on land, including subsurface leach fields, injection wells, and evaporation ponds. Such techniques are generally limited in their range of application [Pounds, 1973].

Method of Application

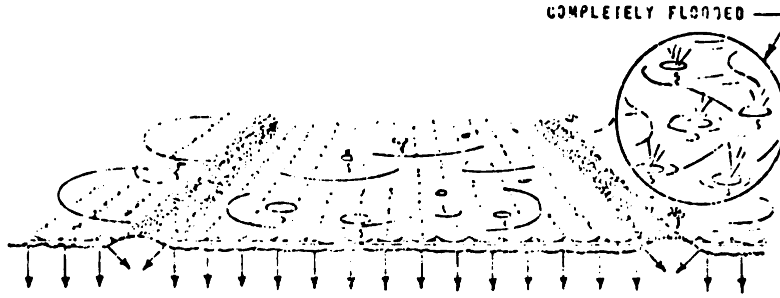
The most commonly used methods of application of wastewater to the land in Michigan are spray, flooding, seepage lagoons, and ridge and furrow systems. Each site will have physical characteristics that influence the choice of the method. Each of these methods is illustrated on page 38 in Figure 4.

Spraying. In the spraying method, effluent is applied above the ground surface in a way similar to rainfall. The spray is developed by the flow of effluent under pressure through nozzles or sprinkler heads. The pressure is supplied by a pump or a source high enough above the sprinkler heads. By adjusting the pressure and nozzle aperture size, the rate of discharge can be varied to any desired rate.

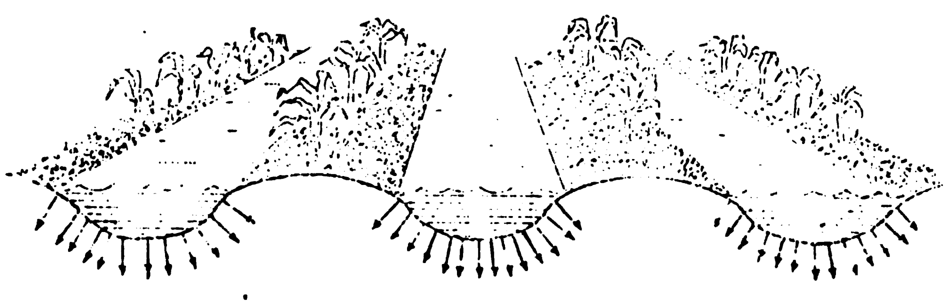
The elements of a spray system are the pump or source of pressure, a supply main, laterals, risers, and nozzles or sprinkler heads. Since



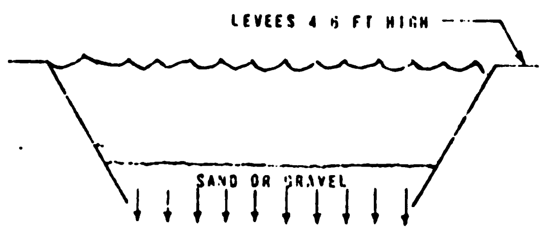
(a) SPRINKLER



(b) FLOODING



(c) RIDGE AND FURROW



(d) SEEPAGE LAGOON

SOURCE: Pounds, 1973.

FIG. 4. Basic Methods of Application

the system operates under pressure, there is a wide variety of ground configurations suitable for this type of disposal. The spray system can be portable or permanent, moving or stationary.

The cost of a spray system is relatively high because of pump and piping costs and pump operating costs. The effluent used in a spray disposal system cannot have solids that are large enough to plug the nozzles. Sprinkling is the most efficient method of irrigation with respect to uniform distribution [Pounds, 1973].

Flooding. The second type of application is flooding. This type can be accomplished in different ways: border strip, contour check, or spreading basin. Flooding, as the term implies, is the inundation of the land with a certain depth of effluent. The depth is determined by the choice of vegetation and the type of soil. The land has to be level or nearly level so that a uniform depth can be maintained. The land does need "drying out" so that soil clogging does not occur. The type of crop grown has to be able to withstand the periodic flooding. The type of flooding that is relevant to this study is the type that uses spreading basins.

Spreading basins are shallow ponds which are periodically flooded with effluent. The basins hold the effluent until it percolates into the ground, is used by crops, or evaporates into the air. Spreading basins are generally used for rapid infiltration [Pounds, 1973].

Ridge and Furrow Method. The ridge and furrow method is accomplished by gravity flow only. The effluent flows in the furrows and seeps into the ground. Ground that is suitable for this type of operation must be relatively flat. The ground is groomed into alternating ridges and furrows, the width and depth varying with the amount of effluent to be disposed and the type of soil. The rate of infiltration into the ground will control the amount of effluent used. If crops are to be irrigated with effluent, the width of the ridge where the crop is planted will vary with the type of crop. The furrows must be allowed to dry out after application of sewage effluent so that the soil pores do not become clogged [Pounds, 1973].

Seepage Lagoon. The fourth type of application is with use of a seepage lagoon. This type of application is an infiltration-percolation technique. The major portion of the wastewater enters the groundwater although there may be some loss by evaporation. The lagoon is a holding pond with a permeable base. The lagoon is not closed on an intermittent basis but is constantly maintained at a certain level until it is allowed to drain completely for maintenance purposes. The four methods are illustrated on page 38.

Perspective on Land Application and Grants in Michigan

This section presents information on the use of land treatment systems in Michigan and a review of the use of the grant process for funding of wastewater treatment.

During the period beginning June 30, 1967 and through the time the 1976 priority list for grants was compiled there have been 643 wastewater treatment projects which have been approved to receive federal and state funds in Michigan. During this period the EPA approved grants totaling $938,234,492[1] and the State of Michigan

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[1] This figure includes supplemental EDA grants administered through Federal Public Works. Since 1971 there have been no supplemental grants of this type.

approved grants of $240,787,301.[2] The State of Michigan also approved $30,537,428 in collecting sewer grants from 1969 to 1972. Total grants came to $1,209,559,221. The amount of state grants is approximately 22 percent of the grant total. As of December 31, 1976, $204,098,704 of the State Clean Water Bond money and $29,665,322 of collecting sewer grant money has been paid to the municipalities. A schedule of approved grant expenditures is found in Table 1.

The amount approved in grants for projects involving land treatment during this period is $60,995,910. The EPA grants total $36,775,019 and the State of Michigan grants total $24,220,891. This state figure includes state advances which will be paid back to the state by the federal government in the amount of $4,854,028. The total amount of grants for land treatment projects is approximately 5.04 percent of the total amount of grants for wastewater treatment in Michigan.

There are currently 66 wastewater treatment systems operating or under construction (6 under construction) which incorporate some form of land treatment into their design (systems which use the soil in the treatment process). This is 17.8 percent of the total of approximately 369 municipal wastewater treatment systems in Michigan. Four of the systems contain two methods of application. Of the 66 municipalities operating land treatment systems, approximately 50 have received the grant money previously mentioned. These 50 projects use various methods of application of wastewater to the land. A listing of projects and their method of application is included in Table 2. The number of

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[2]This figure includes state advances of $20,647,078.

Table 1. Approved Grant Expenditure in Michigan

Legislation	Total Projects	EPA Grants	State Advance	State Basic Grants
Section 3.1, Act 329	32	22,114,141	443,304	11,478,518
June 27, 1968 Priority List	49	59,097,663	8,665,935	30,887,525
F.Y. 1970 Priority List	111	117,960,299	20,647,078	65,854,858
F.Y. 1971 Priority List	9	45,418,260		21,063,231
F.Y. 1972 Priority List	37	90,783,038		41,246,965
F.Y. 1973 Priority List	29	180,957,531		12,352,320
F.Y. 1974 Priority List	168	402,406,264		26,375,520
F.Y. 1976 Priority List	208	19,497,296		1,771,046
Total	643	938,234,492	29,756,317	211,033,984

SOURCE: DNR, 1976a.

Table 2. Land Treatment Project List

Municipality	County	Application Type	Number Served	Total EPA Grants	Total State Grants*
Alpha	Iron	Seepage Lagoon	380	92,434	33,498
Bangor	Van Buren	Seepage Lagoon	2,300	--	--
Baraga	Baraga	Seepage Lagoon	1,110	486,021	220,919
Belding	Ionia	Seepage Lagoon	4,300	--	--
Bellaire	Antrim	Ridge & Furrow	750	98,380	76,016
Beulah	Benzie	Seepage Lagoon	650	74,640	46,365
Bloomingdale	Van Buren	Spray Irr.	496	96,210	147,910
Bowne Twp.	Kent	Flood Irr.	327	--	--
Butman Twp.	Gladwin	Ridge & Furrow	100	--	--
Caledonia	Kent	Flood Irr. (NC)	700	769,875	51,325 III
				19,904	1,327 I
Calumet	Houghton	Seepage Lagoon	8,523	--	--
Cassopolis	Cass	Spray Irr.	1,950	96,825	6,455 I
		Seepage Lagoon			
Cedar Springs	Kent	Seepage Lagoon	1,610	21,525	1,435 I
Chatham	Alger	Seepage Lagoon	260	224,925	14,995
Clark Twp.	Mackinaw	Spray Irr.	--	337,433	168,717
Coleman	Midland		1,295	100,990	342,668
Colon	St. Joseph	Spray Irr.	1,172	4,950	330 I
				251,120	604,320
Columbiaville	Lapeer	Spray Irr.	975	302,520	258,742
Crystal Falls	Iron	Seepage Lagoon	1,935	399,580	142,358
Denton Twp.	Roscommon	Flood Irr.	548	140,060	140,791
Diamondale	Eaton	Seepage Lagoon	972	199,670	230,881
East Jordan	Charlevoix	Spray Irr.	1,600	27,000	1,800 I
				213,200	164,211
Edmore	Montcalm	Seepage Lagoon	1,150	--	--

Table 2. Continued

Municipality	County	Application Type	Number Served	Total EPA Grants	Total State Grants*
Epworth Hgts.	Mason	Subsurface App.	550	--	--
Farwell	Clare	Flood Irr.	900	107,450	436,737
Forsyth Twp.	Marquette	Seepage Lagoon		8,775	585 I
				306,720	76,561
Fremont	Newago	Flood Irr.	3,760	1,778,560	793,600
Gaastra #2	Iron	Seepage Lagoon	160	--	--
Gaylord	Otsego	Seepage Lagoon	3,000	--	--
Gryling	Crawford	Seepage Lagoon	2,000	183,000	136,026
Harbor Springs	Emmet	Spray Irr.	W3,580	4,771,700	646,350
Authority		Flood Irr.	S5,800		
Harrison	Clare	Flood Irr.	1,460	100,150	689,252
Hart	Oceana	Ridge & Furrow	1,815	9,075	605 I
				616,330	280,150
Honor	Benzie	Flood Irr.	500	--	59,750
Howard City	Montcalm	Seepage Lagoon	900	51,642	28,202
Ironwood #2	Gogebic	Subsurface App.	390	--	--
Kalkaska	Kalkaska	Flood Irr.	1,800	109,318	36,439
				28,650	1,910 I
Lake Odessa	Ionia	Spray Irr.	1,890	68,400	4,560 I
				374,410	219,496
Lawton	Van Buren	Seepage Lagoon	1,100	--	--
Leoni Twp.	Jackson	Spray Irr.	6,600	--	--
Livingston Co.	Livingston	Spray Irr.	108	--	--
Mackinaw City	Cheboygan	Spray Irr.	W1,200	18,525	1,235 I
			S6,000	419,167	190,530
Manton	Wexford	Seepage Lagoon	1,050	--	61,221

Table 2. Continued

Municipality	County	Application Type	Number Served	Total EPA Grants	Total State Grants*
Marion	Oscoda	Flood Irr.	925	196,900	341,089
Middleville	Barry	Subsurface App.	1,800	145,440	93,246
Mt. Pleasant Subdivision	Allegan	Subsurface App.	180	--	--
Muskegon Co.	Muskegon	Spray Irr.	69,476	304,275	20,285 I
Metro				14,682,440	12,834,760
Muskegon Co. Whitehall-Montague	Muskegon	Spray Irr.	3,000	80,775	5,385 I
Olivet	Eaton	Flood Irr.	1,550	--	--
		Seepage Lagoon			
Onekama	Manistee	Seepage Lagoon	638	228,698	103,954
Paw Paw	Van Buren	Flood Irr.	3,160	1,317,950	599,072
Pinckney	Livingston	Ridge & Furrow	925	73,550	50,448
Powell Twp.	Marquette	Subsurface App.	110	--	--
Quincy	Branch	Spray Irr.	1,500	265,710	242,439
Ravenna	Muskegon	Flood Irr.	1,020	90,110	55,645
Roscommon	Roscommon	Spray Irr.	643	274,215	124,643
Roscommon Twp.	Roscommon	Flood Irr.	3,258	28,500	1,900 I
				1,337,600	1,608,000
Shelby	Oceana	Seepage Lagoon	1,700	--	--
Spring Arbor	Jackson	Seepage Lagoon	700	3,663,150	244,210 III
Springport	Jackson	Spray Irr.	640	127,720	265,637
Stockbridge	Ingham	Seepage Lagoon	1,300	11,250	750 I
Sunfield	Eaton	Flood Irr.	450	124,200	237,693
		Flood Irr.	450	32,550	2,170 I

Table 2. Continued

Municipality	County	Application Type	Number Served	Total EPA Grants	Total State Grants*
Vermontville	Eaton	Flood Irr.	750	82,960	208,239
Wayland	Allegan	Spray Irr.	1,860	176,300	582,541
Webberville	Ingham	Seepage Lagoon	1,000	95,112	52,010
Wixom	Oakland	Seepage Lagoon	2,400	27,825	1,855 I
				498,625	226,648
TOTAL			171,871	36,774,989	24,220,891

*Including advances and grants from collecting sewer construction fund.

people served by the project and amount of grants are also included. The roman numeral after the grant amount indicated which step the project is in. For an explanation of the step system, see Chapter 2, page 19.

The total number of persons served by land treatment systems in Michigan is approximately 171,871. This is 2.74 percent of the population of approximately 6,272,594 being served by municipal sewage treatment systems in Michigan. However, this does not include all sewage treatment facilities in Michigan. Facilities such as mobile home parks, apartment houses, industries, schools, campgrounds, commercial establishments, hospitals, restaurants and federal, state and local institutions may have their own sewage treatment unit. It is interesting to note that municipalities using land treatment systems which serve 171,871 people received total grants of $60,995,910 or approximately $354.89 per person served in grant money. On the other hand, communities using other types of systems serving 6,100,723 persons and having received total grants of approximately $1,148,563,311 have been subsidized at a rate of approximately $188.26 per person served. (The data has not been adjusted for inflation.) There are two possible explanations for this difference of approximately $166 per person. First of all, not all projects in Michigan received grant money and, it may be the case, that there were more conventional treatment projects which did not receive grant money mainly because they were in operation before the grant system was in effect. Secondly, many conventional treatment projects serve greater numbers of people per project than land treatment projects do. Additionally the construction cost function on a per person basis of conventional treatment projects may have decreasing marginal costs as the treatment system becomes larger. In other words, there are economies of scale in larger conventional treatment projects. Therefore, the grant on a per person basis may be smaller as compared to a land treatment system. Information is not readily available on the exact number of people served only by projects which received grant money.

As mentioned earlier in the Chapter 2, Act 159 of the Public Act of Michigan 1969 provided a fund for grants to be allocated to municipalities for construction of collecting sewers until Public Law 92-500 came into effect. A schedule of approved grant expenditure is included.

Collecting Sewers	Total Projects	Total State Grants*
September 10, 1969	20	$ 4,474,458
January 15, 1970	39	14,776,478
January 15, 1971	20	6,712,130
January 15, 1972	7	4,574,362
Total	86	$30,537,428

Of these 86 projects, 13 of them were for wastewater treatment systems using a form of land treatment. The total grants for these 13 were $4,044,054 or approximately 13 percent of the total grants for collection systems.

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*SOURCE: DNR, 1976a.

CHAPTER 4

CASE STUDIES

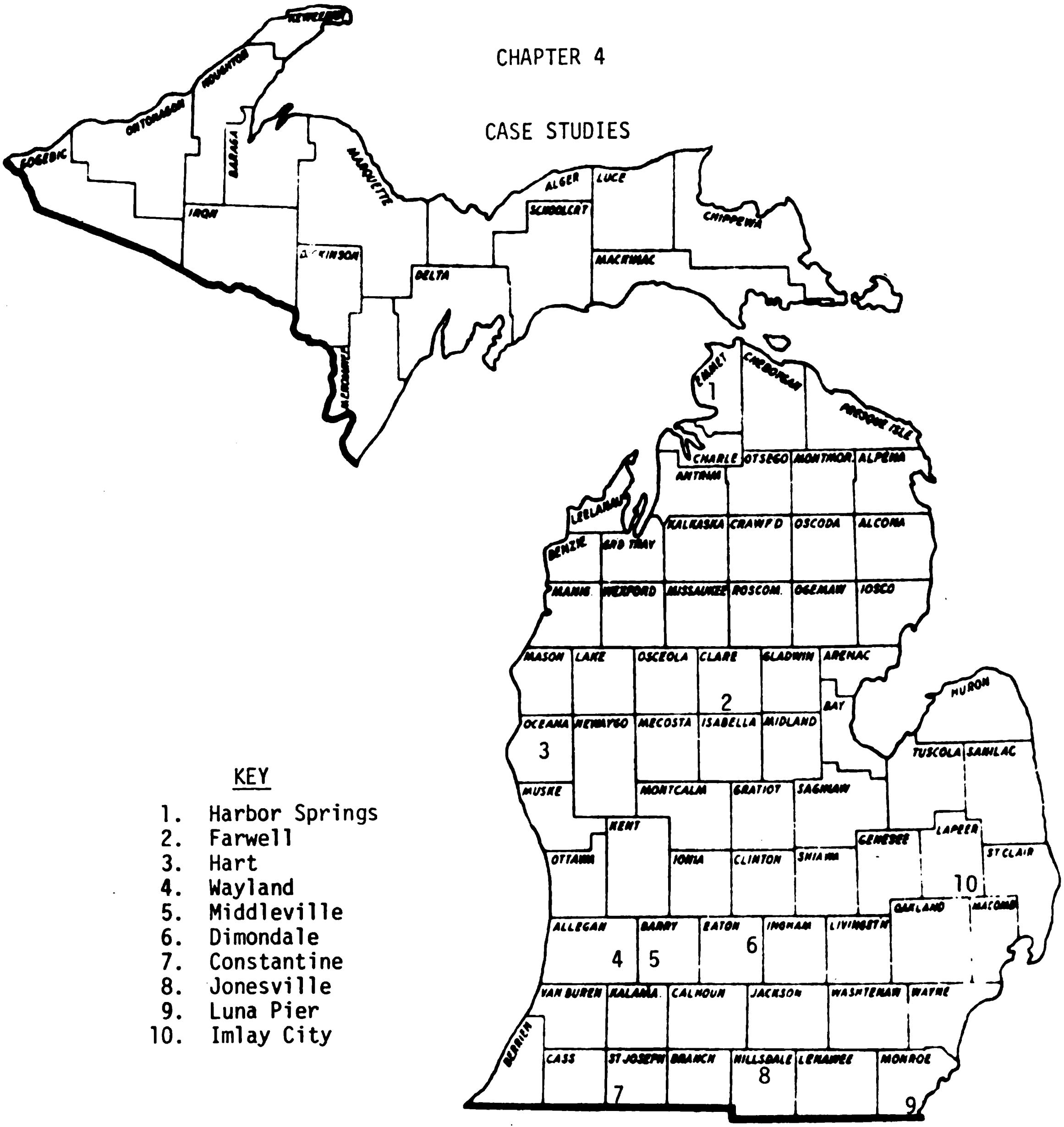

FIG. 5. Location of Case Study Treatment Systems

Harbor Springs

Harbor Springs is located 265 miles northwest of Detroit in Emmet County on the north shore of Little Traverse Bay. The town is in a picturesque location set against high bluffs which overlook the deepest natural harbor of the Great Lakes. For almost a century, the Harbor Springs area has been the most prestegious summer resort in the midwest and is possibly the wealthiest. Until the early sixties, Harbor Springs was typically characterized as a summer resort area. Resorters typically arrived on Memorial Day weekend and stayed through Labor Day. The area virtually closed in the winter and as a result, almost completely folded. However, in the last decade the area started to attract many winter sports enthusiasts. Additionally, people who had been coming to Harbor Springs for the summers for a number of years began to move permanently to the area to retire. Today, thanks to the determination and planning of the residents year round business has improved. New recreation facilities and municipal services exist. Although, the area still relies heavily on the summer influx of residents, the effects of the fall retreat are not as drastic as they were in earlier years.

It was this determination and awareness of community problems which eventually lead to the establishment of the Harbor Springs Area Sewage Disposal Authority. The residents recognized that an improved treatment system would be needed to eliminate wastewater pollution problems in the area before further resort facilities could be developed. The legal authority for this type of action is Act #233 of the Public Act of Michigan, 1955. The articles of incorporation for the authority were drawn up and became effective in November of 1969. A referendum was not required as there was a good deal of public support for the authority. This support stemed from the fact that even though the communities involved in the authority initially had primary treatment facilities, Little Traverse Bay and Crooked Lake were being polluted by effluents and causing danger to health, interfering with swimming and fouling boats in the harbor. Waste-water pollution was endangering the basic attributes of the Harbor Springs resort area.

The authority is currently incorporated to manage sewage treatment and collection facilities that serve the City of Harbor Springs, the Townships of Little Traverse and Littlefield and the Village of Alanson for a period not to exceed forty years. Forty years is the estimated useful life of the treatment system. Initially, the authority was incorporated for the City of Harbor Springs and Little Traverse Township. Eventually interest in the authority grew in the Village of Alanson and Littlefield Township mainly because both of these parties were under order by the Water Resources Commission to improve their sewage treatment. The Village of Alanson and the Township of Littlefield joined the authority in August of 1972. Harbor Springs and Little Traverse Township had also been under order by the Water Resource Commission. However, the preliminary engineering and planning works for a wastewater treatment system had already been started before the order was delivered.

The articles of incorporation originally provided for a seven member board. There were four members from the City of Harbor Springs and three from Little Traverse Township. There are currently eight members; one additional member represents the Village of

Alanson and Littlefield Township. Currently, at least five members of the board are required for a quorum. For a resolution or ordinance providing for the issuance of bonds to be passed, there must be five affirmative votes. Other actions require a simple majority.

The original authority began to take action to organize for the eventual construction of the treatment system in 1970. A contract was signed between the authority and the City of Harbor Springs and Little Traverse Township. The contract spells out regulations and the obligations and rights the authority and each member has. This contract required that the City of Harbor Springs pay 63.84 percent of the cost of the system and Little Traverse Township pay 36.16 percent of the cost of the system not covered by federal and state grants or funds from other sources except bond issues. These costs include, items of capital, bond premiums, bond interest, paying agent fees and administrative expenses related to a bond issue. The contract also states that the city and township shall have the same proportionate capacity rights in the sewage treatment plant and in the sewers and other facilities of the system as the respective proportional shares of the cost of the system.

The contract gives the authority title to the system and the responsibility for operation, maintenance and repair of the system. The authority can also establish rates or charges to be paid by the city and township for transportation and treatment of the sewage. However, the City of Harbor Springs and several residential areas within Little Traverse Township operate their own collection system and utilize only the trunk transportation system and treatment system of the authority.

Engineering site selection and grant application procedures were under way by 1970. In the fall of that year, land was optioned in Little Traverse Township and acquired in fee simple title within 120 days. In all, 423 acres were purchased for the initial project at a cost of $180,000. (Project II will be discussed in a later section.) This land was not eligible for grant money because the purchase occurred while Public Law 84-660 was in effect. (See Chapter 2, page 17 for details of Public Law 84-600.) Of the 423 acres, 320 acres of the land are for the treatment site area and 103 acres are for a buffer zone to isolate the treatment facilities. This area is required for this project by the Michigan Department of Health. Initially, the authority had only purchased land for the treatment site. It was informed later that an additional 800 foot distance from the irrigation area would be required. This presented somewhat of a problem, because the site had already been chosen and an additional 300 feet of land on the south boundary of the site was not as readily available as the land for the actual treatment area had been. Although eminent domain was not required to acquire the land for the project, there were a number of difficulties in persuading land owners to sell their property. Houses had to be purchased and others moved. Two houses and a house trailer were purchased. The house trailer was later sold and one of the houses demolished. The remaining house was purchased by a private party and moved to another location. The authority also payed the expenses of moving another house and installing a public water supply system for a residence which was near the boundary of the land treatment area. It was feared that the well water for the house could possibly be contaminated by the operation of the system. Presently, there are 13 houses connected to this water supply system.

In December of 1970, contracts for construction were signed. Revenue bonds in the amount of $550,000 were also sold. Construction began in the spring of the following year. The project was completed and final field inspection was held in October 1973.

In August of 1972, the articles of incorporation were amended and the Village of Alanson and the Township of Littlefield joined the authority. During 1973 the authority started a program to extend its collection system into Little Traverse and Littlefield Township and the Village of Alanson. An additional 158 acres of land were purchased adjacent to the existing treatment site to allow for the facility to be expanded to meet the needs of the new areas of the authority and for future growth. The cost of land was approximately $133,450. By December of that year, Project II was underway. In June of 1974, revenue bonds were issued in the amount of $1,650,000. When the author visited the site in the summer of 1976, construction was essentially finished but the final inspection had not taken place.

Project I was constructed under terms of a stipulation between the City of Harbor Springs and the Michigan Water Resources Commission to ensure that the water quality standards were met. The project eliminates discharges to surface waters through the use of land disposal. Several alternatives with various treatment methods were considered including plans with Petoskey, Michigan. The most feasible solution favored treatment for the Harbor Springs area alone. Final choice of treatment seemed to be influenced by several characteristics of a land treatment system. It was generally believed that the cost of operating the system would be lower than a conventional method. Additionally, Lewis [1975] reports that land disposal was chosen over other methods for the following reasons.

1. The required land was relatively accessible and moderately priced.

2. The consulting engineer had previous experiences with land treatment methods.

3. Local citizens desired to protect Little Traverse Bay. With the advantage of no discharge into the bay, equipment malfunction or human error would not have the impact on a land disposal system that the same circumstance might have on a conventional system.

4. All nutrients are removed by the land treatment system.

It is interesting to note that Project I was started before the Federal Water Pollution Control Act Amendment of 1972 which required alternative procedures of treatment be investigated including land treatment. Additionally, the cost of the land required in the treatment project was not grant eligible.

Project I consists of trunk sewers that receive sewage flow from initially existing collecting sewer systems in the City of Harbor Springs and the resort association of Harbor Point and Wequetonsing. The intercepting sewer begins at the previous sewage treatment plant at Harbor Point and generally follows the Little Traverse Bay shoreline to the new sewage treatment plant. The project also required the construction of a pumping station, four main waste stabilization ponds and irrigation fields.

In Project I the sewage is pumped from the various areas to the treatment plant where it enters two 3/4 acre ponds which are mechanically aerated by floating aerators. From these two ponds it enters a 20 1/2 acre oxidation pond which is normally filled to a depth of twelve feet. After the wastewater leaves the larger lagoon, it is clorinated and pumped to a center pivot irrigation system. This center pivot system is a boom which contains spray nozzles that rotates around a center post. The rotating boom is set on large tires which travel on a gravel track which prevents them from being bogged down in wet soil. The boom is operated 1 day/week during the irrigation season. During the 24 hours, it is operated it makes one complete rotation applying approximately 1,200,000 gallons of water on 23 1/2 acres. The application rate is approximately 4 inches per week and 90 inches per year. A traveling spray gun is also available, if the operating situation calls for its use.

The U.S. Forest Service is conducting research in the center pivot irrigation area and on an additional 4 1/2 acres of land that is irrigated by a solid set spray irrigation system. Experiments are being performed with various species of trees and shrubs to see how the wastewater effluent affects their performance.

Before Project II was undertaken, the Village of Alanson, Littlefield Township and portions of Little Traverse Township discharged raw or partially treated sewage into surface waters. Littlefield Township and the Village of Alanson relied on individual septic tank systems for sewage treatment. Project II required the extension of the authority collection system into Little Traverse and Littlefield Townships and the Village of Alanson. Additional aeration ponds, one holding pond and flood irrigation units were constructed for the treatment of the wastewater from these areas. These components of the treatment system were constructed next to the original land treatment area so

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area so both sections could be operated jointly. The wastewater from these new areas of the authority flow into two 3/4 acre aerated ponds to begin the treatment process. The effluent then flows from the aerated ponds to a 16 1/2 acre lagoon. This new part of the system is not fully operational as yet. During the summer of 1976 the 16 1/2 acre holding lagoon was being filled, however, it was not anticipated that any discharge would occur from the lagoon until the following season. After this portion of the system becomes operational, the wastewater will flow from the large oxidation pond to twenty 2 1/2 acre flooding basins which will be flooded to a depth of six inches and allowed to drain over a two week period.

Soils at the treatment site are very sandy and, according to the survey work done by Michigan State University soil experts, are placed in a series of Kalkaska sand, Blue loamy sand or Mancelona sand. The topsoil of all these series are characterized as drouthy and low in organic matter. Rapid drainage and low water holding capacity, as well as a surface layer which is often subject to wind erosion, are additional attributes of these soils. The vegetation is mainly weedy pasture with some brushy trees on a slope which ranges from 2 to 8 percent [Lewis, 1975]. The land had previously been idle for a number of years and is not currently in use for any operation other than a land treatment site and forestry research.

The system currently serves approximately 3,580 people in the winter and 5,800 people in the summer. When the Project II section becomes fully operational, it is estimated that the system will be serving 7,500 persons. Approximately 540,000 to 550,000 gallons of wastewater per day enters the treatment area during the summer months

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and 420,000 gallons per day during the remainder of the year. An official of the Harbor Springs Authority has informed the author that up to 300,000 gallons of water/day may be entering the old collection systems (not constructed by the Authority) by infiltration in the wet seasons.

To date, the system has performed as expected and removes essentially 100 percent of the forms of nitrogen and phosphate that are contained in the wastewater.

The total cost of the two projects by four categories is:

	(1970 $) Project I	(1974 $) Project II
Construction	941,877.88	4,971,256.00
Engineering-Technical	147,692.77	787,000.00
Legal	4,716.75	39,025.00
Land	180,000.00 (423 acres)	133,450.00 (158 acres)
Total	1,274,287.40	5,930,731.00

Grants from the federal and state governments in aid of construction for Project I totaled $820,715. The EPA grant was $461,700 with the state grant and advance being $273,572 and $85,443 respectively. The initial grants were $45,100 from the EPA and $225,000 in grants and $225,000 in advances from the State of Michigan. After Public Law 92-500 went into effect, adjustments were made and the federal share of grants increased substantially. The state advance is less because the federal government has reimbursed the state in part for the advance. This is also true of many other wastewater treatment projects in Michigan.

Project II received grants totaling $4,597,335. State grant money comes to the amount of $287,335 with the remainder of the $4,310,000 being EPA grant money.

Revenue bonds in the amount of $550,000 were issued to finance the local share of the construction costs of Project I. The bonds are serial bonds maturing in varying amounts on the first of each September from 1974 through 1991. Initial maturity was $15,000 and the final maturity is $60,000. Interest payments are due the first of March and September each year. The first two interest payments on September 1, 1971 and March 1, 1972 were payable from bond proceeds. Payment of bond interest after those dates is defined under terms of the contract between the authority, city, and township. The city and township agree to pay all debt service costs. These payments are required on the first of each August in the amount equal to the bond interest, principal, and service charges payable for that year. The City of Harbor Springs was originally required to pay 63.84 percent of the costs and the township 36.16 percent. These percentages were later readjusted and presently the city pays 59.11 percent and the township 40.89 percent. These percentages were constructed according to the anticipated use of the project by each member. Each party has agreed to include in its annual property tax levy an amount sufficient to make the required payment. Additionally, the full faith and credit of the city and township is pledged for payment of each annual amount plus an amount not exceeding 25 percent of the monies each governmental unit received annually as a return of state sales tax if needed to cover the annual expense. Bonds maturing after September 1, 1984 are subject to early redemption at the option of the authority in inverse numerical order on any interest payment date on or after September 1, 1984, at par value plus a premium ranging up to 3 percent of par value.

For Project II, under terms of a contractual agreement between the authority, the Village of Alanson and Little Traverse and Littlefield Townships agreed to pay to the authority all debt service costs associated with the revenue bond issue of $1,650,000. These bonds were not sold to the public but were purchased entirely by the Farmers Home Administration. These bonds are serial bonds maturing in various amounts on the first of each January from 1977 through 2014. Initial maturity is $20,000 and final maturity is $80,000. Interest payments are due on the first of January and July each year. The payment from July 1, 1974 to January 1, 1976 were capitalized as part of the system cost and paid from proceeds of the bond issue. The debt service charges to be paid to the authority by the village and townships are due on the first of each December starting in 1975. The Village of Alanson is required to pay 26.59 percent of the debt service costs, Little Traverse Township is responsible for 20.24 percent and Littlefield Township 53.17 percent. These shares were determined differently than the shares were in Project I. The shares of the cost were divided up according to the cost of the collection system in each unit of government. The trunk and treatment area construction costs were divided up between the Village of Alanson and Littlefield Township. This was done because all of the land for the treatment site came out of the tax base of Little Traverse Township. The cost of the trunk and site was proportioned one-third to the Village of Alanson and two-thirds to Littlefield Township. Costs were shared in this fashion because project officials felt Littlefield Township had a greater potential for growth and development than Alanson. Almost all of Alanson was fully developed. Each unit of government agreed to include in its annual property tax levy an amount sufficient to make the required payments.

The city, village, and townships are charged for sewage collection, transportation, treatment and disposal at rates which are to be sufficient to provide for all operating costs excluding depreciation. In addition, a separate charge is made to provide for a repair and replacement reserve.

As of December 1, 1976, the Harbor Springs Authority charges each member of the Authority according to the amount of wastewater they pump to the treatment plant and a fixed charge to help cover costs of maintenance of the treatment plant. The rate that is charged to those members who operate their own collection system is $1.60/ residential equivalent/month + $.18/1,000 gallons used. For those who use a collection system the Authority built the rate is $2.70/residential equivalent/month + $.18/1,000 gallons. The variable rate was previously $.12/1,000 gallons. This rate had to be increased because the electric utility rates nearly doubled during 1976.

The rates of the townships of Little Traverse and Littlefield and the Village of Alanson are flat rates based on the number of residential equivalents. Harbor Springs charges 100 percent of the water bill. The rates are as follows:

Little Traverse Township	\$ 6.00/month/residential equivalent
Littlefield Township	\$11.00/month/residential equivalent
Village of Alanson	\$ 9.00/month/residential equivalent
City of Harbor Springs	\$ 2.00/month minimum up to 2,000 gallons the next 13,000 gallons at \$.50/1,000 gallons over 15,000 total at \$.25/1,000 gallons

A single family residence is charged for one residential equivalent. These diverse charges are partially a result of the difference in the debt obligation by each unit of government. All units also charge a $500 tap in fee to connect to the sewage treatment system.

The operating expenses of the Harbor Springs Sewage Authority are presented in Chapter 5.

Wayland

The City of Wayland is located in the northeastern portion of Allegan County, approximately 15 miles south of Grand Rapids. The community is basically a residential community with approximately a dozen light industries. A good portion of the residents are retired people on Social Security. Many of the younger residents are employed outside of the city in Grand Rapids. The area surrounding the city is dotted with farms and popular recreation areas.

In the 1960s, the city did not have a public sewage collection or treatment system. Previously there were times when raw or semi-treated sewage was finding its way to surface waters in the city. The central business district of the community was pressed to find space for on-site disposal. These conditions were creating a health hazard and causing pollution of the Rabbit River, a tributary of the Kalamazoo River which drains to Lake Michigan.

During the 1960s, the City Council became interested in trying to alleviate the problems. Initial plans were approved by the Department of Public Health in 1963 for a system which would consist of waste stabilization lagoons that would discharge the effluent to the Rabbit River during periods of high flow [Lewis, 1975]. However, these plans were never followed through because there was a lack of public support for such a project. By 1970, a sewer bond issue, to provide enough funds for construction of the project, had been defeated by local referendum three times.

In 1970, the City Council was still persistent in its quest to construct a sewage system. In April of that year, the City Council entered into a contract with the Allegan County Board of Public Works for the construction of a wastewater collection and treatment system for the city. The legal authority for this action is spelled out in Act 185 of the Public Acts of Michigan, 1957. Under this act, the County Board of Public Works can act as the legal authority for the city in all phases of the construction of a treatment system. Additionally, the electorate in the local community does not have the referendum option in the bond issuing procedure. However, the county and the city must pledge its full faith and credit for the issuance of bonds to raise enough funds to cover the local share of costs of the system.

As might be expected many of the citizens in the local community were not pleased with the City Council's actions in the matter. Lewis [1975] stated that local leaders undoubtedly felt that although a sewer system had not been forced on the unsewered community as yet, various state agencies had been developing acceptable sewage alternatives since the early 1960s with local officials, and in the absence of positive local action, the state could force Wayland to install a sewage system at great disadvantage to the local people.

The contract provided that the Board of Public Works acquire and construct the system and upon completion of the system, let and lease it to the city for the period of the contract; 40 years or until such lesser time that the bonds issued by the county are paid in full. Operation, maintenance and management of the system are the responsibility of the city. The contract also spells out the regulations of the procedure for payment of interest and principal of the bonds by the city to the county. The city commencing in 1971 levies an ad valorem tax on all taxable property in the city in an amount which will be sufficient to pay such bond retirement obligations.

Plans for the type of system to be constructed were also changed in 1970. In addition to stabilization ponds, a spray irrigation site was to be included. Project consultants felt that this change was necessary because new rigid controls on phosphorus levels in effluent discharges were expected in the near future and that land treatment with application by spray irrigation would alleviate this problem. This plan was approved by the Michigan Department of Health.

Later in 1970 and early 1971, other problems began to appear on the scene. Initially, the bidding on the project was completed but the low bid for the project was about $500,000 more than was estimated. It was apparent to the City Council that they would have to back an increased bond issue and apply for additional state and federal grants to cover the unexpected difference in construction costs. The contract between the city and county would have to be amended to reflect this increase. The Allegan County Board of Public Works approved but since there had been quite a fight to get the necessary 3/5 majority vote of the County Commissioners to pledge the county's full faith and credit for the bond initially it was not surprising that they rejected this change in the contract. Within a short time the Board of County Commissioners changed its vote and approved the additional bonding.

The second problem concerned the proposed site for the wastewater treatment plant. Citizens of Leighton Township adjacent to Wayland were opposed to having the site near them, because they did not want Wayland's wastewater without some type of compensation. Wayland solved the problem by annexing the land to the city after purchase. The Leighton citizens asked for an injunction because they maintained the project would be a nuisance. However, the case was dismissed from court. After all these preliminary problems were solved and grant application had been approved, construction was started in the late spring of 1971. The system was essentially complete by December 1972.

Basically, the project consisted of construction of a collection system and treatment system comprised of three waste stabilization lagoons and irrigation fields. The 131.7 acre treatment facility is located in the northeast portion of the city. The treatment lagoons consist of one aeration lagoon with approximately one acre of surface area and two other lagoons being 15 acres each. The wastewater from the city is pumped into the one acre lagoon which has a floating aerator in it. From there the effluent moves through the 15 acre lagoons in series. Clorination is provided for the effluent before it is pumped to the irrigation fields.

During the late spring until early fall, the effluent is irrigated over approximately 53 acres of pasture. The pasture land is covered by timothy, alfalfa and clover. Two types of spray irrigation are used at the site. Approximately 33 acres of land are irrigated by a center pivot system. The Center Pivot system is similar to the type used at the Harbor Springs site. It consists of a pivot and automatic and manual controls located in the center of a circular field; the header piping supported by electrically driven towers which travel in gravel tracks; and sprinkler heads located along header pipe which is connected to the center pivot. The header pipe or boom with the spray nozzles rotates around the pivot. The speed of rotation of the boom can be selected by the operator depending on the optimum amount of effluent for production of the cover crop and wastewater renovation.

The system also has a traveling gun sprinkler which is mounted on a frame that contains an electric winch that pulls it along one of two available 10 acre fields.

A cover crop of mixed alfalfa, clover and timothy hay has been grown in the irrigation areas by local farmers. Originally three farmers agreed to remove the crop from the area. However, this arrangement did not work well because they could not agree on what responsibilities each of them had in the operation. As a result, they lost interest in the project.

However in 1976, a local farmer and the city reached a verbal agreement. The farmer would incur all costs of cutting the crop if the city did not receive any compensation for the land and crop. It is believed that local officials were happy to have the crop removed from the irrigation fields. That year, the farmer harvested 5,000-6,000 bales from the land. This required two cuttings on some of the area. The remaining portion was only cut once. In some cases, it was not cut again because it was too damp. The harvested crop was used for horse feed on the farmer's horse farm.

Operation of the farming plan is being altered for the upcoming year. Approximately 40 acres of corn are to be planted in the irrigation fields. The local farmer will sign a written contract with the city to split all costs and profits with the city on a 50:50 basis. The corn will be sold to local dairy farmers for feed. The city hopes to clear $6,000 in this agreement in the ensuing year. Money received from this operation will be used to defray operation costs.

Additionally, two local farmers have shown an interest in receiving the effluent water from the system for their private farm land. At present, there have been no arrangements or approval to do such a thing.

The approximately 132 acres at the treatment plant was purchased from a farmer for approximately $67,600 or $512 per acre. There were no apparent problems in negotiating. It was felt that the deal was particularly attractive for the farmer because the city was willing to pay for the land in cash. The site basically consists of sandy soils.

The total costs of construction of the system come to approximately $2,219,763. A four category list of the construction costs is below.

	(1971 $)
Land	$ 67,600
Building	157,253
Equipment	22,086
Treatment Facility and Collection System	1,972,824
Total	$2,219,763

At the time the applications were made for grant money, the project was eligible under the old Federal Law 84-660 and the state law which provided collecting sewer grants, P.A. 159, 1969. Because collecting sewers were not grant eligible under P.L. 84-660, the city made application for grants to cover a portion of the cost of the collecting sewer system under P.A. 159, 1969. The initial grants that were received from both federal and state sources totaled $629,937.

The project received $445,087 in state grant money for the collection system. This was approximately 30 percent of the eligible cost of the collection system. The treatment system portion of the plan initially received $16,800 from the Federal Water Pollution Control Administration or approximately 5 percent of the estimated eligible project costs. The initial state grant and advance were $84,025.00 each. The advance from the state was granted to the city in anticipation of an increasing share of the federal government's participation in grant allocation. The state is reimbursed by the federal government for the advance funds.

The grants, as they are at the present time, differ because of the change in the percentage that the state and federal government will fund and the reimbursement of the state's advance funding. Currently, the grants total $758,841 or approximately 35 percent of the actual cost of the project, or 40 percent of the eligible costs of the system. The federal and state grants and advance for the treatment portion of the system are $176,300, $104,124, and $31,947 respectively. This total is 75 percent of the eligible costs of the treatment section of the system. The collection grant from the state increased only slightly to $446,470, which is still approximately 30 percent of the eligible cost.

The county also issued general obligation bonds on behalf of the city in the amount of $1,435,000. These bonds mature in various amounts of principal until the year 1995 and bean interest rates ranging from 4.5 percent to 6.5 percent.

The City of Wayland previously levied a property tax plus a quarterly usage charge to cover the costs of debt retirement and operation. Annual principal and interest expenses have been paid with a combination of revenues from the system, and a 3 mill tax allocation. The user charge system combines a minimum quarterly charge with a 3 segment charge for different ranges of water use. The customer was previously charged at the rates listed below:

First 3,000 gal/quarter or a minimum of $16.50/quarter

Next 7,000 gal/quarter at $.60/1000 gallons

Next 90,000 gal/quarter at $.50/1000 gallons

Over 1000,000 gal/quarter at $.20/1000 gallons

These rates had to be adjusted because when they were originally estimated in the planning stage, it was anticipated that the community would grow enough that these rates would be able to cover expenses. However, the city stopped growing and the amount of operating revenue was not sufficient to cover costs. The new rates, which were adopted in July of 1976, are based on the size of the meter each user has. The majority of the residents have 3/4" meters so they are charged at a rate of $18.00/quarter plus $.60 per 1000 gallons. This rate change caused a small to modest increase in residential use charge. The larger users, however, experienced a dramatic increase in charge. Furthermore, this rate change meets federal regulations that require a city to collect revenue from industrial customers in proportion to the waste load contributed by the industry, for operation and maintenance and debt retirement. The previous rate did not do this because larger users were charged at a decreasing rate. There is an additional $260 tap in fee for connecting the sewer system.

After the new sewer rates went into effect the local officials found themselves faced with another problem. Electric rates were increased 144 percent for the system. At first it was feared that this increase would make it necessary to increase usage rates again. However, a recent conversation with a city official indicated that the city should be able to cover the costs of the system in the next fiscal year without a rate increase.

Operating costs for the system can be found in Chapter 5.

Middleville

The Village of Middleville is located on the Thornapple River in northwestern portion of Barry County, approximately 15 miles southeast of Grand Rapids. The area is characterized, in part, as a rural agricultural area. There are also numerous small lakes and forested areas in this area of the state that provide various forms of year-round recreation. Middleville has a population of approximately 1,800. Several small industries are located in the village, including a metal plating plant.

Previously, the Village of Middleville had a sewage treatment facility, consisting of an imhoff tank followed by chlorination and sludge beds. Due to an overload on the system, effluent from the plant was being discharged to the Thornapple River. In February of 1965, the Michigan Department of Health asked the community to institute a sampling and lab testing program on the effluent coming from the treatment facility. In January of 1968, the Water Resources Commission inspected the plant and determined that it was not adequate to treat the wastes of the community. Then in July of that year, the Michigan Department of Health recommended that the town take an option on land it had previously chosen to construct stabilization lagoons and spray irrigation facilities. Eventually 125 acres of land were purchased adjacent to the community. Some of this area is forested and other is pasture. Part of the area used to be a peach orchard. The land was acquired in fee simple title at $350 per acre; $25 more per acre than its assessed value. Officials of the community contended that they were willing to pay a little more for the property so it could be acquired with few problems.

Preliminary engineering work was done in 1969 and the recommendation was to allow effluent to flow from the proposed lagoons into the Thornapple River twice every year at a location downstream from the village. However, the Water Resources Commission stated that this type of treatment and discharge to the river was not adequate to remove phosphorus from the effluent. Plans were then altered and eventually the land treatment method of spray irrigation was selected. The go ahead was given to build two 11-acre waste stabilization ponds, a 30-acre spray irrigation site, and facilities in January of 1970.

In general, the local residents were not opposed to the construction of the project. This may be partly due to the fact that the local paper was supporting the project and an educational program was used to inform the residents of the need for the project.

In 1969, the village had applied for federal and state grants and in April of 1970, $230,000 of revenue bonds were issued by the village. At that time there was no existing County Department of Public Works to aid the village in the construction and issuing of bonds. A local official has mentioned that if the opportunity had existed the county would most likely have been asked to act in behalf of the community. The bonds are serial bonds which mature in varying amounts with various interest rates from the years 1971 until 1999. All bond expenses are paid from sewer revenues. Bonds maturing in the years after 1981 are subject to early redemption at the option of the village. Bonds called for redemption shall be redeemed at par and accrued interest to the date fixed for redemption plus a premium. Grants were awarded in late 1969 in the total amount of $220,000. The initial federal grant was $8,486 with the initial state grant and advance being $100,000 and $111,514 respectively. The total amount of the awards was 55 percent of the estimated cost eligible for grant participation. At this time, the cost of the land and site preparation for the land treatment process was not grant eligible. Estimated costs of the site were $50,000, while the actual cost of the land purchased was $43,750. Because the village previously had a collection system, there was not any application made for state collecting sewers grant money.

The initial grants were later revised several times because of the changes in estimated eligible costs and the amount of grant money the federal government would award. At the present time, federal grants total $145,440 with the state grant and advance being $79,562 and $13,684 respectively. Total grants are $238,686 or 75 percent of the total eligible cost of $318,248.

Total cost of this system is listed in the five accounts below:

	(1970 $)
Land	$ 33,780
Sewage Plant	309,182
Force Mains	24,554
Organization Costs	3,032
Equipment	11,882
Total	$382,430

In 1972, the first full year of operation, the water levels in the lagoons were not sufficiently high enough to permit use of the irrigation system, partly because the ponds were leaking to some degree. Measures were undertaken to alleviate the problem.

Currently the waste treatment plant receives approximately 220,000 gallons of municipal wastewater daily. The major sources of the wastewater are schools, residential, and commercial establishments. There is some industrial wastes but it is pretreated before it enters the municipal system. When the wastewater arrives at the treatment site, it is pumped into the first of a series of two 11-acre cells in the waste stabilization lagoon. These cells are run in series and are flooded to a depth of approximately 5 feet. From the second cell, the effluent flows to a chlorine contact chamber. The effluent is then pumped to the irrigation areas. The irrigation area consists of approximately 20 acres of land planted with corn each year. There is, in addition, approximately five acres of land with broam grass cover which is allocated for irrigation purposes when the corn irrigation area is too wet to be suitable for corn production. Additionally, two experimental tree irrigation areas, near the treatment site, are receiving effluent from the system.

After the effluent leaves the chlorine contact tank, it is pumped to the irrigation areas. The irrigation system, in the corn field, is a solid set spray system. Sprinklers are attached to four-foot risers which are connected to laterals which have been permanently placed in the ground. During irrigation times, two lateral irrigation lines operate for one hour at a time. At the end of the hour, the effluent will flow to two other laterals in the corn field. This system can be run on an intermittent basis or 24 hours a day schedule depending upon what is desirable for the treatment of the wastewater and corn production. Corn in the irrigation area is planted and harvested by a local farmer. The corn is dried and mixed with soybeans and other grain to make turkey feed. The corn field is classified as Plainfield sand characterized as droughtly, infertile and subject to wind erosion. In 1973, nitrogen fertilizer was added to the soil at approximately 615 pounds/acre. Fertilizer and lime have been applied in following years according to desirable management practices. Irrigation in May through July was intermittent but in August and September the average application per week was 2.6 inches. The rows of corn are spaced at 38 inches and individual plants grow very close in each row. During that year, the irrigated corn reached a height of approximately 6 1/2 feet. Corn outside of the spray irrigation area did not grow taller than approximately 1 1/2 feet. For the season, the yield for 22 acres was approximately 88 1/2 bushels/ acre of dry shelled corn or roughtly 200 bushels/acre of ears [Sutherland, 1974]. Average yield for all years since the operation began is approximately 80 bushels/acre.

The Village of Middleville has a verbal contract with the farmer who plants and harvests the irrigation area. Basically he gets use of the area for returning one-third of the revenue he receives from the crop to the village. Although the production of corn is secondary to the primary goal of wastewater treatment, efforts are made to irrigate in a suitable way for both corn production and wastewater renovation. The revenue the village receives from the farmers goes into the sewer fund to help cover operating expenses. The revenue from the corn production, that the village received in 1976, was $810.50. Previously, the revenue was believed to be somewhat higher in the neighborhood of $1,200.

The U.S.D.A. is also doing research on various species of trees at the Middleville treatment site. A 20-year old stand of red pine trees has been irrigated during the summer growing season. Various experimental plots in the stand have been spray irrigated to measure the performance of the trees and extent of nutrient renovation under different application rates. Cuttings and seedlings of hardwoods were also planted on the site in experimental plots to provide information on similar aspects as the red pine experiments.

The site also has another potential forest product. There is approximately 40 acres of hardwoods, as well as the five acres of red pine, which could possibly be harvested to generate revenue for operating and maintenance purposes or expansion expenses.

To date the system has been operating basically as expected. Nitrogen removal has been 83 to 92 percent and phosphorus removal has been at least 96 percent in the red pine stands [Sutherland, 1974]. In the summer of 1976, the corn field was characterized by areas of stunted growth. This appeared to be a soil deficiency in intermittent areas.

Currently the rates for use of the sewage treatment system involve the use of flat rates and variable usage rates. Each residential unit is charged at a rate of $6.00 per quarter plus $.72 per 1,000 gallons. Churches and clubs are charged $9.00 per quarter and industry is charged $6.00 per quarter plus $9.72 per customer equivalent rate designated for it.

The annual operating costs of the land treatment system are in Chapter 5.

Farwell

Farwell, a village of approximately 900 persons, is located in Clare County, near the center of Michigan's lower peninsula. Basically the area survives by the harvest of marginal farm land, a summer tourist trade, and some light industry located in or a short distance from the area. Two industries are located in Farwell. These companies manufacture plastic parts and automotive parts. Approximately 225 persons are employed by these two firms.

Previously, the Village of Farwell had no formal sewage collection and treatment facilities. Disposal was by means of individual septic tank systems. Many of these systems failed and as a result, discharged untreated or inadequately treated sewage directly and indirectly via storm sewers and open ditches into the Tobacco River. These discharges created conditions which were potentially injurious to public health and were a hinderance to recreational uses of the river and Lake Shamrock of Clare, which it drains into. Additionally, Farwell had many residences that pumped their water from relatively shallow water wells. The wells were in danger of being polluted from septic tank seepage.

In the late sixties, the situation became quite disturbing to the public. Raw, untreated sewage could be found in areas of the village. In 1968, several concerned village citizens circulated a petition in the village and presented it to the village council to request a feasibility study for construction of a sewer system. An engineering firm was eventually hired and preliminary studies were conducted. According to a local official, the engineering firm determined that a land treatment system would be the most economic way to treat the community's wastewater and would also eliminate any discharge to surface water.

After the preliminary engineering work was completed in 1970, the grant application procedure was started. The community decided to enlist the help of Clare County in August of 1970. At that time the village entered into a contract with the Clare County Department of Public Works for assistance in obtaining grants and bonds for the proposed system. The legal authority for such action is given under Act 185, Public Acts of Michigan, 1957. It was necessary for the county to act on behalf of the village because the village could only obtain bonds on a state equalized valuation of $1,986,580. The amount of bonds that could be issued by the village based on this valuation would be $198,580. This amount would not be enough to cover the local share of the costs of the system which would require a bond issue of about $725,000.

After the contract between the village and county was signed, the county issued revenue bonds in the amount of $725,000 on behalf of the village. The bonds mature in varying amounts until the year 1995 and bear interest rates ranging from 4 to 6 percent. Bonds which are due to mature after 1985 can be called for early redemption with various premiums from 1 to 3 percent. It is apparent there were no particular problems involved in getting the required 3/5 majority vote of the county commissioners to pledge the county's full faith and credit along with the village's pledge.

Basically the contract which was entered into between the county and the village for the construction of the wastewater treatment system is in effect for 40 years and provides that the county act as the official applicant and constructor of the treatment system. It provides for the leasing of the system to the Village of Farwell for the operation, maintenance, and management of the system. The contract also provides that the village be required to levy a tax to meet its bonded debt retirement obligations. The village incurs all costs of operation and maintenance of the system in addition to all the debts attributed to the bond issue.

Application for grants for this project was under Federal Law 84-660 and State Laws Act 329 of the Public Acts of Michigan, 1966 and Act 159 of the Public Acts of Michigan, 1969. The project was initiated before the Federal Water Pollution Control Act of 1972 came into being. Therefore, the cost of land and collecting sewers was not grant eligible. However, a collecting sewers grant was awarded under the State Collecting Sewers Act in the later part of 1970. Other grants were also awarded and total intial grants and advances for the treatment portion of the system were $109,230 or 55 percent of the eligible cost of $198,600. The federal grant was $9,930 and the state grant and advance were $49,650 each. The collection sewer grant from the state amounted to $362,855 or approximately 40 percent of the eligible cost of $924,367. After the federal portions of the grant program increased and all other adjustments were made, the final amounts of grants for the treatment portion of the system are $181,332. The federal grant increased to $107,450, with the state adjusting their basic grant and advance to $56,666 and $17,216 respectively. This is approximately 80 percent of the final cost eligible for grant participation of $226,666. Total of all grants for construction, including the collection system, is $544,187 or 47 percent of total eligible costs of $1,151,033.

The actual construction costs of the system can be found below:

	(1970 $)
Sewer System	$1,219,689.75
Equipment	2,608.43
Office Equipment	55.88
Total	$1,222,354.06

The amount listed for the sewer system includes the cost of the land for the treatment site of $4,200. Approximately 40 acres of land were purchased, approximately 1,000 feet outside of the southeastern portion of the village. The actual treatment process is composed of approximately 14 acres of land. Apparently, there were no major problems involved with the negotiations and purchase of the land. However, neighboring property owners insisted that the treatment area would lower the price they would be able to receive for their property if they wished to sell it. Therefore, the State Equalized Valuation of their property was lowered to some extent. The immediate effect of this action was that the property owners' property tax was reduced.

Farwell's treatment system was designed to be a flood irrigation type of operation. The system consists of a collection system which carries residential, commercial, and light industrial type wastes to the waste stabilization ponds through approximately 3/4 of a mile of force mains from the village. Approximately 63,000 gallons of wastewater is collected daily and pumped to two aerated lagoons which are run in series. From the aerated lagoons, the effluent flows to a 1.1 acre waste stabilization pond. When the project was in planning, it was expected that after the waste stabilization lagoon was full, it would discharge effluent to the two 3.4 acre percolation cells, which

were composed of basically sandy soils. However, the bottom of the waste stabilization lagoon was not sealed well and, as a result, was operated as a percolation cell the first few years of operation. During the past year, however, the waste stabilization lagoon has sealed enough to hold water as was originally planned. Effluent is currently overflowing into the first percolation cell and it is expected that effluent will be discharged to both percolation cells in the near future. In other words, the operation, in the past, was, at first, similar to flood irrigation. However, as water begun to accumulate in the first cell, its operation was similar to a seepage lagoon. Now that the waste stabilization cell is sealed, the system will be operating as a flood irrigation unit, discharging wastewater to the two percolation cells.

The charges which the village uses to cover operation, maintenance, and debt retirement costs are flat rates that are not based on usage. All taxpayers are charged two mills on their State Equalized Valuation of their property. In other words, they pay $1 for every $1,000 of one-half of their total assessed property value. This amount is used to pay bond retirement costs. In addition, all family residences are charged $5.00 per month regardless of how much wastewater they contribute. There is also a tap-in fee which increases $50.00 every May. Currently it is $1,350.00. Originally, a residence was charged $950.00 per unit factor or residential equivalent to connect to the collection system. Various other commercial and industrial establishments pay rates of $5.00 per each unit factor assigned them.

Local people seemed to be pleased with the system because it has alleviated their water pollution problems in the community, and feel that the community is better able to attract light industry because they have a system which would be able to handle the wastewater. The operation costs of this system can be found in Chapter 5.

Hart

The City of Hart, which is the county seat of Oceana County, is located approximately 50 miles north of Muskegon, a short distance from the eastern shore of Lake Michigan. Agriculture is the predominate industry in the area, which accounts for approximately 70 percent of the income. The area ranks third in fruit production in Michigan, with the major fruits being cherries, apples, peaches, pears, plums, prunes, and apricots. It is the nation's number one tart cherry producing area. There are six processing plants and other food processing related industries. Four of these fruit packing and canning factories are located in the City of Hart.

On May 21, 1971, the City of Hart was notified by the Water Resources Commission that they were violating the provisions of Act 245, Public Acts of 1929, as amended, in that they were failing to adequately control the polluting contents of sewage and wastes discharged into Chippewa Creek, Hart Lake, and the South Branch of the Pentwater River. At that time, effluent from the City of Hart's wastewater treatment plant was not meeting the established water quality standards, particularly because there was not adequate treatment for removal of phosphorus compounds. It was also determined that the wastes were becoming injurious to the public health and recreational uses of the state waters.

The city, at that time, had a wastewater collection and treatment system which consisted of waste stabilization ponds. The effluent from the system was discharged into Chippewa Creek. Additionally, several fruit canning companies had their own wastewater treatment facilities. These facilities, in some instances, were inadequate and, as a result, were under order by the Water Resources Commission to either limit production or provide additional treatment. In 1968 the Department of Public Health had informed the city that its existing lagoon system would not handle a sizeable increase in wastewater, particularly canning wastes. In 1969, the Water Resources Commission had informed Hart Frozen Fruit, Inc. that the waste disposal facilities for its cherry processing wastes were inadequate and that steps to assure proper disposal of wastes were needed.

The Department of Natural Resources suggested that the problems experienced with the various company-operated disposal systems resulted mainly from operation at or in excess of the capacity of the system and that proper engineering and operation of an industrial land dispodisposal system by the City of Hart would minimize these problems.

The stage was set for the planning and construction for a wastewater treatment system to adequately treat municipal and industrial canning wastes or the city would be faced with the possibility of closing industry, slowing of expanding industry, and further depression of an existing 13 percent unemployment situation.

Some planning had previously been conducted in 1970, but the project negotiation and planning really started to get underway in the summer of 1971. There were no major public objections to the proposed project and presently the city is happy that the waters in the area, particularly Hart Lake, are much improved.

The city began negotiations in September of 1971 with persons located on or near all the alternative sites of the proposed project. Negotiations were completed in January of 1972 and terms were agreed upon and options signed. Appraised value of the land was set between $300 to $350 an acre. Actual purchase prices ranged from $150 to $500 an acre. Condemnation was not necessary and all parties involved proceeded with the attitude that the project was necessary. However, at least one landowner agreed to sell his land to the city because he was told he would be able to continue farming on the land which was to be irrigated. This was when the plan called for spray irrigation instead of the current ridge and furrow system. Currently there is no farming allowed on the ridge and furrow area.

Negotiations were also conducted with the industries in the City of Hart. During the summer of 1972, contracts were signed with Vroom Cold Storage, Hart Frozen Fruit, Inc., W. O. Summers, and Silver Mills Frozen Food, Inc. to participate in the use of the municipal sewage system and to pay their fair share of the costs of the system. Other industry chose to operate their own waste treatment processes.

The estimated fair share of the cost incurred by the cooperating industry was estimated by considering three cost categories pertaining to the construction and operation of the waste treatment system. The three categories are the capital cost share due each industry, each industry's share in the bonded indebtedness of the city pertaining to the construction of the system, and each industry's share of the annual rate of payment for operation and maintenance of the city's treatment system. The estimates of each of the industry's share of the preceding cost categories were based on the industry's past effluent discharges. The contracts stated that changes in the costs of the treatment system and its operation would change the share of the cost incurred by each industry and that each industry would agree to abide by reasonable changes in the amounts allocated to them. The contracts pertained only to the costs related to the lift station and treatment plant and did not involve costs related to the construction and operation of the collection system.

During the period from 1970 to 1972, the city also applied for grants with the state and federal governments. Initial grants totaled $840,450. The federal grant was $560,300 or 50 percent of the estimated eligible project cost which was $1,120,600. In addition, the initial state grant was $280,150 or 25 percent of the eligible cost.

Applications were also filed with the Economic Development Administration-U.S. Department of Commerce for a supplemental grant covering the cost of the collection system. At that time Oceana county was considered an economically depressed area eligible for such grants. In the fiscal year 1970, the Economic Development Administration made a grant of $280,000 or 80 percent of the eligible project costs of $350,000 for improvements and extension of the previously existing collection system.

On May 12, 1972, the Hart City Council authorized the issuance of a total of $595,000 in bonds to cover the local share of the costs of the wastewater treatment system. General obligation bonds in the amount of $230,000 were issued in $5,000 denominations. Bonds mature in the years ending June 30 from 1974 to 1993. Various interest rates are applied over these years. Bonds maturing after 1983 are subject to redemption prior to maturity at various percentages of par value.

The issue also provided for $365,000 of revenue bonds. These bonds are also in $5,000 denominations and mature in various years from 1974 to 1995. They are also subject to varying interest rates. Bonds maturing in the years 1984 and after may be called for early redemption at the option of the city at par value and accrued interest to the date fixed for redemption, plus a premium varying from 1 to 3 percent.

The city is also responsible for a previous general obligation bond issue in 1963 for $245,000. These bonds also have varying interest rates and mature in various years until 1993. These bonds were issued for the purpose of making improvements, extension and enlargements to the previous wastewater treatment system.

As of June 30, 1976, the construction costs of this sytem are as follows:

Land	$ 67,659.31
Equipment	6,733.00
Construction	1,176,533.75
Engineering and Legal	187,989.32
Total	$1,438,915,38

Total grants covered approximately 80 percent of these costs or $1,176,480. This includes grants of $616,330 from the

Environmental Protection Agency and $280,150 from the state and $280,000 from the Economic Development Administration. EPA and state grants covered 80 percent of the eligible costs.

The land treatment component of the wastewater treatment system is the ridge and furrow type. However, initial plans considered a spray irrigation system for use in place of a ridge and furrow system. The initial plans were changed, however, because the city was not able to secure enough land for a buffer zone required by the Michigan Department of Health. The department was requiring the system to have a 1,000-foot buffer zone around the 80 acres of land, which were to be used as the spray irrigation area. Additionally, the engineers felt that the cost of the application system in the ridge and furrow system would be less expensive than a spray irrigation system.

Land treatment was considered from the start of the planning, basically, because the wastewater treatment system would be handling industrial wastes. The Water Resources Commission and Department of Natural Resources recommended land disposal because it provides one of the most desirable methods of disposal of fruit and vegetable canning wastes. They felt it was especially appropriate and necessary for the Hart area to adequately protect water quality and uses of Hart and Pentwater Lakes.

The wastewater treatment system currently includes a collection system which serves 1,815 persons and the industry's various food processors in Hart.

The wastewater, consisting of approximately 75 percent residential type wastes and 25 percent industrial wastes, is pumped to a lagoon system which consists of two aeration ponds which are aerated by structurally fixed aeration equipment. Each of these ponds hold approximately 9 million gallons. Additionally, there are three waste stabilization ponds which hold a total of approximately 89 million gallons and cover an area of approximately 31 acres. The previously existing lagoons were modified and incorporated into this system of ponds. The total lagoon site is approximately 60 acres. The ponds are run in a series with the wastewater receiving treatment as it passes through the series of ponds beginning at the initial aeration pond. After the effluent is "treated" in the ponds, it is chlorinated and pumped to the 160-acre irrigation site which is located approximately one mile east of the waste stabilization lagoons. Because of the makeup of the soils at the lagoon site (mainly clay), it was necessary to locate the irrigation site at this distant location. The soils at this site are predominately Kalkaska Loamy Sand which is relatively porous soil.

Effluent is distributed at the irrigation site by gated aluminum pipe which rests directly on the ground and runs perpendicular to the ridge and furrows. The 6-inch pipe has gate apertures in its side which can be opened at various intervals, up to approximately 1 1/2 inches, to apply water at varying rates to the furrows constructed in the soil. The application system is set up in approximately 10 8-acre units. Each 8-acre unit is irrigated for approximately one hour at a time. Automatic equipment turns off a unit after one hour and switches on another 8-acre unit. The system can be operated at various intervals up to 24 hours a day depending upon what is needed to accommodate varying waste loads.

The actual treatment area is only approximately 80 acres which is composed of open meadows and wooded areas consisting mainly of pines. It is hoped that the trees will be harvested at a future date. On the remaining 80 acres, which are not irrigated, there are 40 acres of land which are planted with corn and asparagus each year.

Since the 1973 growing season, a local farmer has harvested approximately 18 acres of corn and 12 acres of asparagus. The corn is either picked or chopped and fed to livestock on the farmer's farm. The asparagus is sold to local food processing industries. The farmer originally started out with a one-year lease that was renewed each year for the following two years. At the beginning of the fourth year, a three-year lease agreement was entered into between the city and farmer. For use of the 18 acres from which corn is harvested, the city receives $240 per year. Additionally, 30 percent of the gross that the farmer receives from the 12-acre asparagus crop is returned to the city each year. This amount has been approximately $900-$1,000 per year for the past four years. The farmer incurs all costs of planting and harvesting the crop. Further interest has been expressed by the farmer for using the wastewater effluent to irrigate his own private farm land. Although the city has shown some interest to cooperate in this effort, there has been no approval from the regulatory agencies for such action.

Previously it was mentioned that contracts were signed with four industries to pay for their fair share of the construction and operating costs of the system. Since the originals were signed in 1972, there have been some changes. Basically, the change has come about because of the changes in the costs of operating the system, particularly the increasing cost of power. A local official stated that the electric rate has tripled since operation began. Additionally, the industry's fair share of the construction costs has changed to some degree because Hart Frozen Fruit, Inc. has gone out of business. W. O. Summers has expanded their business to the Hart Frozen Fruit's previous location. At least part of the reason for Hart Frozen Fruit's closing had to do with the increased cost of handling their wastewater properly. Various cost recovery methods have been tried with the industries to cover the increasing operating costs of the system. One method included a variable rate of charge dependent upon the amount of effluent and the number of pounds of BOD discharged by the industry. Apparently, local officials could never come up with a system of charge which would collect the necessary revenue to cover costs. The current system which is being used, a fixed charge, is expected to solve the problem. The schedule for the industry charges is presented below:

Silver Mills Frozen Food, Inc.	$16,000/quarter
W. O. Summers	$ 2,500/quarter
Vroom Cold Storage	$ 60-70/quarter

At the end of the year there may be additional adjustments made to reflect changes in usage and costs of the operation of the system.

The residential charges are based on a variable and fixed charge. Currently the residential customer pays $.64/1,000 gallons with a minimum of 10,000 gallons or $8.60/quarter. Originally, the fixed portion of this charge was $5.00/quarter for a minimum of 10,000 gallons. It is estimated by the consulting engineering firm that each residence pays approximately $60/year. There is an additional tap-in fee of $200 for each sewer connection.

The operating costs for the system can be found in Chapter 5.

Dimondale

Dimondale is located in the central part of Windsor Township in Eaton County, approximately seven miles southwest of the City of Lansing. The village is divided by the Grand River and made up of numerous small lots which were previously served by individual wells and septic tank systems.

In earlier years, the village had a good number of businesses for a small village. However, near the turn of the century, the village industries began to dwindle and the railroad discontinued service to the village. In more recent years, there has been relatively little development. Although the population has increased somewhat in the last decade, the village remains basically characterized as a bedroom community of the Lansing area.

In the late fifties, Michigan Associates of Lansing prepared a comprehensive report for a water supply and sewage system for Dimondale. A survey, at that time, showed families responding were about 50:50 in favor of a sewerage system but decidedly opposed to a water system. This was probably due to the cost which would be incurred.

In July, 1963, an Indiana firm made a report on a sewer system for the villages. However, the report was not well received by the residents and a subsequent public vote for a sewerage treatment system was unfavorable. The village was unsuccessful in an application for a federal grant at that time. All homes within the village were then served by septic tanks, a few of which may have been connected to storm drains which discharged into the Grand River.

By June of 1966, the Village was placed under order by the Michigan Water Resources Commission for violating state law by allowing sewage from the Village to be discharged into the Grand River. The Village of Dimondale appealed the order of determination in the circuit court of Eaton County. On December 26, 1968, the court handed down a decision. It ordered the village to comply with the Water Resources Commission determination. The court order instructed the village that construction be completed and the wastewater treatment facilities be operational before June 1, 1970. After this date the village would be restrained from discharging untreated wastes into the Grand River. While this appeal process had been going on in 1967, Dimondale was again unsuccessful in an application for a grant for the wastewater treatment facilities from the Department of Health, Education, and Welfare.

The village must have anticipated the court decision because plans and specifications had previously been completed in June of 1968. Construction bids were advertised for in the following year and construction contracts were awarded in December 1969.

During the summer of 1969, there was some discussion of hooking up to a regional system in Delta Township's sewage facilities which were going to be extended to serve the secondary state capital complex, which was being planned at that time. This turned out not to be a viable alternative becuase of the time factor. The village had to award contracts by December 31, 1969 or lose expected clean water grant money from the state.

Because of the need to issue bonds to cover the local share of the cost of the sewage treatment system it was necessary for the village to enter into a contract with Eaton County. This contract between the village and Eaton County, for the purpose of establishing a wastewater treatment system for the village, was signed in November of 1969. Authority for a contract of this type is given in Act 185, Public Acts of Michigan, 1957. Under this contract, the County Department of Public Works acquires and constructs the treatment system for the village. The County Board of Public Works acts as the legal authority for the village in all grant applications and other contractual obligations for the purpose of constructing the system. However, the village actually leases the system from the county and is responsible for the operation and maintenance of the treatment system and all costs incurred with the operation. Furthermore, the village did have the responsibility of purchasing the necessary land for the project.

On March 1, 1970, Eaton County issued and sold revenue bonds in the amount of $510,000.00 to cover the cost of the local share construction. The bonds are serial bonds which are subject to varying interest rates and mature in various years until the year 1990. The village must pay the installments and all interest and service charges attributed to the bond issue. This bond issue had to be approved by a 3/5 majority vote of the Board of Supervisors of Eaton County. In addition, the village pledged their full faith and credit for its obligations and will each year maintain a tax on all taxable property in the village in an amount which will be sufficient to pay such obligations.

This project was also able to receive grants from both state and federal governments. The initial federal grant was in the amount of $8,288 with state grants and advances being $100,125 and $111,862 respectively. The total grant represented 55 percent of the estimated eligible project cost of $400,500. At the time when the grant applications were made, the costs of the land and collection systems were not eligible for grant participation. However, a state collecting sewers grant was available in the amount of $109,732 under Act 159, Public Acts of 1969. Land which had previously been purchased for the treatment area did not receive any form of grant money. Initially, the village purchased 25 acres of land at a cost of $1,000/acre. Eight more acres of land were purchased later to make the treatment site contiguous with existing village property for the purpose of annexation. Eminent domain was not required although negotiations for the purchase involved some problems but they were eventually taken care of. The quantity of land purchased is large enough for a 200-foot buffer zone around the treatment site.

A number of alternative methods of treatment were investigated, but the two methods given major consideration were a total lagoon system and a small package secondary treatment plant. The consulting engineers preferred the construction of a conventional secondary treatment plant as opposed to a lagoon system. This type of plant was favored largely on the basis that the required amount of low-cost land for a lagoon system was not readily available. The only lagoon site was costly and a good distance from the village.

Additionally, the engineers felt that due to the porous nature of the soil on the site, that it would be expensive to line the lagoons with impervious material. The conventional type plant would require a much smaller parcel of land and would be located closer to the village. However, it was estimated that this type of plant would have higher operating costs than a lagoon system. Estimated costs showed the lagoon system being $150,000 more than the conventional type plant. This divergence was mainly due to the difference in land costs and the additional number of feet required in force mains and other collecting piping for transporting the wastewater to the lagoon site.

The conventional type plant was to be followed by a seepage lagoon unit. The four-cell final effluent seepage lagoon was chosen to provide tertiary treatment and phosphate removal. It also alleviated all discharge of wastewater to the Grand River.

The plant now in operation serves approximately 972 persons and receives, on the average, approximately 55,000 gallons of wastewater per day from residential, commercial and school sources. An additional 15,000 gallons of wastewater from two restaurants outside of the village are received at the plant daily. Wastewater enters the plant and, initially, passes through an aerated mechanical grit chamber. The wastewater then flows to the activated sludge processing units that use extended aeration and circular secondary clarifier units with mechanical skimming after the activated sludge process the effluent is chlorinated and pumped to the four seepage lagoon cells which are approximately one acre each. Each cell is flooded to a constant depth of approximately two feet. Upon reaching the four-cell seepage lagoon, the effluent has had 90-95 percent of the BOD and suspended solids removed. In the seepage lagoon cells, the effluent drains through the bottom of the cell into the sandy soil. Since there are four cells, one can be dried out for general operating and maintenance purposes while the others are still in operation. Additionally, these seepage cells can be kept in operation on a year-round basis and do not have to be shut down like other methods of land application.

Sludge is mechanically removed from the clarifier and pumped to an aerobic sludge digestion unit and sludge drying beds. The sludge is then raked from the drying beds and stored nearby. Currently, the sludge is given away to local people for use on the gardens and lawns.

The total cost of this treatment system is listed below in four categories:

Land acquired from 1969-1972	$ 31,573.50
Collection system, 1971-1972	474,856.83
Treatment plant, 1971-1972	424,963.88
Equipment, 1971-1974	7,074.54
Total	$938,468.75

After all readjustments were made in the grants for this project, they totaled $430,551. At the present time, the EPA grant is $199,670 with the state grant and advance being $98,096 and $16,140 respectively. The State of Michigan, also, made a collecting sewers grant in the amount of $116,645.

The village also made several cash contributions to the construction funds. A transfer of $3,471.67 was made from the street fund to pay for a portion of the costs of street repairs as a result of sewer main excavation a transfer from the general fund totaling $38,823.50 to cover the cost of the land, engineering fees and a financial study.

Currently the Village of Dimondale charges each household a flat charge of $11 per month. Of this amount, $5.00 goes to the operation and maintenance of the system, and $6.00 is used for debt retirement. There is also a $500 tap-in fee to connect to the collection system. The annual operating costs can be found in Chapter 5.

Table 3. Summary of Physical, Financial, Agricultural and Institutional Characteristics of the Land Treatment Systems

Municipality County	Harbor Springs[1] Emmet	Harbor Springs[2] Emmet	Wayland Allegan	Middleville Barry	Farwell Clare	Hart Oceana	Dimondale Eaton
Application Type	Spray	Flood	Spray	Spray	Flood	Ridge & Furrow	Seepage
Population Served	W 3,580 S 5,800	S 7,500	1,860	1,800	900	1,815	972
Design Flow (MGD)	.450	Total I&II 1.0	.500	.220	.135	.900	.200
Lagoons (Acres)	22	18	31	22	1.3	31+	Conventional Secondary Treatment
Irrigation Area (Acres)	28	50	53	30	6.8	80	4
Total Area (Acres)	423	Additional 158	131.7	125	40	220	33
Agricultural Management	Forest Service Research		Cover Crops and Corn	Forest Service Research, Corn		Corn, Asparagus from Around Site	
Michigan Act	233, 329	233, 329	185, 159, 329	329	185, 159, 329	329	185, 159, 329
Federal Act	84-660	92-500	84-660	84-660	84-660	92-500	84-660
Total Construction Cost	(1970) $1,274,287.40	(1974) $5,930,731	(1971) $2,219,763	(1970) $382,430[3]	(1970) $1,222,354	(1972) $1,438,915[4]	(1969-1971) $938,468
Present Federal Grant	$ 461,700	$4,310,000	$ 176,300	$145,440	$ 107,450	$ 616,330	$199,670
Present State Grants	$ 273,572	$ 287,335	$ 550,594	$ 79,562	$ 419,521	$ 280,150	$214,741
Present State Advance	$ 85,443		$ 31,947	$ 13,684	$ 17,216		$ 16,140
Amount of Bonds Issued	$ 550,000	$1,650,000	$1,435,000	$230,000	$ 725,000	$ 595,000	$510,000
Type of Bonds	Revenue	Revenue	General Obligation	Revenue	Revenue	Revenue & General Obligation	Revenue
Total Construction Cost (1976 $)	$2,378,417	$7,144,796	$3,694,555	$712,732[3]	$2,272,650	$2,168,252[4]	$1,564,080
Miscellaneous				Corn used for Turkey Feed		Local Industry Involved with Financing. EDA Grant of $280,000.	

[1]Project I

[2]Project II

[3]Costs do not include previously existing collection system.

[4]Costs do not include previously existing system which were incorporated into the 1972 system.

CHAPTER 5

COST COMPARISON ANALYSIS OF LAND TREATMENT AND CONVENTIONAL TREATMENT SYSTEMS

This chapter presents data on the construction and operating costs of the six land treatment systems previously discussed plus four conventional treatment systems. A brief description of the technology used in each of the conventional systems is also described. A comparative cost analysis of the land treatment systems and conventional treatment systems is presented to identify which systems in general have the lowest operation costs. Although construction costs of alternative systems can be estimated fairly accurately, it is more difficult to estimate the operation costs. However, this analysis should show generally which operation costs are lower for the two general types of systems.

Before presenting the cost comparison analysis, it is necessary to present some basic information on the conventional treatment systems so the reader has a basis on which to compare types of treatment systems and their costs. The information on the four conventional systems follows.

Jonesville

The Jonesville wastewater treatment system is basically a conventional primary and secondary treatment plant for residential and commercial strength wastewater. Secondary treatment is accomplished

with the use of a trickling filter. Phosphorus is removed from the wastewater with the use of chemicals. The system also uses anaerobic sludge digestion and sludge drying beds. After the sludge has been dried, it is mixed with refuse and disposed of at a landfill site. Sludge from the treatment plant is also used for surface application on agricultural land.

When the system was constructed in the early 1970s, it cost approximately $915,000. Currently, advanced wastewater treatment units are being planned and constructed.

The rates for use of the system for residences are listed below.

0 - 6,000 gals/quarter	$9.00 minimum
7,000 - 13,000 gals/quarter	$ .75/1000 gallons
14,000 - 28,000 gals/quarter	$ .60/1000 gallons
29,000 - 48,000 gals/quarter	$ .54/1000 gallons
48,000 and over gals/quarter	$ .36/1000 gallons

Luna Pier

The Luna Pier plant serves approximately 1,418 persons. Wastewater is of the residential and commercial type. The conventional plant uses the activated sludge process for secondary treatment. Phosphates are removed with addition of chemicals in the primary treatment process. Sludge from the system is dewatered in a sludge centrifuge and burried on available land at the plant site.

Construction of the wastewater treatment system in 1969 and 1970 cost approximately $1,961,260. Four categories of the capital investment are listed below.

Land	$ 6,500.00
Treatment Plant	436,159.73
Equipment	467,392.85
Sewer Lines	1,051,207.50
Total	$1,961,260.08

Residences connected to the system are charged at a rate of $50 per year for the use of the wastewater treatment system.

Constantine

Constantine's wastewater treatment system serves both residential and industrial customers. Industries served by the system consist of a creamery and papermill. The treatment plant uses the conventional process which incorporates a conventional activated sludge unit in its secondary treatment process. Chemical coagulation is used for phosphorus removal only. Sludge digestion and conditioning are accomplished with anaerobic digestion and open sludge drying beds. All sludge which is removed from the drying beds are applied to agricultural land around Constantine.

The initial wastewater treatment system was constructed in 1965 for $211,814.62. In 1972 the system was expanded and updated at a total cost of $1,263,088.08.

Currently the system serves approximately 1,720 persons. Each residence is charged $10 per month. Commercial and industrial users pay a monthly rate based on the following schedule:

0 - 10,000 gals/month	$10.00 minimum
10,000 - 100,000 gals/month	$ .95/1,000 gallons
100,000 - 1,000,000 gals/month	$ .90/1,000 gallons
Over 1,000,000 gals/month	$ .85/1,000 gallons

An additional charge may also be added if industrial or commercial users impose a heavy burden on the treatment system.

Imlay City

The Imlay City treatment plant, which serves approximately 1,965 persons, is a conventional treatment plant which uses a trickling filter in its secondary treatment process. Currently, there is not a process for phosphorus removal. Anaerobic sludge digestion is also incorporated into the system. Sludge is dried on open sludge drying beds. After it is removed from the beds it is piled on the plant grounds until it is removed to a landfill site.

This system, which serves residential, commercial and light industrial customers, is the oldest system included in this study. The original system in this community dates back to the late 1950s. In the early 1970s the system was improved and enlarged. Because the system dates back several years, the actual construction costs of the system is unavailable. However, expansion in the early 1970s cost approximately $702,673.66.

Imlay city uses a wastewater treatment usage charge based on the amount of water used by each residence from the public water supply system. Residences, commercial, schools and churches are charged 100 percent of the water charge. The usage rate at which the charge is based is listed below.

0 - 5,000	gals/quarter	$14.87 minimum
5,000 - 70,000	gals/quarter	$ 1.04/1,000 gallons
70,000 - 450,000	gals/quarter	$ .75/1,000 gallons
Over 450,000	gals/quarter	$ .60/1,000 gallons

Comparative Cost Analysis Accounts

The information on the capital investments and operation costs of the systems has been collected from local community officials and the local governing unit's audit reports. The information on operation costs has been combined into several accounts. These accounts are summarized below.

Salaries and Wages - All labor expense for general operation, maintenance and administration of the system.

Utilities - Expenses attributed to power for pumping and treating the wastewater in the system.

Supplies Expense - Cost of supplies for operation of the treatment system.

Maintenance - Cost of supplies and parts for maintenance of the system.

Equipment Rental - Expense for rental of equipment from private parties and other public departments in the community for operation and maintenance purposes.

Professional Services - Fees for engineering services by a consulting engineering firm.

Outside Services - Costs reflect expenses for operation and maintenance services provided by a private firm or other public department within the community except where specifically described differently.

General Office Expenses - Costs of maintaining an office for administrative purposes such as billing and collection, bookkeeping, auditing, legal expenses, and correspondence with regulatory agencies, private firms and the general public.

Insurance - Expense for insurance on property, plant and equipment. This does not include health insurance, workers compensation or unemployment insurance.

Transportation Expense - This is allowance for travel by local officials which concerns general management of the system.

The operation costs for each of the systems are presented in Appendix A using the preceding accounts. Each chart has several dates and numbers at the top of the columns which contain operation cost information. The cost data are presented for the fiscal year ending at the indicated date at the top of the column. The number above each date is a code number assigned to that date for purposes of graphic and linear regression analysis. The expense in actual dollars is presented in each account along with the respective costs on the basis of dollars per 1,000 gallons treated. The later calculation was made based on a 365 day year and the average daily flow rates for each respective system.

For cost comparison analysis it has been necessary to group several accounts together in categories because of differences in the actual audit report accounts of each community. When data were collected, an effort was made to match the audit report accounts as closely as possible with the accounts defined in this study.

However, due to some differences in the data, it was best to group some of the accounts into the following categories. The categories should be comparable across systems.

Expense Categories:

1. Salaries and Wages
2. Utilities
3. Operations and Maintenance
   a. Supplies
   b. Maintenance
   c. Equipment rental
   d. Professional services
   e. Outside services
   f. Miscellaneous
4. General Administrative
   a. Office
   b. Insurance
   c. Transportation

The operation costs of the land treatment and the conventional treatment systems are plotted using the preceding categories and combinations thereof. In addition, linear regressions are plotted for operation costs incurred for all conventional treatment systems and land treatment systems. For linear regression analysis, the Dimondale treatment system costs were included in the conventional treatment group regression. This was done because of the Dimondale system's characteristic conventional primary and secondary treatment processes.

The figures on pages 107 through 112 present the operation costs on a basis of dollars per 1,000 gallons treated for each corresponding fiscal year.

Comparative Cost Analysis of Operation Expenses

To begin the comparative cost analysis, it is best to focus on the total costs of all categories displayed on Figure 11. The total cost curves position on this figure are influenced by each cost category which are plotted on Figure 6, 7, 8 and 10.

From Figure 11 it appears that the Hart land treatment system consistently has the lowest total operation costs of all the systems in the study. This is due to the fact that this system, in general, has the lowest cost per 1,000 gallons treated in all the other operating cost categories, except utilities.

Above the Hart system on the figure, there is a good deal of intersection of the curves. However, it appears that the land treatment systems operated by Middleville and Harbor Springs and the conventional treatment system at Imlay City are the next most consistently inexpensive systems to operate relative to the others. There are several points which do need to be clarified in terms of these systems to explain their operation costs. The Imlay City treatment plant does not use any process for phosphorus removal. If chemical coagulation or any other process were instituted, the operation costs would be higher. The peak in the Middleville system's cost curve is due to an expensive engineering study which was conducted during the 1974 fiscal year. This study, which amounted to several thousand dollars, would usually not be incurred very often by any type of treatment system.

The Middleville system has the second least expense of the systems in terms of salaries and wages. This may be so because much of the system is automated. In terms of the general operation and maintenance category, the curve would most likely be relatively flat and very close to the curve for the Harbor Springs system if the expense of the engineering study was not included.

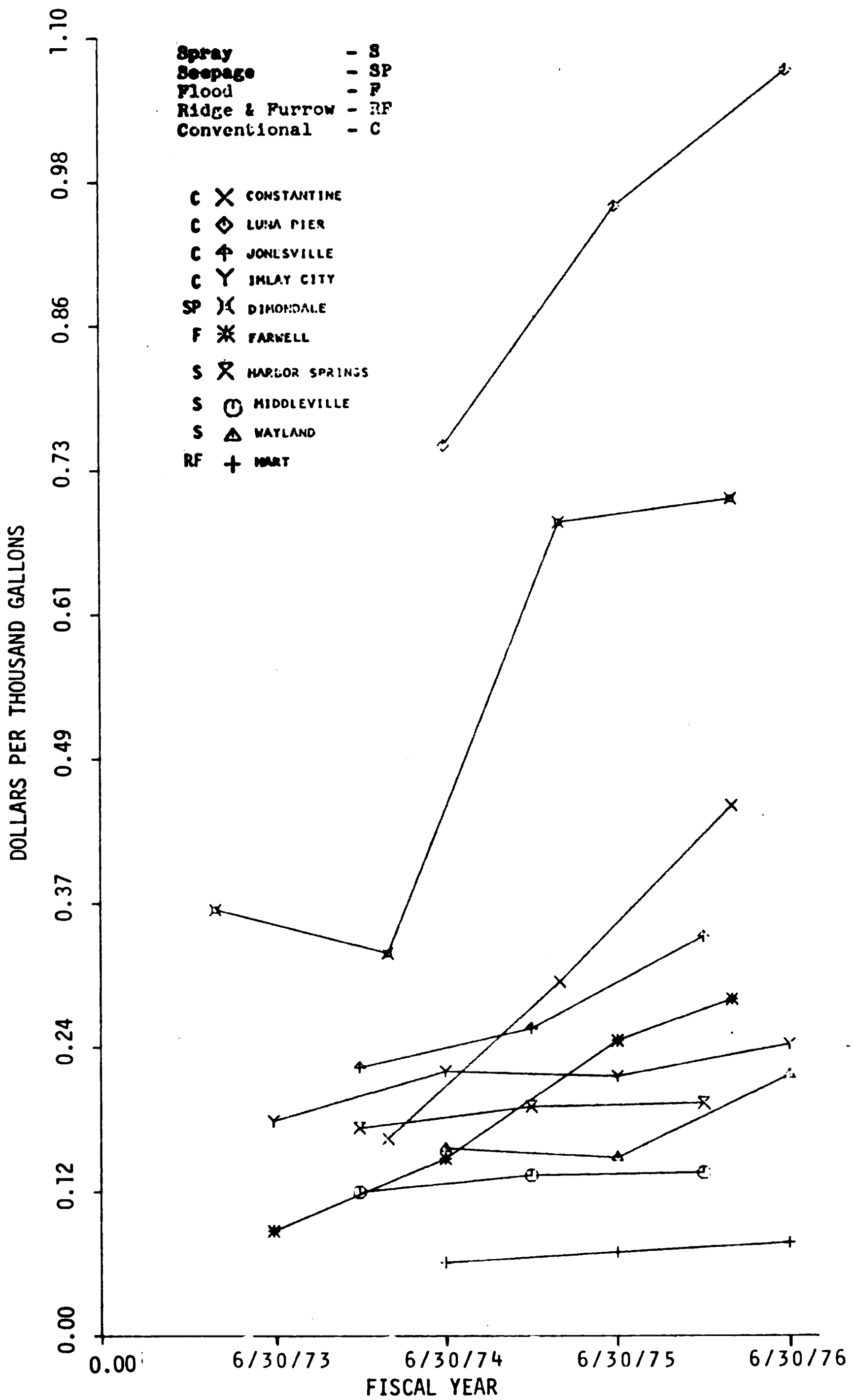


Fig. 6. Salaries and wages expense

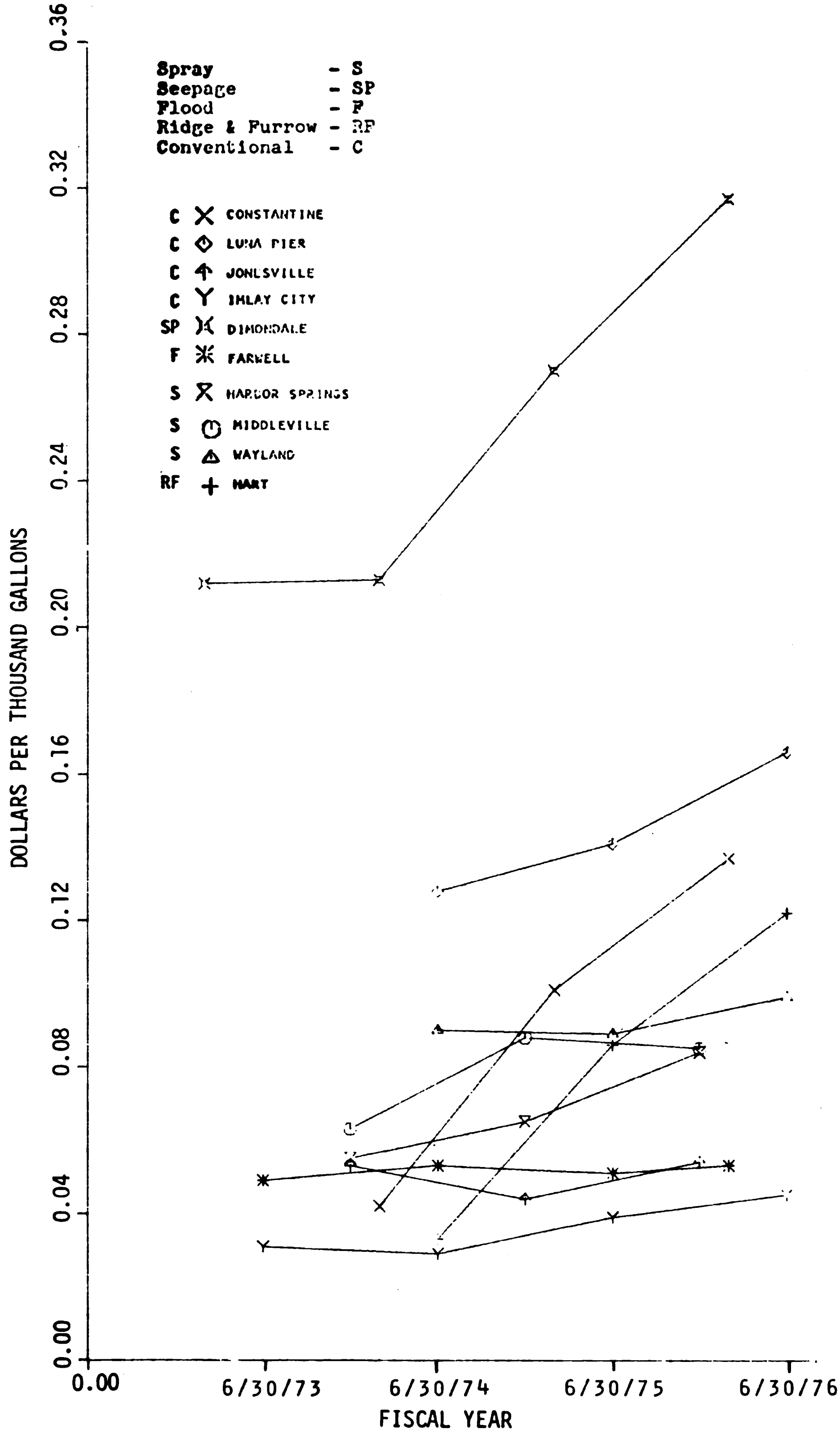


Fig. 7. Utilities expense

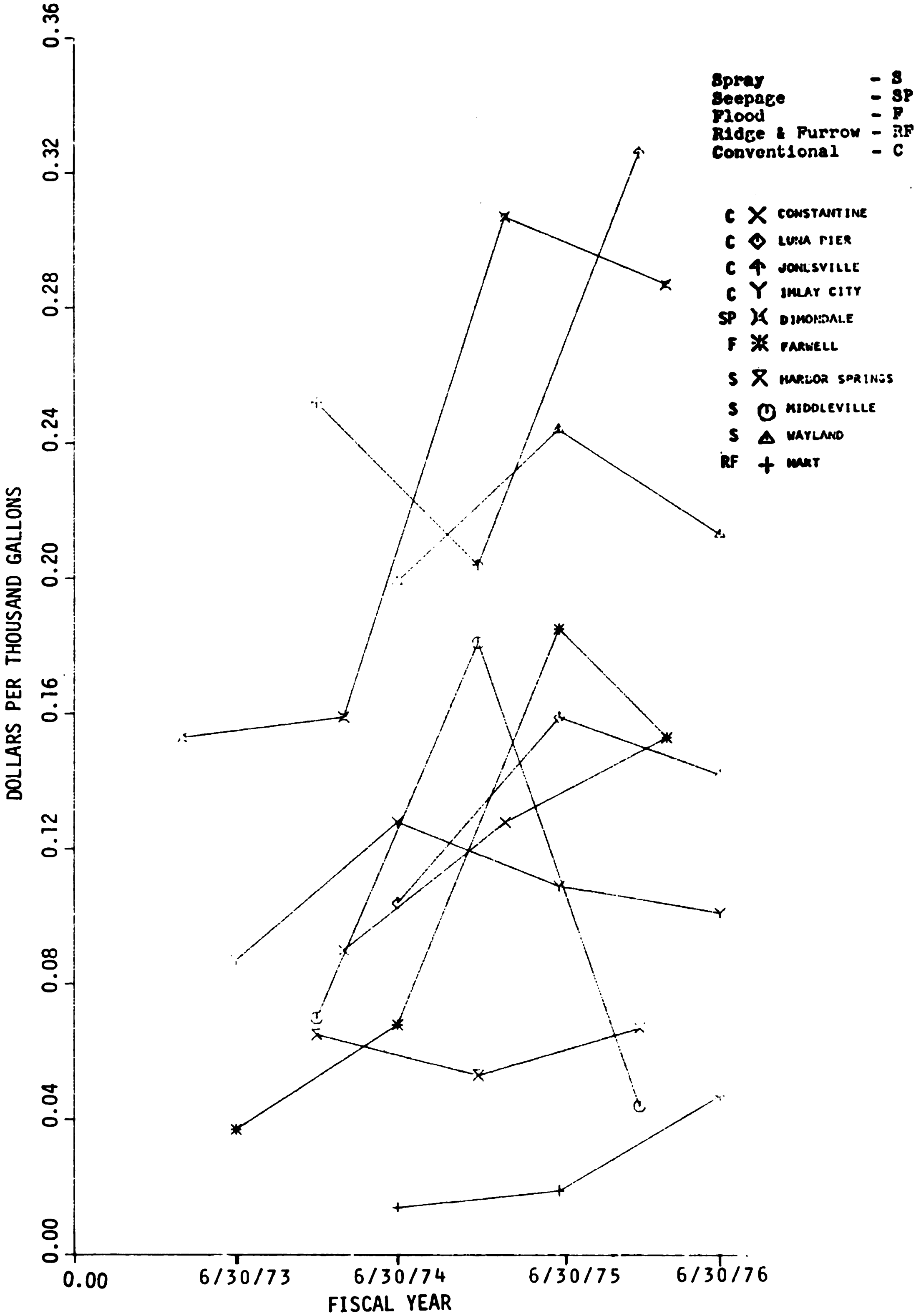


Fig. 8. General operation and maintenance expense

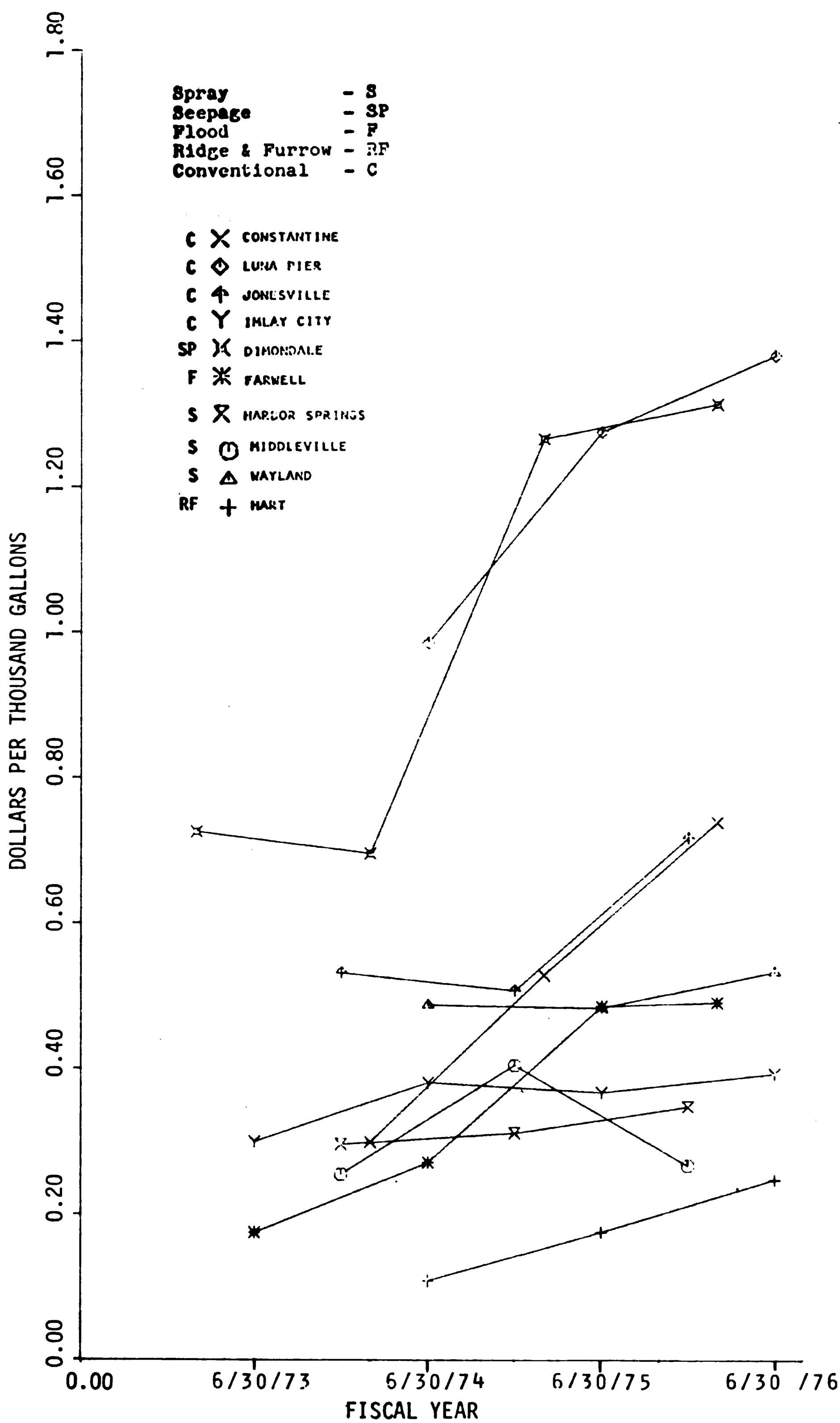


Fig. 9. Total of categories I, II, III

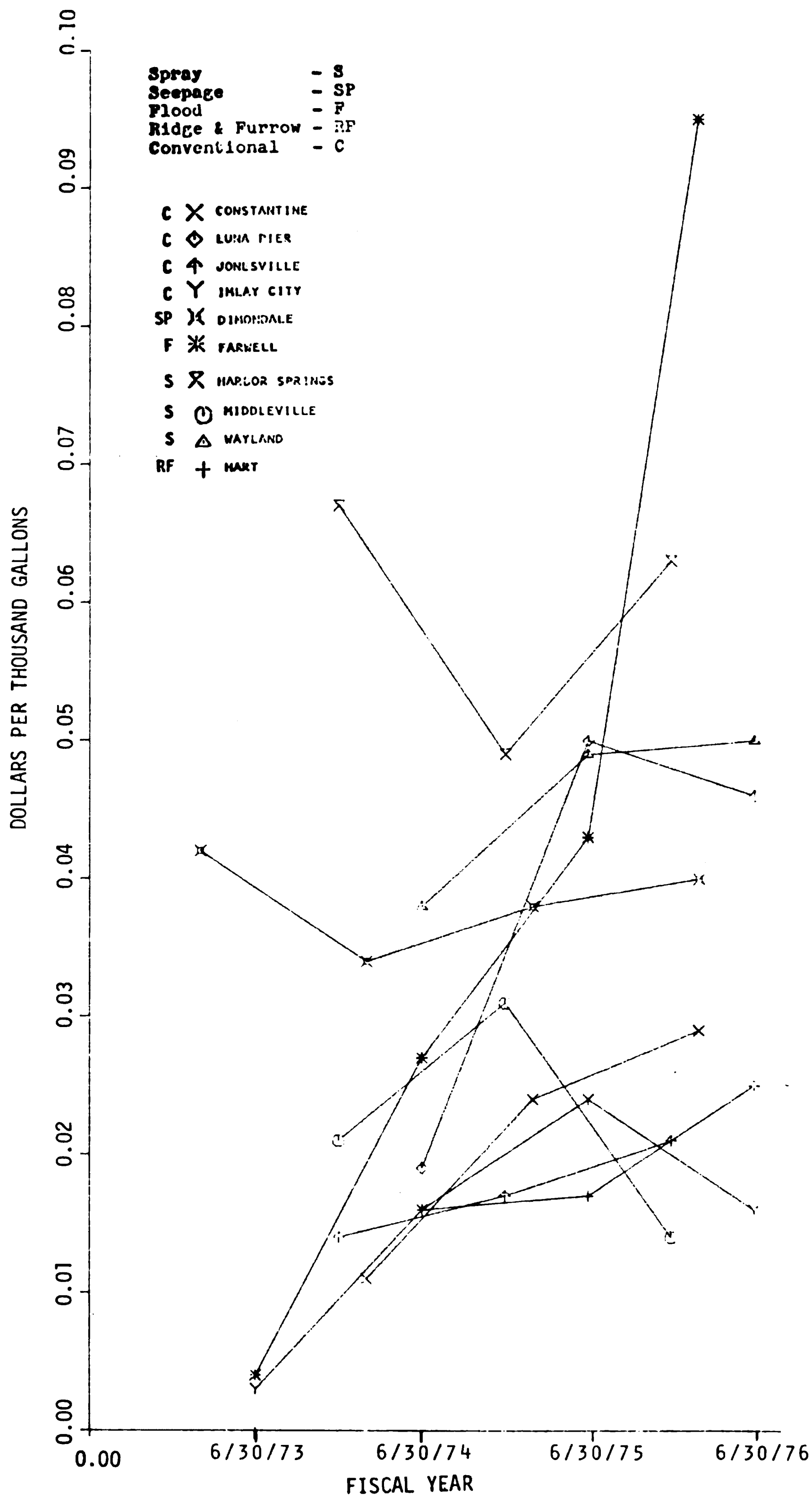


Fig. 10. General administrative expense

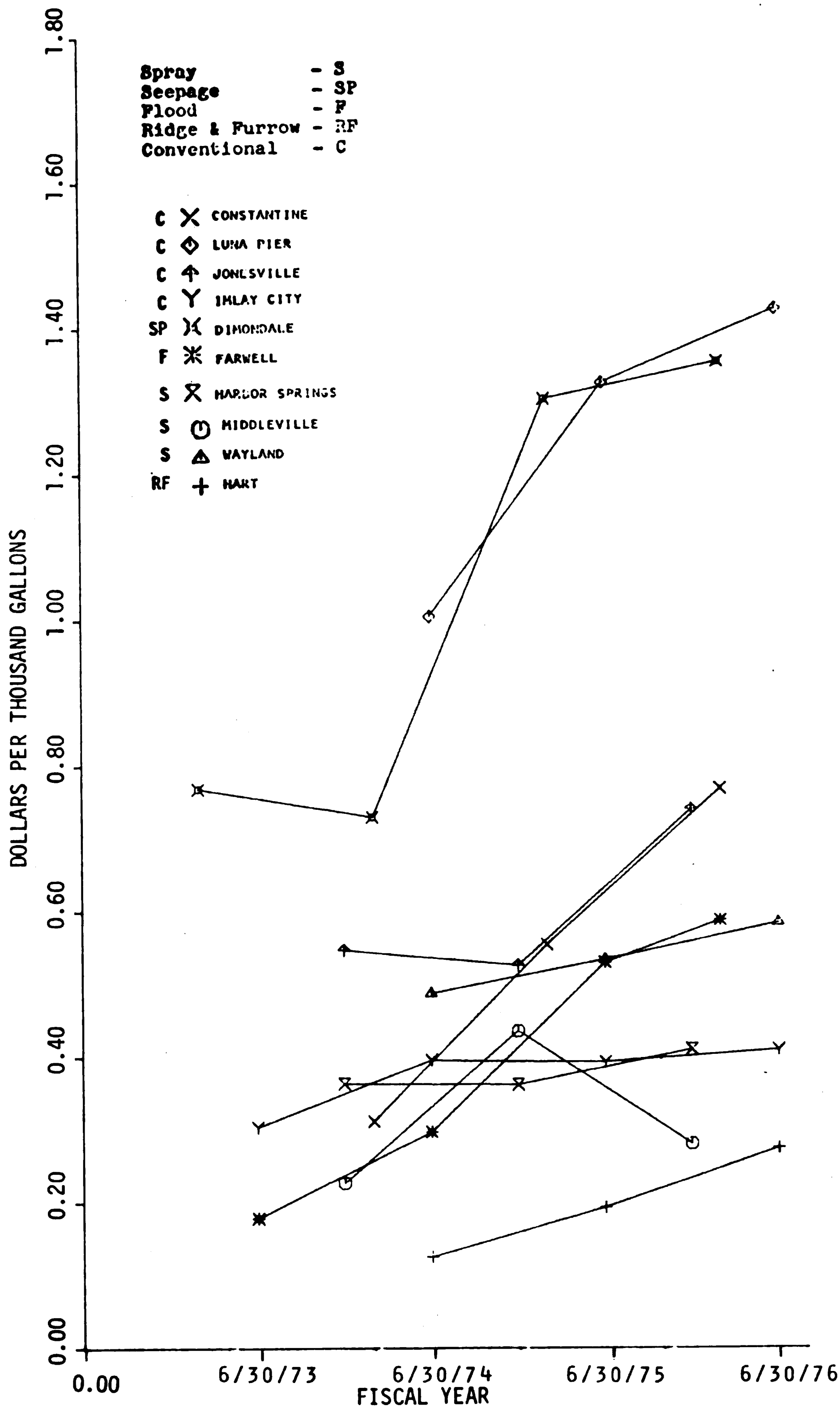


Fig. 11. Total of categories I, II, III and V

Harbor Springs has the next to least expensive costs for the general operation and maintenance category. In the general administrative expense category it is generally the most expensive. This is understandable due to the fact that the system is an authority which serves several units of government. The administration costs are higher because there would generally be more work involved in coordinating several units of government than just dealing with one as is the case in all the other systems. Also "double billing" and bookkeeping expenses take place. The authority must bill each individual local unit of government for its use of the system and in turn each unit of government bills its local user for the use of the system. Additionally, the authority keeps books on the operation and administration of the system and each local unit in the authority keeps books for its separate part of the system. Although the authority does treat more gallons of water in its system than others, which could possibly have the effect of lowering the cost per 1,000 gallons of water treated or having economies of scale in the overall total treatment cost category, it appears that for the General Administrative cost category the system may possibly be experiencing diseconomies of scale.

The Imlay City system has the lowest cost per 1,000 gallons treated in the utility expense category. In addition, this system has had the lowest expense for salaries and wages for all of the conventional treatment systems.

For the Hart, Harbor Springs and Imlay City systems it may be possible that economies of scale are occurring for the total operation expense on a dollars per 1,000 gallons treated basis. These three systems had the highest average daily flows of the systems in the study. Although this may be occurring in all three systems to some extent, it is more probable that its effect is greater for the Harbor Springs system because the system has some of the higher expenses in actual dollars expended than the others.

The curve displaying the Farwell system's costs, shows that they are increasing fairly rapidly. This seems to be due to the fact that the amount spent on salaries and wages, general operation and maintenance and general administrative expenses increased rapidly. However, the utility expense category maintained a fairly constant level. There is no immediate explanation for the increases in the other categories.

Total operation costs in dollars per 1,000 gallons for the Constantine system are increasing dramatically. These substantial increases in costs on this basis can be partly explained by the fact that the flows in this system were less in the last two fiscal years because of a strike and consequent stoppage of production and output of wastewater by a large industrial user in the community. By examining the actual dollars spent for total operation of the system, it is found that they increased even as flows decreased. However, if flows to the system had remained fairly stable, the increase in costs per 1,000 gallons may not have been as dramatic. However, actual dollars expended would probably be higher with higher or more normal average daily flows.

The Wayland system appears to be consistently the most expensive land treatment system, excluding Dimondale which uses conventional primary and secondary treatment processes. It's utility expense, general operation and maintenance expense and general administrative expenses are consistently higher than the other land treatment systems. The amount spent for professional services is generally higher than any other land treatment system in the study.

The next most expensive system appears to be the Jonesville system. This conventional system has the highest costs in the general operation and maintenance category of the conventional systems, excluding Dimondale. However, this system is fairly inexpensive in terms of utility expense compared to other treatment systems in the study. It's general administrative expenses were also fairly low relative to other systems.

Luna Pier and Dimondale's treatment systems are the most expensive treatment systems included in the study. Dimondale's system, which incorporates conventional primary and secondary treatment units in its process along with seepage lagoons for tertiary treatment, has either the highest or second highest expenses on the basis of dollars per 1,000 gallons treated of all the cost categories except general administrative expenses.

The Luna Pier system has the highest costs per 1,000 gallons treated in the salary and wage category of all the systems. It also has the highest expenses on the same basis for the utility category excluding Dimondale. In the general administrative expense category it ranks highest among the conventional treatment systems.

Linear Regression Analysis of Operation Expense

A two variable linear regression technique was used on three general groups of data. The cost of operating the system is the dependent variable and time is the independent variable. The general groups were all land treatment systems excluding Dimondale; all conventional treatment systems excluding Dimondale; and all conventional treatment systems including Dimondale. Regressions were run for each group of data in each cost category. Figures 12 through 17 show the regression lines in each category and combination of categories. The letters A, B and C on the graphs denote the different general groups of data on which the regression was performed.

A = Conventional Systems with Dimondale

B = Conventional Systems without Dimondale

C = Land Treatment Systems without Dimondale

Statistical tests were also conducted to determine if the slopes and intercepts of the regression lines were significantly different from one another. The regression lines were pooled and the t statistic and significance level calculated for the beta coefficients in the pooled multiple regression equation. Details concerning the regression technique and results are reported in Appendix B.

From Figure 12 it appears that the salary and wage expense for conventional type treatment systems is substantially higher than the same costs for land treatment systems. This figure shows that for the fiscal year ending at June 30, 1976 (48) the salary and wage expense for the conventional systems was approximately $.41 (difference between lines B & C) higher per 1,000 gallons treated than the land treatment systems. This is understandable because many of the conventional treatment systems require more manhours of labor to permit normal operation than land treatment systems. Whereas conventional systems may require at least one or more full time employees at the treatment plant at all times. Alternatively, a land

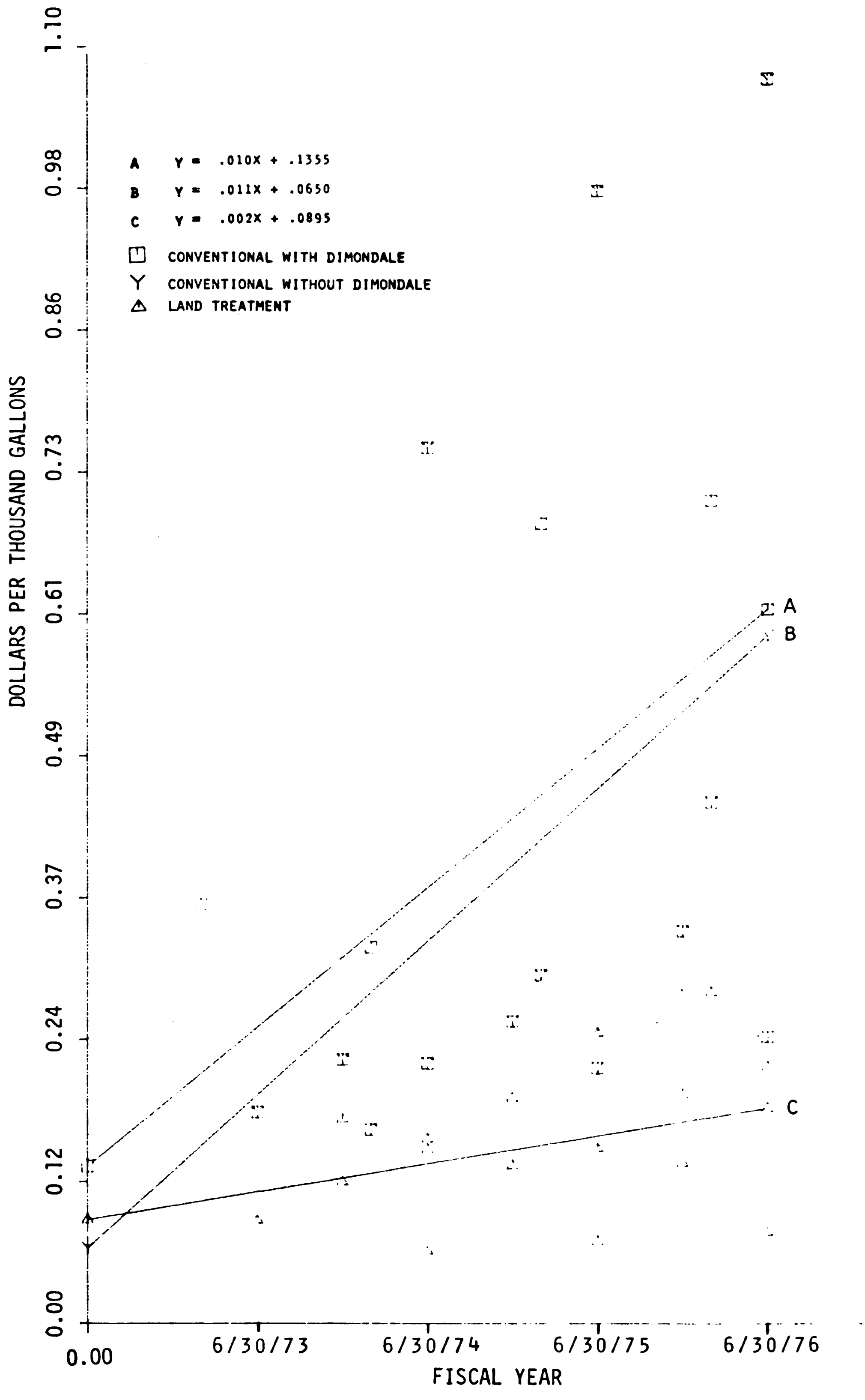


Fig. 12. Regression of salaries and wages expense

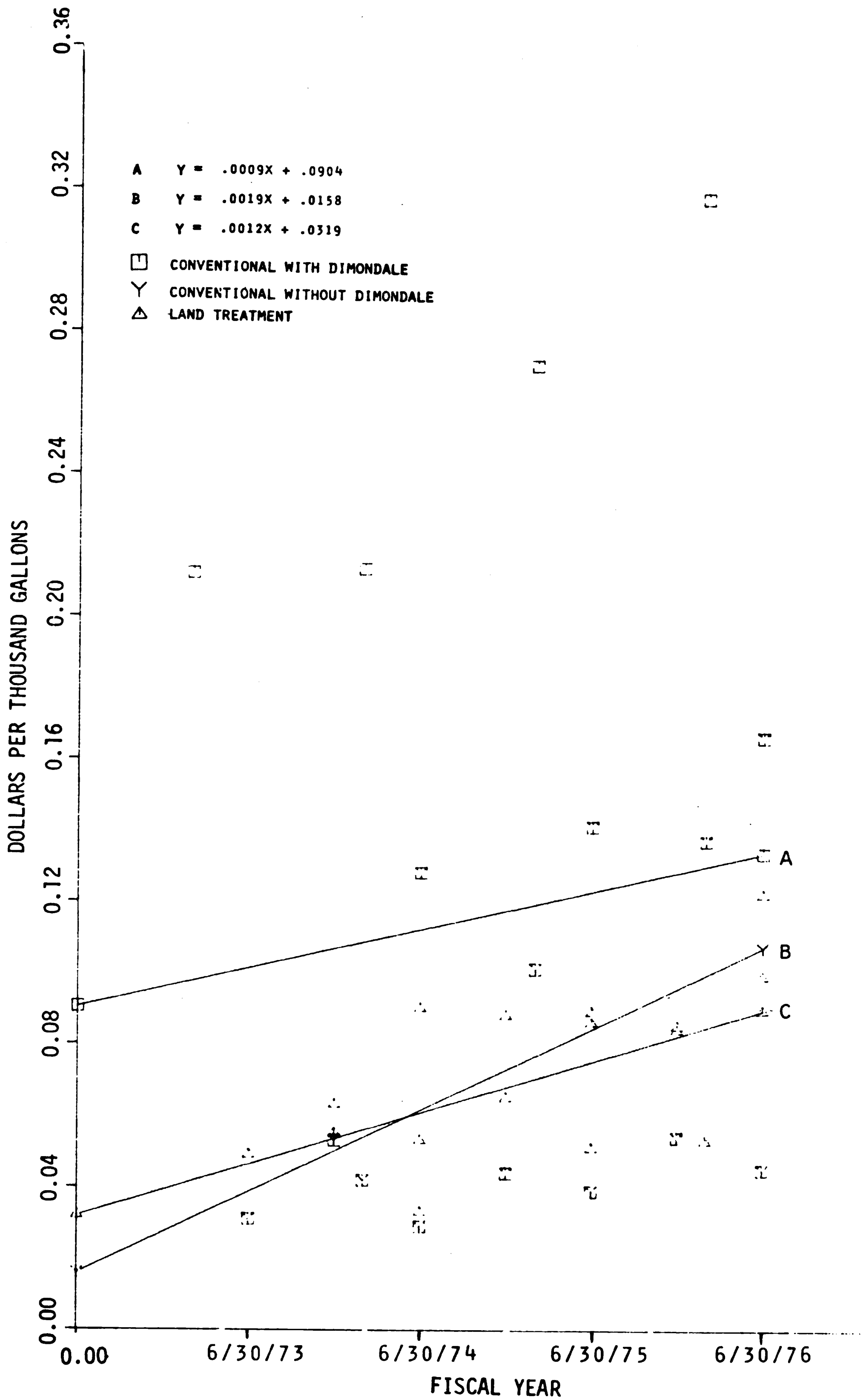


Fig. 13. Regression of utilities expense

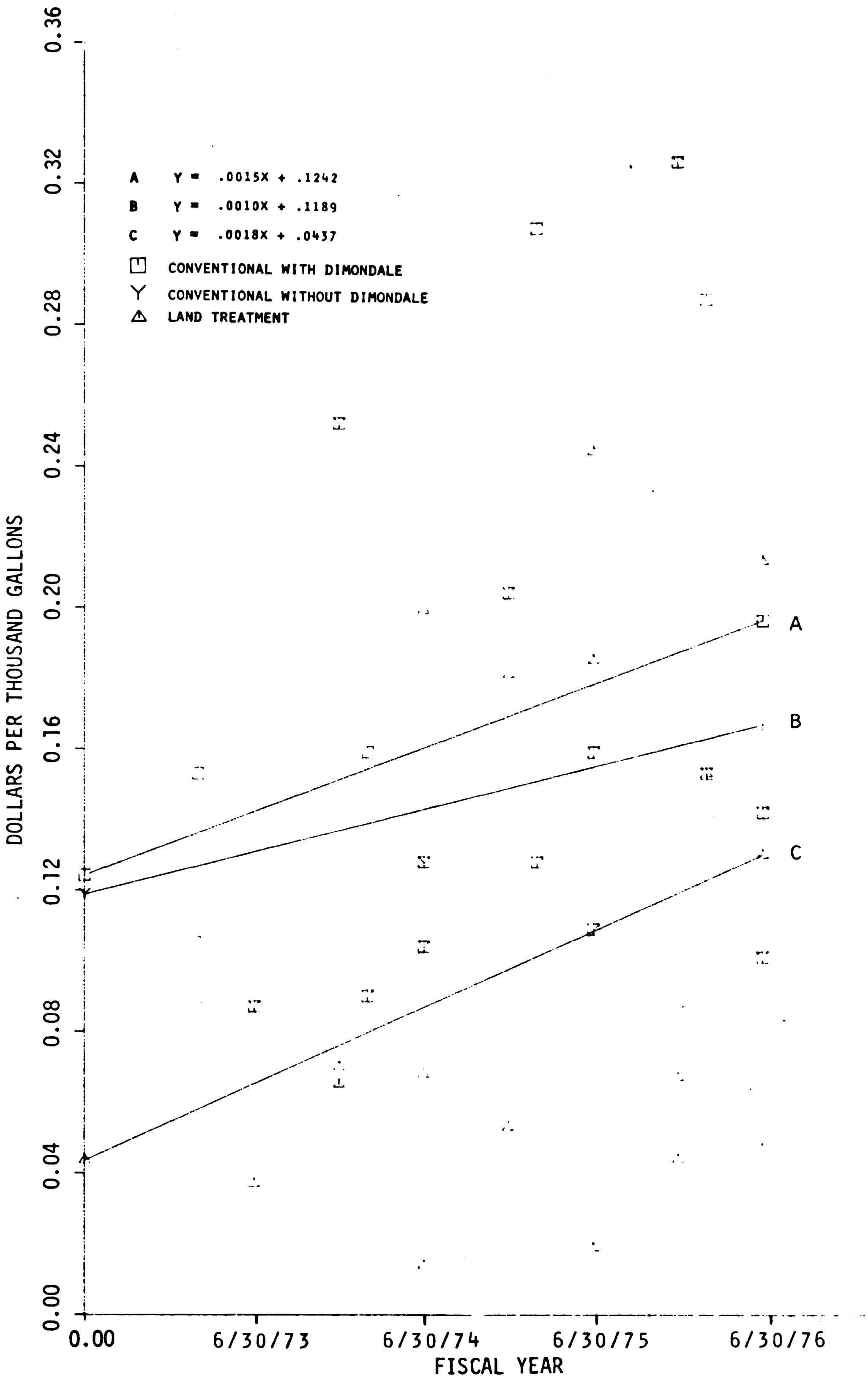


Fig. 14. Regression of general operation and maintenance expense

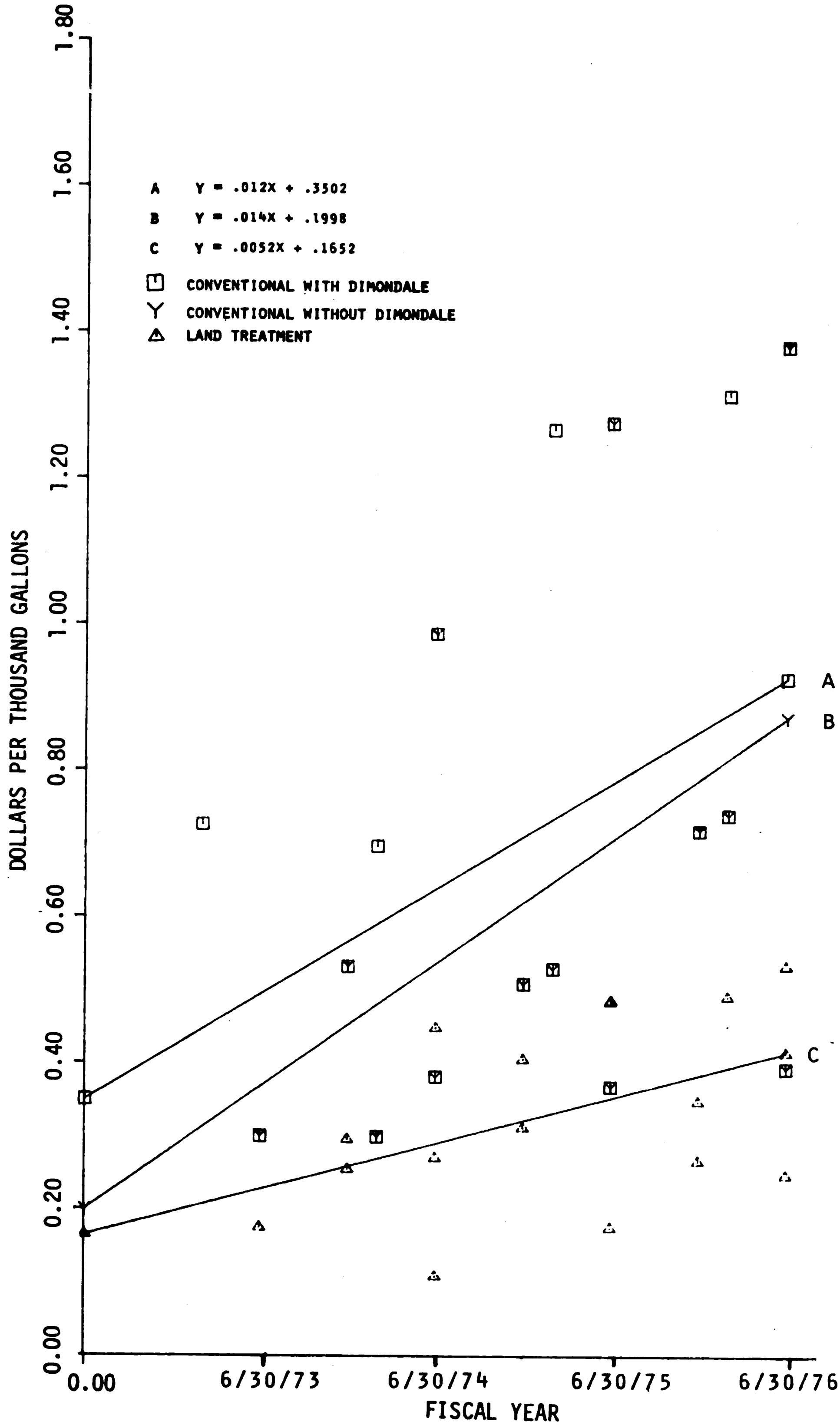


Fig. 15. Regression of total of categories I, II, III

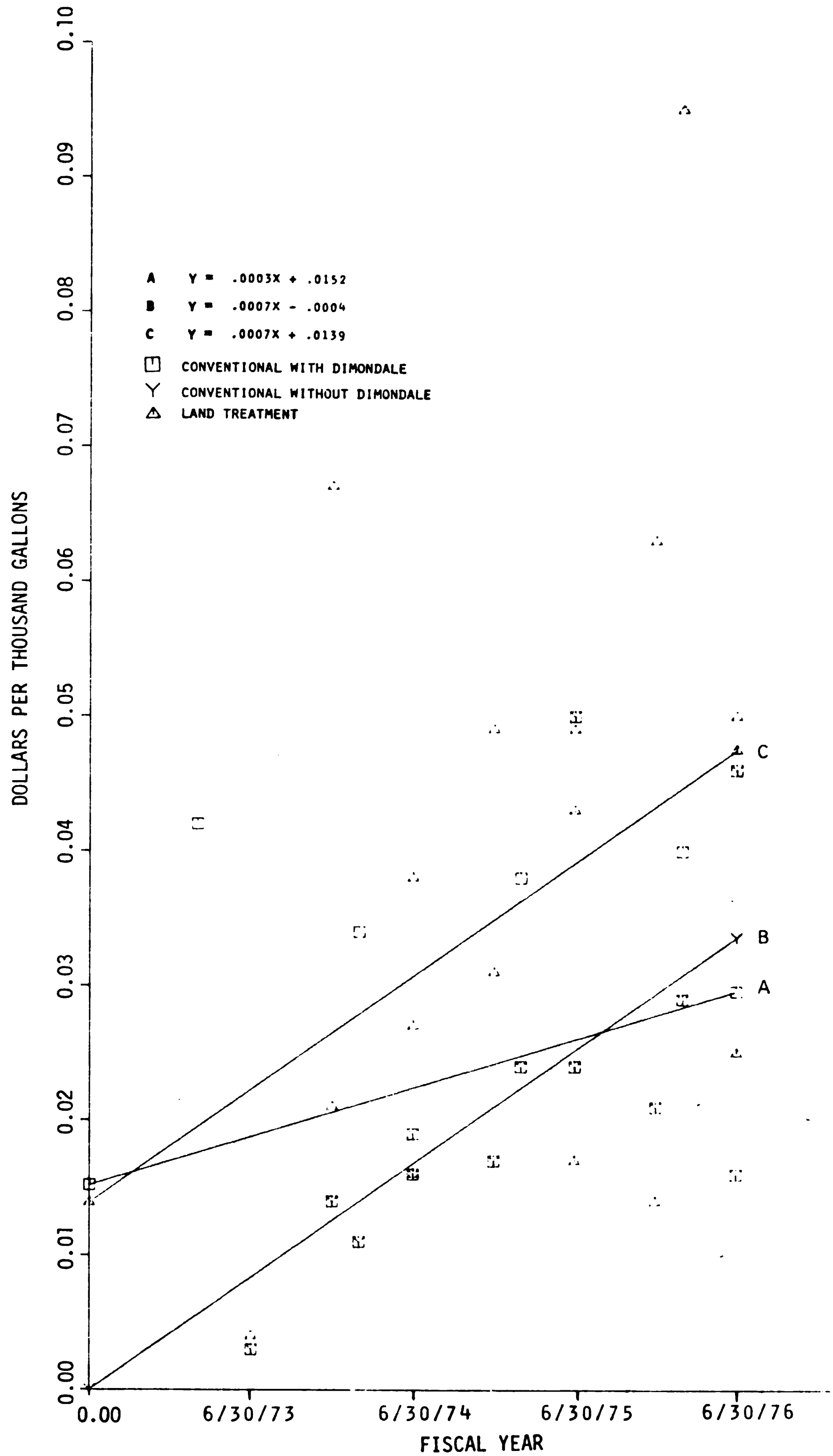


Fig. 16. Regression of general administrative expense

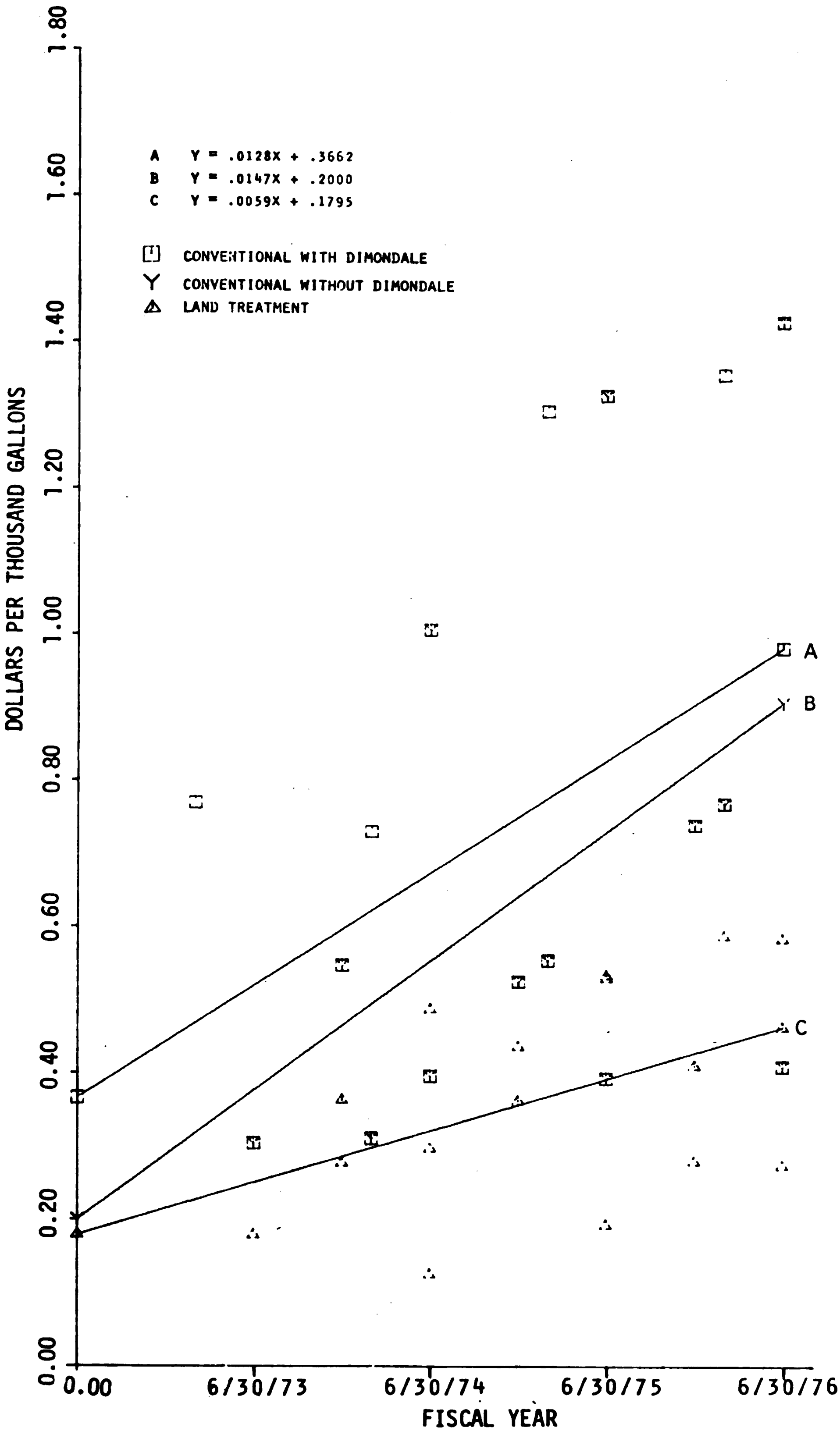


Fig. 17. Regression of total operating costs

treatment system can be run in some instances by a person who works for several departments at the local unit of government. In other words, operation labor is much less than that required at similarly sized, secondary treatment plants using the activated sludge process or trickling filter. Lagoon and irrigation systems do not require two or three-shift operator attention. Operator attention in Michigan is primarily devoted to dike maintenance around the ponds in spring and summer and to effluent distribution and crop management during the irrigation season [Malhotra]. In addition, these costs may be higher because it is possible that employees on a conventional system are relatively more skilled or specialized laborers than land treatment laborers and receive a higher wage rate.

From the figure it also appears that the expenses in this category are increasing at a faster rate for conventional systems than land treatment systems. A partial explanation of this increase can be explained by the elasticity of labor supply. Assuming that the supply for skilled labor is more inelastic relative to the unskilled labor supply for these wastewater treatment systems, it is possible that the price for skilled labor for conventional treatment systems will increase faster than the price for unskilled labor for land treatment systems when demand for labor, as a whole, for wastewater treatment systems increases.

The regression analysis for the utility expense is less clear cut. By including, or not including, the Dimondale system in the conventional treatment group, we see that the regression line changes position substantially. It is also quite possible that the difference in the conventional utility expenses and land treatment utility expenses is due mainly to the variance of the cost of electricity in each area.

General operation and maintenance expenses appear to be higher for conventional treatment than land treatment according to Figure 14. The expense of general operation and maintenance of the conventional systems for the fiscal year ending June 20, 1976 is approximately $.35 (line B less line C) or $.60 (line A less line C) per 1,000 gallons treated greater than the land treatment systems.

If Dimondale is included as a conventional treatment system, the regression curves show that the expense of operation and maintenance have increased at approximately the same rate.

Moving to Figure 15 the total of the first three expense categories shows that the conventional systems are substantially more expensive to operate in terms of the total of these categories and that the operating expenses for the systems included in this study are increasing faster for conventional systems than land treatment systems. For the fiscal year ending June 30, 1976 the conventional systems are approximately $.46 (line B less line C) per 1,000 gallons treated more expensive than the land treatment systems.

The regression curves for the general administrative expenses show that the land treatment systems in the study were generally more expensive on the basis of dollars per 1,000 gallons treated than the conventional treatment systems. For the fiscal year ending June 30, 1976 the land treatment systems were approximately $.16 (line C less line B) per 1,000 gallons treated more expensive than the conventional treatment systems in this expense category.

The final figure, showing regression lines for all costs incurred in the operation of the systems shows that the conventional systems included in the study were more expensive to operate than the land treatment system. For the fiscal year ending June 30, 1976 the conventional treatment systems were approximately $.45 (line B less line C) per 1,000 gallons treated more expensive than the land treatment systems in this total operation costs category. It also shows that costs for these conventional systems is increasing approximately twice as fast as the costs of operation of the land treatment system as a whole.

In conclusion of this analysis, a final note on the comparative cost analysis of operation costs is needed. The revenue collected by the Middleville and Hart treatment systems for the use of land and sale of crops from the treatment site would offset the operation costs of the system. If the revenue obtained from the farming enterprise were subtracted from operation expenses, the result would be a reduction in the cost of operation at the Middleville system by $1,200 in the 1975 fiscal year. The reduction on the basis per 1,000 gallons treated would be $.28 to $.265. Approximately $1,140 were received from the farm operation at the Hart system for the fiscal year ending June 30, 1975. This is a reduction of operation costs from $.193 to $.186 per 1,000 gallons treated. The community of Wayland also hopes to offset part of its operation costs with an expected $6,000 profit from its farm operation in 1977. This would be a reduction of $.089/ 1,000 gallons treated.

It appears that the revenue collected from the farming operation at land treatment systems included in this study do not have a substantial effect in offsetting the operation expenses. However, it is likely that the communities appreciate any revenue which they may receive from such an operation.

To conclude the discussion of the farm operations, a final comment is needed about the bookkeeping for such an operation. Separate accounts for expenses incurred and revenues received by the farm operation should be kept and not combined with the "regular" operating expense and revenue accounts of the treatment system. This is needed so the operators of the system can tell if the farming operation is profitable and if any adjustments can be made in the farm plan to make it more profitable. If separate accounts are not kept, the operator will not be able to determine if the farm operation is actually increasing overall operation expenses or is working to offset operation expenses.

Capital Cost Analysis

Capital or construction costs are also an important factor to be considered when evaluating alternative methods of wastewater treatment. In general the community will incur each year along with operation expenses, the expense of bond issues used to construct the treatment system. Construction costs will vary depending upon type of system, its components and the overall size. In addition, land treatment system's capital costs will also vary because of the availability of land, type of land and type of application system used. Various types of application systems will require different amounts of land. It is important to examine construction alternatives to determine the most cost effective alternatives not only in operating expenses but in capital expenses as well.

Construction cost information for the systems included in the study is presented in Table 4 in both actual dollars and constant dollars. The left column presents construction costs in actual dollars for the year in which the system was constructed. The right column presents the construction cost data in constant dollars (actual dollars adjusted to 1976). Three indexes were used to adjust the construction cost data. The Economic Research Service's USDA Farm Real Estate Market Development index was used to adjust the land costs to constant dollars in 1976. The Environmental Protection Agency's Sewage Treatment Plant and Sewer Construction Cost indexes were used to adjust the construction costs of the conventional and land treatment system to constant comparable dollars.

Table 5 presents construction cost information based on the average daily flows and design flows. Column 3 in the table expresses the percent of average daily flow of the design flow. This gives a perspective on how much excess capacity there is in the system. It appears that there is a good deal of excess capacity in some of the systems. It is important to have excess capacity though for two reasons. First, the system must be able to handle the peak flows during different periods of the day and year. In fact, column 3 may be somewhat misleading because it expresses the difference between the average daily flow and design flow and not the difference between normal peak flows and design flows. In other words, at certain times of the year or day, there may exist little or no excess capacity in the system. Secondly, excess capacity is needed in the system to allow for growth in the volume of wastewater that must be treated.

Table 4. Construction Costs of Wastewater Treatment Systems

	Harbor Springs	
Project I	1970 $	Comparable 1976 $
Construction	$ 941,877.88	$1,751,007.87
Engineering-Tech.	147,692.77	274,569.78
Legal	4,716.75	8,768.72
Land	180,000.00	344,070.79
Total	$1,274,287.40	$2,378,417.16
Project II	1974 $	
Construction	$4,971,256.00	$5,987,121.35
Engineering-Tech.	787,000.00	947,821.73
Legal	39,025.00	46,999.67
Land	133,450.00	162,854.23
Total	$5,930,731.00	$7,144,796.98
	Wayland	
	1971 $	Comparable 1976 $
Treatment & Collection	$1,972,824	$3,272,288.91
Equipment	22,086	36,633.66
Building	157,253	260,832.82
Land	67,600	124,800.00
Total	$2,219,763	$3,694,555.39
	Middleville	
	1970 $	Comparable 1976 $
Land	$ 33,780	$ 64,570.61
Sewage Plant	309,182	574,788.01
Force Mains	24,554	45,647.36
Organization Costs	3,032	5,636.67
Equipment	11,882	22,089.35
Total	$ 382,430	$ 712,732.00

Table 4. Continued

	Farwell 1970 $	Comparable 1976 $
Land	$ 4,200.00	$ 8,028.31
Sewer System	1,215,489.75	2,259,668.86
Equipment	2,608.43	4,849.22
Office Equipment	55.88	103.88
Total	$1,222,354,06	$2,272,650.27

	Hart 1972 $	Comparable 1976 $
Land	$ 67,659.31	$ 115,074.10
Equipment	6,733.00	10,081.30
Construction	1,176,533.75	1,761,620.80
Engineering & Legal	187,989.32	281,475.90
Total	$1,438,915.38	$2,168,252.10

Original Wastewater Treatment System

	1963 $	Comparable 1976 $
Land	$ 10,000.00	$ 27,341.77
Sewer Lines	241,788.91	592,703.78
Lift Stations	28,459.20	69,762.81
Lagoon Treatment Plant	190,005.37	465,765.37
Total	$ 470,253.48	$1,155,573.73
TOTAL OF BOTH		$3,323,825.83

	Dimondale	Comparable 1976 $
Land (1969-1972)	$ 31,573.50	$ 59,828.76
Collection (1971)	474,856.83	787,636.77
Treatment (1971)	424,963.88	704,880.20
Equipment (1971)	7,074.54	11,734.41
Total	$ 938,468.75	$1,564,080.14

Table 4. Continued

Luna Pier

	1969 $	Comparable 1976 $
Land	$ 6,500.00	$ 12,648.64
Treatment Plant	436,159.73	865,710.97
Equipment	467,392.85	927,703.99
Sewer Lines	1,051,207.50	2,086,487.61
Total	$1,961,260.08	$3,892,551.21

Constantine

		Comparable 1976 $
Property Plant and Equipment (1965)	$ 211,814.62	$ 499,958.83
Property Plant and Equipment (1972)	1,263,088.08	1,935,257.76
Total	$1,474,902.70	$2,435,216.59

Jonesville

	1970 $	Comparable 1976 $
Property Plant and Equipment	$ 915,000	$1,676,433.56

Imlay City

Due to differences in bookkeeping procedures, the construction costs of wastewater treatment system are not available.

Figure 18 compares the construction costs of the system with the use of bar scales. Refer to the community numbers in Table 5 to identify each system's costs. The left side of each bar in the graph represents the construction costs on a basis of dollars per gallon treated per day and the right side represents the costs on a basis of dollars per gallon per day design flow. These are presented to give a general idea of the capital costs involved for each system in the study. Caution is needed in making comparisons across systems, however, because of the inherent characteristics of each system. Some difficulties in comparison analysis include:

1. Technology or type of treatment used not only is different between general categories of conventional and land treatment but also varies within each category. There are various types of treatment systems which are classified as land treatment just as there are different types of conventional treatment.

2. Differences in size of systems exist in terms of volume of wastewater treated. Additional population served may not be a good indicator of the volume of wastewater treated because of commercial and industrial contributions.

3. Utilization of existing capacity also varies among systems.

4. Land costs can vary substantially from community to community.

Table 6 presents the capital costs in an additional manner. The average construction costs of land treatment including and excluding the Dimondale system are presented along with the conventional system average capital costs on the same basis. A weighted average of the capital costs for the land treatment and conventional systems is also presented. The weighted average is calculated by dividing the total flow of all the land treatment systems into the

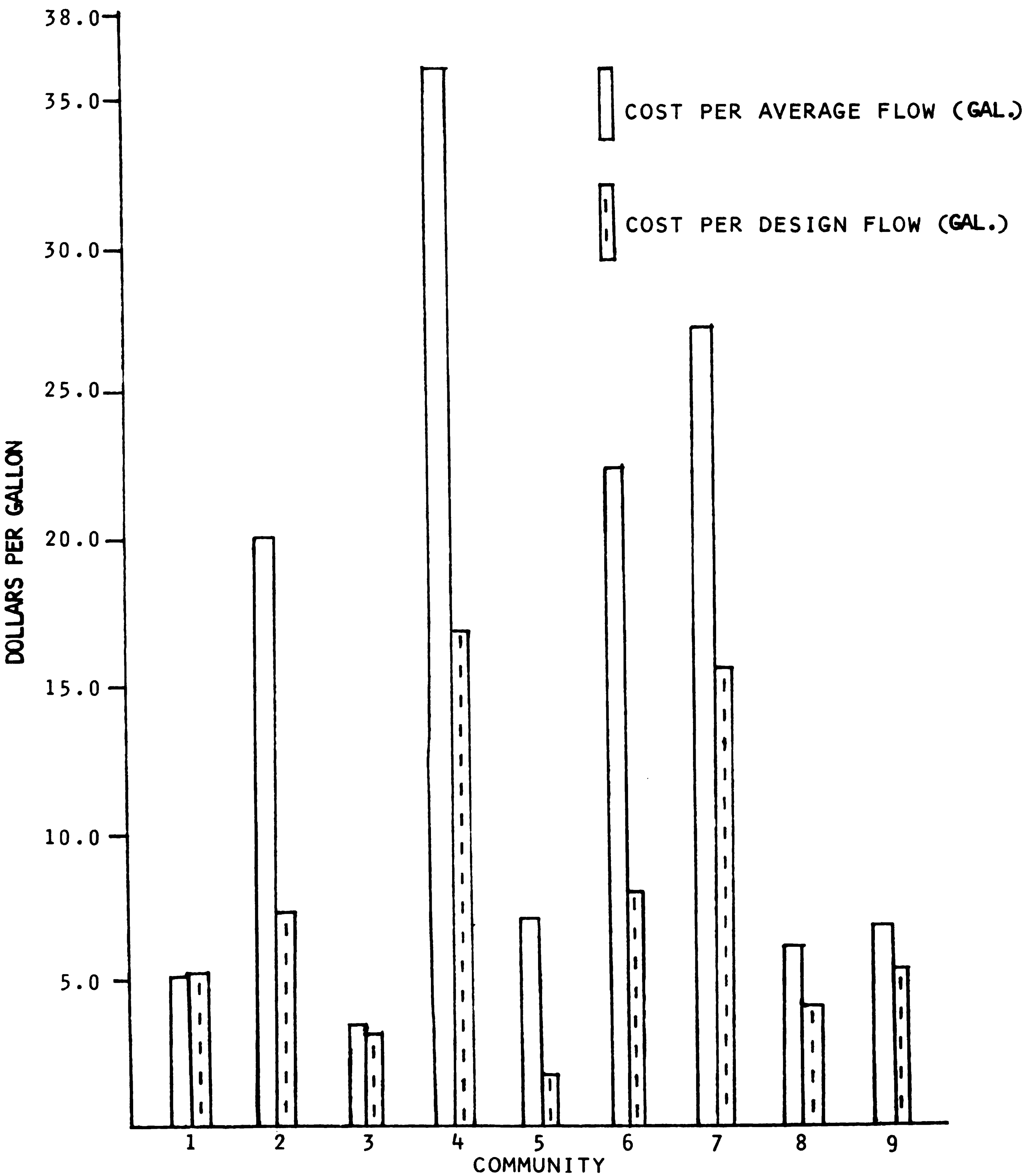
Table 5. Construction Costs Comparison of Treatment Systems (Comparable Dollars)

Community	Design Flow (TGD)	Average Flow (TGD)	Actual Flow as a % of Design	Cost in Comparable 1976 Dollars	Cost Per Average Flow (GAL)	Cost Per Design Flow (GAL)
1. Harbor Springs[a]	450	465	1.033	$2,378,417.16	$ 5.115	$ 5.285
2. Wayland	500	184	.368	3,694,555.39	20.079	7.389
3. Middleville[b]	220	217	.986	712,732.00	3.284	3.240
4. Farwell	135	63	.466	2,272,650.27	36.074	16.834
5. Hart	900	470	.247	3,323,825.83	7.072	1.749
6. Dimondale	200	70	.350	1,564,080.14	22.344	7.820
7. Luna Pier	250	143	.572	3,892,551.21	27.221	15.570
8. Constantine	600	400[c]	.666	2,435,216.59	6.088	4.059
9. Jonesville	320	250	.781	1,676,433.56	6.706	5.239

[a]Project I, Flows correspond to Project I only.

[b]Costs do not include previously existing collection system.

[c]Flows estimated to what they would normally be if industry in the community were contributing their normal volume of wastewater.



REFER TO COMMUNITY NUMBERS IN TABLE 4.
FIG. 18. CONSTRUCTION COSTS COMPARISON
(COMPARABLE DOLLARS)

total capital costs of all land treatment systems. The same is done for the conventional system's capital expenditures.

Table 6. Construction Cost Comparison of Treatment Types--Comparable Dollars

System	Average Costs	Weighted Average Costs	
		Average Flow	Design Flow
Land Treatment	$2,476,436.13	$ 8.85	$5.615
	2,324,376.79[1]	9.494[1]	5.799[1]
Conventional	$2,668,067.12	$10.093	$6.841
	2,392,070.37[1]	11.087[1]	6.984[1]

[1]Calculations include the Dimondale System.

This comparison shows that for the systems included in this study that land treatment systems required a smaller capital expenditure than the conventional treatment systems. However, this result may be affected somewhat because the cost of Middleville's original collection system is not included in costs of land treatment systems. On an average daily flow basis the capital costs for land treatment were approximately $1.243/gallon less than the conventional systems (excluding Dimondale). On a design flow basis the result was a difference of $1.226/gallon with the land treatment systems being less expensive than the conventional systems (excluding Dimondale). In addition to these results, it is important to point out that of the land treatment systems studies in detail, the main reason given for selection of the land treatment method of wastewater treatment as an alternative to conventional methods was that capital investment required for a land treatment system consisting of primary and secondary treatment lagoons and a land disposal area for the wastewater was less than the capital expenditure which would be required to construct a conventional treatment system that would attain approximately the same level of treatment. In only one case studied, that of the Dimondale system, were the circumstances better for the construction of conventional primary and secondary treatment units. However, due to the relatively high operation costs of the Dimondale system, it may have been advisable to construct a land treatment system at a larger capital investment and saved on operation costs over the long run.

In other words, each situation must be considered separately. Each type of alternative system for a single community must be evaluated in terms of its expected operation costs and capital costs. Determination of these costs requires detailed planning and study taking into account all cost factors relative to the respective local unit of government situation. Alternatively, evaluation of the average occurrences of operating characteristics and costs such as this study has done with case histories and time series data, regression analysis indicates what can be expected from the use of alternative methods of treatment. These types of studies can aid engineers, planners and local governmental officials in conducting the evaluation of alternative types of treatment for a given situation.

Concluding Points for Comparative Cost Evaluation

Before closing this section of the study, some additional points should be considered when evaluating alternative treatment methods which have not been dealt with in this chapter. Generally, the expenditure required to purchase land for land treatment systems will be substantially higher than for land purchased for a conventional system. This is basically due to the quantity needed. However, this land should be thought of as an asset that will more than likely increase in value rather than depreciate like the equipment incorporated into the system.

It is important to remember that there is a dual cost structure. In other words, we should not only be concerned with the price for the inputs but also the inputs salvage value when the system has exhausted its useful life. In the case of land treatment systems, the salvage value of the system would be positive because of the value of the usable land. The land could be sold by the local unit of government to pay debt retirement requirements or to help finance a new type of system. (Land could possibly be used for agricultural and forestry production or developed for recreation purposes, wildlife habitats or a variety of commercial uses. Even the ponds could be filled with soil and regraded to the natural topography.) For conventional systems, however, the salvage value of the system may be small or even negative becuase the majority of the assets involved in the conventional system would likely have no alternative use.

There is also the advantage of producing forestry and agricultural products for sale on certain types of land treatment system which could help defray operation and maintain expenses. However, operation costs may also increase because of the complexity of the farm operation. The farm operation should be run as a separate enterprise to determine its profitability. The expected production and profitability should be closely studied in an evaluation of alternatives. These types of opportunities do not exist with conventional systems but alternatively they may be able to sell conditioned sludge from the treatment process as a fertilizer and soil conditioner to farmers and home gardners. Sludge is not removed and conditioned from the lagoons in the land treatment systems.

Comparisons made in this study are really not comparisons of land treatment with other forms of physical chemical advanced wastewater treatment in terms of the level of treatment. As pointed out before, the quality of treatment generally achieved by the land treatment process is of a higher degree than the conventional treatment processes which incorporate chemical coagulation for phosphorus removal. Keeping this in mind, it appears that the land treatment systems in this study were more cost effective and most likely achieved a higher level of treatment than the conventional systems.

CHAPTER 6

SUMMARY

The purpose of this study was to document and evaluate the economic and institutional aspects of small municipal land treatment systems which are an alternative for wastewater treatment. More specifically, the purpose was to study several small land treatment systems in Michigan and document their development in terms of institutional arrangements and to compare their operation and initial capital expenses with several comparable (in terms of treatment quality and size) conventional treatment systems.

The objectives of the study were:

1. To describe the various types of land treatment systems used by municipalities in Michigan.
2. To identify the institutional characteristics of the systems included in the study.
3. To present data on the construction, operating and maintenance costs for six land treatment systems and four conventional treatment systems which are currently operating in Michigan.
4. To give a description of the treatment technology used in each system.
5. To compare and analyze categories of cost information of land treatment systems with the conventional treatment costs.

Procedure

The study presents case histories of six small municipal land treatment systems in Michigan. The legal background which establishes authority for such systems has been documented along with the concepts of land treatment.

Information was collected from state and local officials on the economic and institutional characteristics of each land treatment facility. Operation and construction cost information was collected chiefly from local community audit reports. For comparative cost analysis operation and construction cost information was collected for four conventional treatment systems which are comparable in terms of size, type of wastewater treated and quality of treatment. The operation cost information was assigned to various cost accounts, and in turn the accounts were grouped into four general operating expense categories for purposes of comparative cost analysis. These cost categories in terms of dollars per 1,000 gallons treated were plotted for each system according to the fiscal year in which they occurred. The plots were compared and discussed.

Linear regression analysis was performed on the operation costs of the total group of land treatment systems and compared with the regression analysis of the operating expenses of the total group of conventional systems. A third regression equation was also made on each cost category for the conventional treatment system including one system which uses a land application technique although it is characterized by primary and secondary conventional treatment methods.

For the capital cost analysis, it was necessary to adjust actual construction costs to constant or comparable dollars. Three indexes were used to adjust actual construction costs to 1976 dollars. Additionally, the construction costs were presented in a bar chart in terms of dollars per average daily flows (gallons per day) and dollars per design flow (gallons per day).

Conclusions

This study identified that municipalities use institutional arrangements which are given legal authority under Act 233, 1955 and Act 185, 1957 of the Public Acts of Michigan. The use of Act 185 which allows the local unit of government to enlist the aid of the county for constructing and operating of a wastewater treatment system appears to be quite common. This act is essential because without it or a similar law, many small communities would have difficulty in raising the required funds for construction of a wastewater system.

Several land treatment systems were found to have some form of farm operation connected with them. In two cases, the planting and harvesting of crops from the irrigation site was being conducted. Another system was leasing the land around the irrigation site to a local farmer for a farming operation. Various lease arrangement for agriculture operation on these sites exist. In all cases the local unit of government has been or will be offsetting its operation costs from profit generated from the farming enterprise. However, the effect on offsetting the operation costs has not been substantial.

The comparative cost analysis of the operation expenses of the two general categories of types of treatment, land and conventional, has in general shown that the land treatment systems on the whole seem to be less expensive to operate than conventional systems. This finding is even more significant in that the land treatment systems may be achieving a higher level of wastewater treatment than the conventional facilities. More specifically, the land treatment systems were less expensive to operate than the conventional systems in two of the four individual expense categories documented: Salary and Wage Expense, and General Operation and Maintenance Expense. In the Utility Expense category, the operation costs were approximately the same. The conventional systems appeared to be less expensive to operate than the land treatment systems in the General Administrative Expense category. The total of all expense categories showed that the land treatment systems were experiencing lower operation costs per 1,000 gallons treated. Additionally, the yearly operation costs of the conventional treatment systems were increasing approximately twice as fast as the land treatment facilities.

The comparison of the capital investment required for construction of the systems showed that land treatment was somewhat less costly than the conventional systems. Although, the documentation of the capital costs indicates that general expense of construction, it is difficult to make cost comparisons across types of systems because of the inherent physical characteristics of each system. Each type of alternative system for a single community must be evaluated in terms of its expected operation costs and capital expenditure. Determination of these costs require detailed planning and study taking into account all cost factors relative to the respective community situation. Alternatively, evaluation of the average occurrences of operating characteristics and costs such as this study has done with case histories and time series data regression analysis indicate what can be expected from the use of ultimate methods of treatment.

With the results of this study in hand and the advantages of land treatment the question arrises as to why land treatment is not more widely used. There are several reasons which are particularly apparent. Soils in many areas are not suitable for the land treatment process. There may be local opposition to the land treatment concept for various reasons including aesthetic reasons, health concerns, and lack of understanding of the land treatment concept. The amount of land required may be unavailable or the cost of purchasing or leasing such land may be prohibitive. In addition to these it may be the case that local consulting firms have a lack of knowledge or experience with land treatment. It is clear that although there are distinct advantages for certain communities who use the land treatment method for wastewater treatment there are also disadvantages in some situations. Therefore, land treatment should not be considered a panacea for every community's sewage problems.

Limitations of the Study

The major limitations of the study are involved with data on the operation and maintenance expenses. Because audit accounts were somewhat different in each community it was somewhat difficult to determine if similar costs were being compared. An effort was made to identify the costs which were included in each account. Accounts were also combined into categories to make the comparisons more valid. Additionally, the sample size is small because few communities had bookkeeping procedures which were detailed enough to be useful for this study. Cost comparison of the land treatment systems with conventional treatment systems is also limited to some extent because of the different technologies within each category of wastewater treatment. One form of land treatment may in fact be more expensive than another. However, this cannot be determined from this study because of data limitations. Due to the fact that some communities do not keep flow records for their fiscal year but for the calendar year there was a need for some degree of calculation and judgment by the local officials and author to arrive at the flow for the fiscal year. Therefore there may be a small discrepancy between actual flows and the flows reported for use in the study.

The results of this study cannot be generalized to larger systems because of size differences and different technologies which may be involved with large systems. These limitations point out the need for future research.

Suggestions for Future Research

Further questions surrounding the use of land treatment for wastewater treatment alternatives for small communities need to be investigated. Basically, this study has investigated the differences in operation expenses between small land treatment systems and small conventional treatment systems. Future studies could possibly investigate the most cost effective form of land treatment. Although each situation should be evaluated separately, a study of this type could identify the major differences in capital and operation costs of the various application techniques.

While conducting this study it became extremely apparent that local governmental unit bookkeeping methods vary considerably from community to community. Data collection and comparative cost analysis is hampered by this situation. Future work may investigate and suggest a more uniform bookkeeping system of accounts. This would greatly help when evaluating the cost effectiveness of community services across local government units.

Additional research needs to be conducted on marketing opportunities for agricultural products grown on land treatment areas, the measurement and distribution of costs and benefits of land treatment system on the region, and what options for land acquisition or lease arrangements are being used and which seem to be the most suitable for the operation of a land treatment facility.

Research on larger systems may also be able to identify aspects of economies and diseconomies of size. More specifically, research is needed to investigate the relationship of operation and maintenance costs and capital expenditure of land treatment and conventional treatment to their size in terms of gallons of wastewater treated.

This information could be useful for local decision makers, engineering consulting firms and government officials for evaluating alternatives for wastewater treatment.

APPENDIX A

OPERATION COSTS OF THE LAND AND CONVENTIONAL TREATMENT SYSTEMS

Table A-1. Operation Costs, Harbor Springs, Population Served: Winter--3,580; Summer--5,800

Fiscal Year Ending	12/31/75	12/31/74	12/31/73
Code Number	42	30	18
Flow in MGD	.465	.465	.465
I. Salaries & Wages	33,450.16	32,990.12	29,971.57
$/1,000 gal.	.197	.194	.176
II. Utilities	14,268.80	11,121.60	9,307.20
$/1,000 gal.	.084	.065	.055
III. Oper. & Maint. Exp.			
Supplies	7,045	2,799	3,602.29
Maintenance	3,386.41	5,296.07	7,204.82
Equipment Rental	-	-	-
Professional Serv.	-	-	-
Outside Services	-	-	-
Miscellaneous	876.30	934.99	225.25
Total	11,307.71	9,030.06	11,032.36
$/1,000 gal.	.067	.053	.065
TOTAL - I, II, & III	.348	.312	.296
IV. Gen. Admin. Exp.			
Office Expense	6,655.36	5,366.50	8,783.82
Insurance	2,037.91	1,641.19	1,441.87
Transportation Exp.	1,950.00	1,342.74	1,115.67
Total	10,643.27	8,350.43	11,341.33
$/1,000 gal.	.063	.049	.067
TOTAL	69,669.94	61,492.21	61,652.46
$/1,000 gal.	.410	.362	.363

Table A-2. Operation Costs, Wayland (1,860)

Fiscal Year Ending	6/30/76	6/30/75	6/30/74
Code Number	48	36	24
Flow in MGD	.184	.175	.175
I. Salaries & Wages	14,834	9,632	10,164
$/1,000 gal.	.221	.151	.159
II. Utilities	6,687	5,687	5,780
$/1,000 gal.	.099	.089	.090
III. Oper. & Maint. Exp.			
Supplies	1,460	333	655
Maintenance	2,680	2,317	1,355
Equipment Rental	4,893	9,465	3,685
Professional Serv.	3,224	2,764	4,721
Outside Services	-	-	-
Miscellaneous	2,044	720	2,289
Total	14,301	15,599	12,705
$/1,000 gal.	.213	.244	.199
TOTAL - I, II, & III	.533	.484	.448
IV. Gen. Admin. Exp.			
Office Expense	639	515	613
Insurance	2,221	2,114	1,337
Payment in lieu of Property Taxes	500	500	500
Total	3,360	3,129	2,450
$/1,000 gal.	.050	.049	.038
TOTAL	39,182	34,047	31,099
$/1,000 gal.	.583	.533	.487

Table A-3. Operations Costs, Middleville (1,800)

Fiscal Year Ending	12/31/75	12/31/74	12/31/73
Code Number	42	30	18
Flow in MGD	.217	.217	.217
I. Salaries & Wages	10,913	10,770	9,688
$/1,000 gal.	.138	.136	.122
II. Utilities	6,768	6,951	5,026
$/1,000 gal.	.085	.088	.063
III. Supplies	1,654	4,001	4,336
Maintenance	-	-	-
Equipment Rental	-	-	-
Professional Serv.	399	9,815	295
Outside Services	1,295	249	-
Miscellaneous	106	261	908
Total	3,454	14,326	5,539
$/1,000 gal.	.044	.181	.070
TOTAL - I, II, & III	.267	.405	.255
IV. Office Expense	1,086	2,122	1,463
Insurance	-	376	238
Transportation Exp.	-	-	-
Total	1,086	2,498	1,701
$/1,000 gal.	.014	.031	.021
TOTAL	22,221	34,545	21,954
$/1,000 gal.	.280	.436	.277

Table A-4. Operation Costs, Farwell (900)

Fiscal Year Ending	2/29/76 (244 days)	6/30/75	6/30/74	6/30/73
Code Number	44	36	24	12
Flow in MGD	.063	.063	.063	.063
I. Salaries & Wages	4,387.18	5,748.73	3,434.52	2,046.17
$/1,000 gal.	.285	.250	.150	.089
II. Utilities	821.42	1,169.52	1,214.39	1,118.84
$/1,000 gal.	.053	.051	.053	.049
III. Oper. & Maint. Exp.				
Supplies	1,055.75	756.26	127.19	158.66
Maintenance	35.00	179.33	-	-
Equipment Rental	774.36	698.02	585.32	306.52
Professional Serv.	-	225.00	-	-
Outside Services	-	2,228.08	853.29	75.00
Miscellaneous	493.26	177.54	-	320.00
Total	2,358.37	4,264.25	1,565.80	860.18
$/1,000 gal.	.153	.185	.068	.037
TOTAL - I, II, & III	.491	.486	.271	.175
IV. Gen. Admin. Exp.				
Office Expense	1,175.69	907.85	484.11	90.25
Insurance	286.56	76.95	133.65	-
Transportation Exp.	-	-	-	-
Total	1,462.25	984.80	617.76	90.25
$/1,000 gal.	.095	.043	.027	.004
TOTAL	9,029.22	12,167.28	6,832.47	4,115.44
$/1,000 gal.	.587	.529	.297	.179

Table A-5. Operation Costs, Hart (1,815)

Fiscal Year Ending	6/30/76	6/30/75	6/30/74
Code Number	48	36	24
Flow in MGD	.470	.470	.470
I. Salaries & Wages	13,563.41	12,168.58	10,711.35
$/1,000 gal.	.079	.071	.062
II. Utilities	21,013.06	14,765.41	5,679.94
$/1,000 gal.	.122	.086	.033
III. Oper. & Maint. Exp.			
Supplies	3,582.30	1,284.33	-
Maintenance	359.26	429.86	1,100.60
Equipment Rental	-	-	-
Professional Serv.	1,481.49	731.27	-
Outside Services	1,769.52	-	650.00
Miscellaneous	911.04	756.25	623.59
Total	8,103.61	3,201.71	2,374.19
$/1,000 gal.	.047	.019	.014
TOTAL - I, II, & III	.248	.176	.109
IV. Gen. Admin. Exp.			
Office Expense	1,954.73	1,485.21	1,554.56
Insurance	1,675.81	1,083.30	999.59
Payment in lieu of Property Taxes	181.65	57.02	-
Transportation Exp.	474.93	387.09	209.43
Total	4,287.18	3,012.62	2,763.59
$/1,000 gal.	.025	.017	.016
TOTAL	46,967.26	33,148.32	21,529.06
$/1,000 gal.	.274	.193	.125

Table A-6. Operation Costs, Dimondale (972)

Fiscal Year Ending	2/29/76	2/29/75	2/29/74	2/29/73
Code Number	44	32	20	8
Flow in MGD	.070	.070	.070	.070
I. Salaries & Wages	18,119.56	17,595.70	8,273.34	9,242.94
$/1,000 gal.	.709	.689	.324	.361
II. Utilities	8,105.35	6,904.61	5,450.98	5,426.80
$/1,000 gal.	.317	.270	.213	.212
III. Oper. & Maint. Exp.				
Supplies	381.78	3,045.27	2,518.75	1,712.56
Maintenance	5,188.17	3,417.46	1,412.29	2,165.97
Equipment Rental	-	-	50.23	-
Professional Serv.	1,083.48	629.50	-	-
Outside Services	-	-	-	-
Miscellaneous	691.38	764.85	73.75	25.00
Total	7,344.81	7,857.08	4,055.02	3,903.53
$/1,000 gal.	.287	.307	.159	.153
TOTAL - I, II, & III	1.313	1.266	.696	.726
IV. Gen. Admin. Exp.				
Office Expense	502.32	577.90	797.06	845.48
Insurance	216.00	367.00	65.00	234.00
Transportation Exp.	316.85	30.23	-	-
Total	1,035.17	975.13	862.06	1,079.48
$/1,000 gal.	.040	.038	.034	.042
TOTAL	34,604.89	33,332.52	18,641.40	19,652.75
$/1,000 gal.	1.354	1,304	.730	.769

Table A-7. Operation Costs, Jonesville (1,700)

Fiscal Year Ending	12/31/75	12/31/74	12/31/73
Code Number	42	30	18
Flow in MGD	.250	.250	.250
I. Salaries & Wages	30,817.77	23,737.07	20,686.97
$/1,000 gal.	.338	.260	.227
II. Utilities	4,908.48	4,069.68	4,878.79
$/1,000 gal.	.054	.044	.053
III. Oper. & Maint. Exp.			
Supplies			
Maintenance			
Equipment Rental			
Professional SErv.			
Outisde Services			
Miscellaneous			
Total	29,717.01	18,601.87	23,033.08
$/1,000 gal.	.326	.204	.252
TOTAL - I, II, & III	.718	.508	.532
IV. Gen. Admin. Exp.			
Office Expense			
Insurance			
Transportation Exp.			
Total	1,967.09	1,515.13	1,320.44
$/1,000 gal.	.021	.017	.014
TOTAL	67,410.35	47,923.75	49,919.28
$/1,000 gal.	.739	.525	.547

Table A-8. Operation Costs, Luna Pier (1,418)

Fiscal Year Ending	6/30/76	6/30/75	6/30/74
Code Number	48	36	24
Flow in MGD	.130	.143	.157
I. Salaries & Wages	50,866.96	50,900.40	43,231.83
$/1,000 gal.	1.072	.975	.754
II. Utilities	7,895.56	7,355.14	7,324.48
$/1,000 gal.	.166	.141	.128
III. Oper. & Maint. Exp.			
Supplies	4,060.73	4,549.16	4,812.89
Maintenance	1,795.10	1,563.14	1,018.61
Equipment Rental	-	-	-
Professional Serv.	785.95	-	-
Outside Services	-	2,180.50	-
Miscellaneous	92.26	19.71	131.24
Total	6,734.04	8,312.51	5,962.74
$/1,000 gal.	.142	.159	.104
TOTAL - I, II, & III	1.38	1.275	.986
IV. Gen. Admin. Exp.			
Office Expense	825.00	1,006.50	-
Insurance	1,370.00	1,561.82	1,071.00
Transportation Exp.	-	29.33	-
Total	2,195.00	2,597.65	1,071.00
$/1,000 gal.	.046	.050	.019
TOTAL	67,691.56	69,165.70	57,590.05
$/1,000 gal.	1.426	1.325	1.005

Table A-9. Operation Costs, Constantine (1,720)

Fiscal Year Ending	2/29/76	2/29/75	2/29/74
Code Number	44	32	20
Flow in MGD	.317	.390	.483
I. Salaries & Wages	51,983.18	42,796.84	29,371.76
$/1,000 gal.	.449	.300	.167
II. Utilities	15,809.70	14,343.05	7,507.27
$/1,000 gal.	.137	.101	.042
III. Oper. & Maint. Exp.			
Supplies	8,236.82	11,723.37	8,152.52
Maintenance	7,052.51	3,697.42	6,226.72
Equipment Rental	511.30	96.98	387.74
Professional Serv.	1,830.00	2,520.05	789.11
Outside Services	-	-	-
Miscellaneous	114.25	227.14	393.32
Total	17,744.88	18,264.96	15,949.41
$/1,000 gal.	.153	.128	.090
TOTAL - I, II, & III	.739	.529	.299
IV. Gen. Admin. Exp.			
Office Expense	1,252.71	1,295.75	954.93
Insurance	1,646.45	1,651.82	766.64
Transportation Exp.	416.78	495.00	312.70
Total	3,315.94	3,442.57	2,034.27
$/1,000 gal.	.029	.024	.011
TOTAL	88,853.70	78,837.42	54,462.71
$/1,000 gal.	.768	.554	.311

Table A-10. Operation Costs, Imlay City (1,965)

Fiscal Year Ending	6/30/76	6/30/75	6/30/74	6/30/73
Code Number	48	36	24	12
Flow in MGD	.353	.343	.338	.311
I. Salaries & Wages	31,812.16	27,594.23	27,620.20	20,710.00
$/1,000 gal.	.247	.220	.224	.182
II. Utilities	5,792.01	4,841.77	3,549.20	3,580.62
$/1,000 gal.	.045	.039	.029	.031
III. Oper. & Maint. Exp.				
Supplies	5,525.90	5,844.39	5,589.95	4,558.65
Maintenance	2,116.25	5,513.16	3,863.04	4,137.45
Equipment Rental	2,020.13	2,092.75	2,034.67	1,019.28
Professional Serv.	3,385.94	178.12	4,053.21	140.00
Outside Services	-	-	-	-
Miscellaneous	37.00	28.94	218.78	25.00
Total	13,085.22	13,657.18	15,759.65	9,880.38
$/1,000 gal.	.101	.109	.128	.087
TOTAL - I, II & III	.393	.368	.381	.300
IV. Gen. Admin. Exp.				
Office Expense	720.50	714.18	353.06	147.60
Insurance	1,272.39	2,041.32	1,240.53	205.80
Transportation Exp.	94.01	314.62	374.55	14.38
Total	2,086.90	3,070.12	1,968.14	367.78
$/1,000 gal.	.016	.024	.016	.003
TOTAL	52,776.29	49,163.30	48,897.19	34,538.78
$/1,000 gal.	.409	.393	.396	.304

APPENDIX B

EXPLANATION AND RESULTS OF STATISTICAL TESTS PERFORMED ON THE INTERCEPTS AND SLOPE COEFFICIENTS OF THE LINEAR REGRESSION EQUATIONS TO DETERMINE IF THERE ARE SIGNIFICANT DIFFERENCES BETWEEN THE LAND AND CONVENTIONAL TREATMENT OPERATION EXPENSES

Theoretical background for the significance tests of the intercepts and slopes of the regression equations are presented below along with the results of the tests.

Individual Regression Equations

A. $Y^A = \alpha_0^A + \alpha_1^B X^A + E^A$ Land Treatment

B. $Y^B = \alpha_0^B + \alpha_1^B X^B + E^B$ Conventional Treatment including Dimondale

C. $Y^C = \alpha_0^C + \alpha_1^C X^C + E^C$ Conventional Treatment without Dimondale

Pooled Equation

$$Y = \alpha_0^A + \alpha_0^B B + \alpha_0^C C + \alpha_1^A X^A + \alpha_1^B X^B B + \alpha_1^C X^C C + E$$

$B = 1$ if Conventional Treatment including Dimondale

$B = 0$ if otherwise

$C = 1$ if Conventional Treatment without Dimondale

$C = 0$ if otherwise

$$X_1 = \beta_0 + \beta_1 X_2 + \beta_2 X_3 + \beta_3 X_4 + \beta_4 X_5 B + \beta_5 X_6 C + E$$

This assumes that both the slopes and intercepts are affected by the type of system used.

Tests

Tests of significance were conducted to determine if the slopes and intercepts of the land treatment systems regression equations were significantly different from the slope and intercept terms of the conventional treatment regression equations. The t-statistic and significance levels are presented in Table B-1.

If β_1 is significantly different from 0 then there is a difference in intercept between Land Treatment and Conventional Treatment with the Dimondale system included in the conventional group.

If β_2 is significantly different from 0 then there is a difference in intercept between Land Treatment and Conventional Treatment without the Dimondale system included in the conventional group.

If β_4 is significantly different from 0 then there is a difference in slope between Land Treatment and Conventional Treatment with the Dimondale system included in the conventional group.

If β_5 is significantly different from 0 then there is a difference in slope between Land Treatment and Conventional Treatment without the Dimondale system included in the conventional group.

Table B-1. Summary Table of Statistical Tests on Regression Equation Intercept and Slope Coefficients

Expense Category	Beta	t	Significance
I. Salaries & Wages			
	1	.1982	.844
	2	.0946	.925
	4	1.1479	.258
	5	1.1732	.248
II. Utilities			
	1	.9188	.364
	2	.2274	.821
	4	.1790	.859
	5	.3172	.753
III. Operation and Maintenance Expense			
	1	1.0412	.304
	2	.8716	.389
	4	.1611	.873
	5	.3209	.750
IV. Total of Categories I, II, III			
	1	.6301	.532
	2	.1054	.917
	4	.8259	.414
	5	.9114	.368
V. General Administrative Expense			
	1	.0732	.942
	2	.7644	.449
	4	.7761	.442
	5	.0641	.949
VI. Total Expense			
	1	.6149	.542
	2	.0612	.952
	4	.7537	.455
	5	.8758	.386

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