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Irrigating with Municipal Effluent

A Socioeconomic Study of Community Experiences

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ABSTRACT

This study examines experiences of eight communities using land to treat municipal effluents. Most systems evolved without long-range planning. No distinct methods for land acquisition and management related to the size of the community were identified. Factors identified as important for successful systems operation included a long planning horizon and good working relationships between community officials and landowners. Legal contracts were of secondary importance. Farmers did not adjust their fertilization rates, although they recognized the value of nutrients in the effluent.

Keywords: Land application, agricultural and community impacts, case studies, planning guidance, resource recycling

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SUMMARY

Eight representative communities are examined in this report to identify their long-term experiences with land treatment of municipal effluent and to provide information on socioeconomic issues to other communities considering the adoption of land treatment systems.

Communities and farmers have several options for establishing agreements for use and management of land needed for municipal effluent treatment systems. Communities can obtain rights to land through purchases, easements, or contractual agreements. A community which purchases a treatment site can manage it directly or lease it to another party. Or access to land can be obtained without purchase through contracts with individual landowners or through the formation of a wastewater cooperative.

No distinct ownership and management patterns emerged among the communities studied, nor were there obvious reasons why one method was selected over another. Community size had little influence on the choice. Factors which seemed to influence the methods selected included site specific technical factors; the political, social, and regulatory environment; and local custom and entrepreneurship.

Much more variety existed in acquisition and management methods for slow rate or irrigation systems than for rapid infiltration systems. This reflects the smaller land requirements needed for the rapid infiltration systems and that such systems do not involve agricultural production. All rapid infiltration systems were owned and managed by the community they served. Greater variety existed among communities irrigating crops with effluent. Four communities provided effluent to privately owned land adjacent to the treatment sites. One city owned the treatment site and leased it to a farmer, and another community owned and operated the farm used for land treatment of effluent.

Both community officials and farmers were aware of the economic value of effluent, both as a source of irrigation water and a source of nutrients. But, the resources were not being used economically. Farmers generally paid the communities for the use of effluent, either in cash or by providing access to land, but they had not reduced commercial fertilizer application rates to reflect the nutrient content of the effluent. City officials recognized the value of effluent, but did not charge for its full value.

Community needs for wastewater treatment, together with farmers who perceived an opportunity for improving their supply of water and nutrients at a low cost, led to the

initial development of several of the systems. The land treatment systems then developed as the communities expanded; but little of the expansion of the systems was planned. Important ingredients to the successful operation of such a system are understanding and a good working relationship between the farmer and the community. Legal terms of an agreement can be specified in a contract, but such a contract is not as important as the informal understandings developed between the involved parties.

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INTRODUCTION

Environmental regulations to increase the treatment given municipal effluents have focused additional attention on land treatment of municipal effluent. Land treatment of effluent from municipal wastewater treatment plants involves the use of plants, the soil surface, and the soil matrix to remove many wastewater constituents, and, in many cases, to recycle these constituents in agricultural crop systems.

Land treatment has recently been adopted by several communities and is being considered by many others. This study assesses the economic and institutional factors influencing the selection, design, and operation of municipal land treatment systems for eight representative communities. It is part of a comprehensive study of the long-term effects initiated by the Environmental Protection Agency (EPA). The overall study also reported the results of the water quality and environmental investigations of the long-term effects of the systems. These reports are by Aulenbach (3) Hossner (20), Weaver (54), Koerner and Haus (23), Benham-Blair (5), Stone (41, 42), and Reynolds (34). 1/

Specific study objectives include:

1. Development of a framework of acquisition and management options for use by farmers and communities in establishing land treatment systems, with a discussion of the advantages and disadvantages of each.

1/ Underscored numbers in parentheses refer to items in the Bibliography.

2. Description of the operation of the community systems, emphasizing methods used to acquire and operate sites and the legal agreements used.

3. Analysis of the evolution of the acquisition and management systems used, and an assessment of the strength of systems used.

4. Analysis of associated effects of the specific systems on the local economy.

Increased Interest in Land Treatment

Land treatment offers resource recovery and reuse options rather than treatment and disposal. Numerous opportunities exist to reclaim water and nutrients for crop production and to recharge ground water supplies.

When Federal water quality goals were augmented with the passage of the 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500), land treatment, because of its potential for recycling, received special recognition as a treatment alternative. The purchase of land, an integral part of a land treatment system, became eligible for a Federal construction subsidy for the first time. Added emphasis was given land treatment by EPA policy statements and by provisions of the Clean Water Act of 1977 (16, 46, 51). Receipt of a Federal construction subsidy requires that land treatment alternatives be evaluated. Since October 1, 1978, land treatment systems have been considered innovative and/or alternative treatment technologies eligible for an additional 10-percent construction subsidy. An innovative or alternative treatment system is deemed cost effective if its costs are 115 percent or less of the least cost conventional treatment alternative.

Numerous studies were undertaken in the early seventies to define the process of land treatment of municipal wastewater, identify technical parameters, and assess costs (28, 29, 30, 40, 50, 52). These studies supported land treatment as a viable treatment alternative. But, questions remained about the long-term effects of land treatment systems. While some studies concluded that land treatment was effective, little data were available describing the effects on factors influencing the viability of a system over a long period of time.

Land Treatment Concepts

Land treatment is the application of wastewater to land for treatment, renovation, recycling, and reuse. One objective is the utilization and adsorption of nitrates and phosphates by soil and plants to purify the water. Land treatment uses plants, the soil surface, and the soil matrix to remove many wastewater constituents (52). Three principal processes are available: slow rate, rapid infiltration, and overland flow (29, 52).

Application rates with irrigation or slow rate systems are low, with annual application rates of between 0.6 and 6 meters (m) [2-20 feet (ft)]. Vegetative cover and soil microorganisms act to remove and alter the characteristics of the pollutants as the wastewater percolates through the soil. Depending upon the goals for the system, the vegetative cover may or may not be harvested.

In rapid infiltration systems, most of the applied wastewater percolates through the soil and the treated effluent eventually reaches the ground water. Annual application rates for this type of system range from 6 to 171 m (20-560 ft). Wastewater constituents are removed by the filtering and straining action of the soil.

In overland flow, wastewater is applied over the upper reaches of sloped terraces and is allowed to flow across the vegetated surface to runoff collection ditches. Application rates range from 3 to 21 m (10-70 ft) per year depending on the level of preapplication treatment. The wastewater is cleansed by physical, chemical, and biological means as it flows in a thin film down a relatively impermeable slope.

Historical Perspective

Water quality concerns transcend generations. Great Britain, working for water quality improvement over a century ago, passed the Rivers Pollution Prevention Act of 1876. This act required that treatment of wastes discharged into British waterways be "the best or only practical and available means under the circumstances" (19). Nearly a century later, PL 92-500 established "the best practical waste treatment technology" as a 1983 minimum requirement for publicly owned treatment works discharging wastewaters into navigable waters.

Current emphasis on land treatment in the United States started in the early seventies. However, a historical review of early land treatment systems reveals how human experiences and interests are repeated. References to early systems are numerous (21, 29, 32, 33). Present interest in water quality improvement and particularly applying wastewater to land has precedence in earlier experiences of the United States. Problems and issues addressed by Rafter are currently being addressed through planning efforts for land treatment of wastewater. The current efforts have the added dimension of reuse and recycling of the resources in wastes. Rafter's first article noted that under the right conditions sewage may be profitably utilized (32). He identified general principles applicable now as well as then: the need for properly trained sewage plant operators, the need for site specific analysis so that "each case must be studied by itself on its own merits," and the need to take into account the attitudes of surrounding residents in farm locations. Other early issues that are current today include tradeoffs between waste purification and utilization, compatibility of application rates with agricultural production, the need for storage or sites for intermittent use when effluent flow exceeds crop reuse capacity, and the potential problems arising when profit maximization from using effluent in farming conflicts with the goal of effluent treatment.

The beginnings of an applied scientific approach to sewage farming has been attributed to England in the middle of the 19th century (32). This resulted from concerns in general about water pollution associated with the growth of cities and industry, and the search for solutions. The first effort at sewage irrigation in the eastern United States was in 1872 at an asylum in Augusta, Maine. Approximately 0.3 liters per second (l/s) [7,000 gallons per day (gpd)] passed by gravity into large tanks where it was mixed with absorbents such as straw and leaves. The solids were then periodically carted onto the land while the liquid portion was used to irrigate approximately 1.2 ha (3 ac) of hay and vegetables (33). Cheyenne, Wyo., was the first western U.S. city to irrigate with sewage in 1881 (29). Other early systems were developed at Los Angeles, Calif., San Antonio, Tex., and Lubbock, Tex.

Los Angeles began using sewage for irrigation about 1883, and by 1897 had the most extensive privately owned sewage farming operation in the Nation. In 1883, Los Angeles contracted to give its sewage to the South Side Irrigation Company. This contract was renewed in 1895 with the provision that the city would deliver more sewage. In exchange, the company built a lengthy 24-inch delivery pipe, which became city property in 1903. About 891 ha (2,200 ac) of private land in vegetable crops were irrigated with the sewage conveyed by ditches from the main outfall sewer. The rent for land receiving sewage irrigation was $18 per acre compared to $12 an acre for that irrigated with river water. As the city grew, the irrigated area became city property. Residents who bought nearby land objected to the sewage irrigation and the system was eventually closed (33).

San Antonio was the first Texas community to use irrigation as a means to dispose of its sewage. The city purchased 214 ha (530 ac) of land in 1895, expecting to establish a sewage farm (33). In 1900, the city contracted with a private company to irrigate land with effluent (17).

A 1953 review of the San Antonio system found farmers were satisfied with the use of effluent for their crops. Mitchell Lake, a 275-ha (680-ac) artificial lake about 19.4 kilometers (km) [12 miles (mi)] southwest of the city, has received San Antonio sewage in various stages of treatment. Numerous farms and ranches used the sewage water for irrigation. The four largest farms totaled 1,093 ha (2,700 ac) and irrigated 740 ha (1,827 ac). Significant increases in hay yields and pasture carrying capacities were attributed to the use of effluent (39).

Lubbock's effluent has been used for irrigation since 1925. Prior to 1925, treated wastewater was discharged into a stream flowing through the city. The existence of several privately owned recreation lakes in the canyon below the sewage treatment plant in 1925, coupled with poor water quality in the normally dry water course, prompted the city to look for alternative means of disposal.

Lubbock has contracted with Frank Gray and Associates for reuse of effluent for irrigation since 1937. The original 20-year contract was for the use of 44 to 66 l/s [1-1.5 million gallons per day (mgd)] of effluent on 80 ha (200 ac) of land, 40 ha of which was leased from the city and another 40 from an individual. Effluent volume had increased to 723 l/s (16.5 mgd) by 1976. Gray has expanded his farming operation to control 1,214 ha (3,000 ac) of land, and supplies water on a periodic basis to about 810 ha (2,000 ac) of his neighbors' land. The contract directs the city to continuously deliver all its wastewater to Gray, and for Gray to use it in a manner acceptable to State and local health departments. Gray historically has a surplus of water, sometimes irrigating at an annual rate of 3.6 to 4.6 m (12-15 ft) (56).

ALTERNATIVES FOR LAND ACQUISITION AND MANAGEMENT

Land treatment systems require greater land area than conventional treatment systems. While land is needed for plant location for all systems, it is an integral part of the treatment process for land treatment systems. Type and location of land is also much more important for land treatment systems. Acquisition of rights to this necessary land base is an important planning variable for wastewater authorities.

Although rights to land may be obtained in a number of ways, the alternatives are normally defined by the institutions governing ownership and use of land. Institutions have been defined as "sets of ordered relationships among people which define their rights, exposure to the rights of others, privileges, and responsibilities" (37). They reflect people's perspectives and values and a distribution of political and economic power to influence and control individual behavior and group action.

Property rights are an important legal-economic institution affecting land treatment systems. They govern the contracts and conditions for the acquisition and use of the total "bundle of rights" ascribed to landownership. The bundle of rights to property represents the total of several distinct interests or rights. It may be optimal from a management and environmental viewpoint for a community wastewater authority to acquire the total bundle of rights for land used in such integral operations as treatment lagoons, pretreatment facilities, and pumping and distribution facilities. Access to land for the actual application of wastewater can be acquired without acquiring the complete bundle of rights.

Land costs influence the adoption of land treatment systems. However, while the monetary cost of purchasing land can be large it may not exert as large an impact on costs as might be anticipated (61). Even more important, landowner opposition can prevent the adoption and development of land treatment systems. Land acquisition and management need to be handled carefully, balancing the respective views and goals of both the community and the landowner.

Land is a basic input for diverse and potentially conflicting goals. The community needs land for the primary goal of wastewater treatment. This same land is also a vital resource which farmers need to earn their living. Thus, a community seeking farmland for treating municipal effluent needs to consider the farmer's perspective.

Acquisition and Management Options

Institutional analysis focuses on how land will be acquired and managed and the impact of methods selected on issues of equity, system management, treatment reliability, implementation, and acceptability. Property rights govern the transfer and use of land needed for several purposes including treatment lagoons, pretreatment facilities, conveyance systems, pumping stations, and application sites. Options for acquiring land provide control over the resource itself. Management options obtain certain behavioral actions from both farmers and communities in the use of land. A number of management options can be exercised in conjunction with acquisition options, particularly with fee simple acquisition (purchase) and contracts. Decisionmakers need to evaluate these options in light of site requirements, and impacts on costs, control, and public opinion.

Fee Simple Acquisition

Rights obtained through fee simple acquisition include all rights to land including the right to possess, use, buy, sell, or enter into contractual arrangements. These rights are exclusive rather than absolute as government places limitations on them through the use of taxation, eminent domain, escheat, and police power (4). The use of the land itself is subject to the nuisance doctrine which precludes use of the land that unreasonably interferes with the rights of others.

When fee simple interest is obtained voluntarily, the landowner is presumably paid the full value of the land and thus bears no cost of public action. The community may acquire a fee simple interest through the exercise of its eminent domain authority, if the land is to be used for public purposes. In this instance, the community is required to compensate the landowner for the fair market value of the property taken. However, some of the public costs may be transferred to the displaced landowner. For instance, the State might restrict land use to a specific purpose, such as land treatment. Courts however would probably view this as a taking which requires compensation under eminent domain.

Use of the fee simple acquisition option permits a municipal authority to use the land in any manner compatible with its objectives without obtaining agreement from a second party. This is particularly important since it subjects the engineering and environmental considerations of the treatment system to a unilateral rather than a bilateral decisionmaking process. Fee simple acquisition insures a long-term planning horizon for the treatment site. Disadvantages to the community include the high purchase costs of fee simple interests and the public opposition that may be encountered with large-scale government involvement in the real estate market. Large land purchases by a tax-exempt body could have a significant impact on property tax revenues and on budgets of taxing districts. Such impacts need to be considered in the planning process (14).

With fee simple acquisition, landowners exchange their rights for some dollar amount. With either a voluntary or involuntary property sale, the owner generally can relocate or leave farming entirely, or perhaps continue to farm through a leaseback agreement or as a municipal employee. Social benefits may be realized from fee simple acquisition as it insures continued operation of the waste treatment site. Fee simple acquisition also facilitates using the lands to serve broader public planning objectives. Sites can be specifically selected for soil type, location, and secondary uses such as preservation of open space, protection of water table recharge areas, and planned urban expansion. The acquisition of large tracts of farmland may impose a social cost if communities are disrupted and social and economic bonds are broken.

Options for the management of land acquired in fee simple include purchase and manage, purchase and leaseback, and purchase and resale on condition. The wastewater authority makes the managerial and operational decisions with the purchase and manage option. With the purchase and leaseback option, most managerial and operational responsibilities are transferred to the lessee. The purchase and resale on condition option enables the authority to buy the required land and then resell it with conditions attached compatible with land treatment requirements.

Purchase and Manage--When fee simple title is acquired, a wastewater authority may choose to manage the farming operations as a subsystem of the overall wastewater treatment operation. These additional responsibilities may tax the managerial resources of the wastewater authority, leading to some type of subcontracting arrangement for custom farm operations. However, custom farming may be impractical for a large metropolitan system with a large farming operation. The wastewater authority would have to negotiate numerous contracts with custom operators, provided there were enough operators in the area. An alternative arrangement would be to negotiate a contract with a management firm to run the farming operations. Such a contract existed between a private corporation and Muskegon County, Mich., in the early years of the Muskegon land treatment system. It covered the operation and monitoring of the treatment system, including the farming operation. However, the county subsequently assumed direct responsibility for the operation of the system.

Purchase and Leaseback--Under the purchase and leaseback option the operating authority acquires fee simple title to land and leases it to another party for farming operations. The lessee may be the previous landowner or a third party. This option may require that the authority provide some managerial services. Purchase and leaseback has the potential for establishing subsequent uses for the land. Moreover, purchase and leaseback can be done within the well-established legal framework of the landlord-tenant law. Enforcement of use limitations is not difficult, especially if the terms of the lease spell out the rights and duties of each party and the remedies available for breach of contract.

There is relatively little experience with the purchase and leaseback option on a large scale in the United States. Such an arrangement might be attractive to a farmer approaching retirement age and wanting to relinquish part of his ownership responsibilities. The amount of land acquired by purchase and leaseback would depend upon community size, the farm operator's cooperation, and the public's acceptance of the program.

The usefulness of the purchase and leaseback option is influenced by the term and form of a negotiated lease. The term may vary from less than 3 years to longer periods, up to 99 years. Long-term leases usually run for periods of 15 years or more. Such long planning horizons are important for land treatment sites. Main forms of leases include cash rent and share rent. Cash rent leases typically call for a specific annual cash payment. A cash rent lease protects the landowner but leaves the tenant subject to the risk and uncertainties of the farming activities. Share rents specify a division of the crop yields and the production costs between the landlord and tenant. A major effect of share rents is to shift some risks and responsibilities of management from the tenant to the landlord (4). Since land treatment is a relatively new technology for humid areas, tenants may prefer sharing risks with the treatment authority.

Purchase and Resale on Condition--This option entails the public purchase of land and its subsequent resale for private use, under conditions designed to achieve legitimate public ends. It has been used most frequently in urban renewal projects, and is a means of insuring that land acquired by a public body shall be properly transferred so that development and use will conform to the development plan.

Purchase and resale enables a wastewater authority to obtain the rights to land without making a long-term capital investment. It reduces administrative problems by getting the authority out of the real estate business. Conditions important to the operation, such as amounts of wastewater to be accepted and necessary environmental protection, can be prescribed in the resale conditions and can be enforced by a suit for damage or injunctive relief. Operation from the time of purchase to the time of resale can be accomplished under lease options or other agreements. Once resale occurs, land is returned to the tax rolls and public land maintenance costs are eliminated.

A variation of purchase and resale under condition is the purchase and resale when the land is no longer needed for wastewater application. Gains realized from lease arrangements or subsequent sale of the land could help finance the wastewater authority, or compensate the community for any tax loss resulting from the reduction in taxable property.

Real Property Interest Other Than Fee

An alternative to fee simple acquisition is acquisition of only that portion of the total bundle of rights necessary to meet specific objectives. Easements are a prime example of real interest other than fee. An easement is a transfer of only a part of the total bundle of rights vested in fee simple ownership, from an individual to a government body. The easement concept is well established in agriculture as a method to maintain agricultural land in the path of urban development (49). The California Land Conservation Act is a prime example (12). Easements have a common property character as they represent governmental action to secure property rights for nonowners.

There are two general classes of easements, positive and negative (57). A positive easement is a right held by the purchaser or recipient of that easement to use the property according to some set agreement. Examples of positive easements include fishing rights, and a utility company's right to install lines on, in, or above one's property. Rights for wastewater conveyance lines are another example. A negative easement is a transfer of rights that prevents the landowner from exercising a specific right. Negative easements have most commonly been designated for scenic, conservation, and wetland purposes. An example of a negative easement would be a farmer transferring his rights to drain lands used by waterfowl during migration. In such cases, his rights to drain his land are transferred in exchange for a consideration.

Easements can be donated, purchased, or acquired through condemnation by public agencies. Authority for the acquisition of easements is not as widespread as the authority to purchase the fee simple title. In several instances, legislation has been passed which permits acquisition of less than fee simple interests but excludes use of the power of eminent domain to acquire such rights.

As with fee simple acquisition, the easement concept has characteristics which influence the distribution of impacts among farmers, the community, and society in general. Easements allow farmers to maintain ownership even though they relinquish certain rights in exchange for negotiated compensation. A disadvantage to farmers is that they may have difficulties enforcing their individual rights.

Some major advantages of easements to an authority include lower costs and financing requirements relative to fee simple acquisition, and tailoring of the rights obtained to a specific objective. For example, some easements may permit irrigation, while others may acquire the right for wastewater transmission pipes to pass. Also, less community opposition would be encountered as land remains in private ownership and on the tax rolls.

Major disadvantages to an authority of easements include difficulty in establishing easement values for negotiation purposes, administrative problems in enforcing authority rights, and a potential problem of enforcement against subsequent fee purchases or land uses if the easement is not properly recorded. A disadvantage in rapidly developing areas is that the easement cost can approximate the cost of fee simple ownership. Administrative authorities in such areas may be reluctant to acquire easements that may cost as much as 60 to 80 percent of fee simple ownership.

Contracts With No Real Property Interest

The third category of acquisition options are those which provide access to land without any transfer of real property rights. In this case, negotiation between the involved parties determines the terms of the agreement, usually specified in a contractual agreement. Examples of this acquisition option are a contract between a farmer and a wastewater authority and formation of wastewater cooperatives.

<u>Contracts</u>--Contracts between two or more parties generally specify an agreement of actions to be taken or refrained from in exchange for a specified consideration. Most contracts for land application in the United States have been between a farmer and a community, specifying agreements for applying effluent to private farms or to land owned by the city.

The terms of a contract vary from location to location reflecting site specific conditions. Contracts can specify agreements on the construction of irrigation delivery and drainage systems, distribution of crops from the farming operation, cost sharing, duration of the contract, review procedures, and termination clauses (24). Contracts can also specify the annual amount of effluent that farmers will receive from the authority. Farmers could then allocate the wastewater to crops compatible with their management objectives. A wastewater authority may contract to sell effluent to farmers, although a survey of operating land disposal systems found that such sales have generally been unsuccessful, and there have been few cases where a public agency was able to obtain more than token payment for the treated effluent (43).

The land treatment system at Lubbock is an example of a contractual agreement between a municipality and farmers. Approximately 1,174 ha (2,900 ac) are involved in a system operating since 1937. Approximately 1.2 to 1.8 m (4-6 ft) of effluent are applied annually for use in forage and livestock farming. A prime contractor (farmer) is the intermediary between the municipality and other farmers using the effluent. Some land is owned by the city of Lubbock, some owned by the prime contractor, and some is leased from adjoining farms. A 20-year cash lease was negotiated for city-owned land. The prime contractor is required to take all the effluent from the holding tanks at all times. Land preparation, construction of ditches, installation of pipelines, and related costs are paid by the irrigators, rather than by the city. A cooperative and understanding attitude between the municipal government and the operator of the project was identified as essential to the success of the system. Just as a city wants to insure a place to dispose of its wastes, the farmer must be protected with a long-term contract in order to make the investments necessary to handle the effluent (18).

Wastewater Cooperatives--An alternative to a two-party contract is a cooperative venture where a number of farmers enter into a contract with a city to provide land for wastewater treatment. Such a cooperative approach has not been used in the United States, but has been evaluated as a possibility for a large-scale land treatment system (10). Although farmers form cooperatives to purchase production supplies and sell their crops, these cooperative ventures are not generally extended to land use. It is likely that increasing partnerships and greater cooperative action will be necessary for farmers to function in an environment of contractual systems of control (7).

The cooperative approach to the utilization of land waste treatment has been used successfully in Germany (36, 44). The Sewage Utilization Association of Braunschweig was organized in 1954 to expand the activities of a sewage farm operating in the area since the 1890's. The association is made up of the city of Braunschweig (population 325,000), 476 farmers, and 26 nearby communities. Approximately 30.3 million liters per day (8 mgd) of raw sewage are applied to 4,210 ha (10,400 ac) of land. The total irrigation area consists of land in 12 communities which is divided into four districts of comparable acreage which are further divided into three rural districts and three government districts. Policy decisions for the association are made by a committee of 20 farmers and four city representatives. Farmers pay 25 percent and the city pays 75 percent of the cost of the systems. Many communities bordering the irrigation area have joined the association, paying an annual charge for sewer and pumping station networks.

The cooperative approach would build upon the existing economic and social structure of the rural community. Such a cooperative might also serve as a basis for planning and implementing other community goals. Irrigation districts in the Western United States are a form of cooperative venture with a successful tradition.

A disadvantage in cooperative land use decisions could be the perceived or real loss of highly valued individual freedom of choice. The history of the cooperative movement, however, indicates that mutual gains from cooperation on input purchases and commodity sales adequately compensate cooperators for any perceived loss of freedom.

Implications for Communities and Farmers

Each acquisition and management option affects the respective goals of the farmer and community differently and these need to be considered in evaluating land treatment systems. Both parties are motivated by a combination of economic and other goals. Water and nutrients in effluent may be used to increase agricultural production, which in turn can increase farm income and reduce community treatment costs.

The goals of a community and farmers are diverse and sometimes conflicting. A community orients its goals towards the health and well-being of its residents. Public health concerns translate in part to wastewater treatment objectives and the need to meet them in an economic and politically acceptable manner. Farmer's goals include income generation, wealth accumulation, firm growth, freedom of decisionmaking, and the sense of community (9).

Farmers

The impact on farmer's goals is the greatest when fee simple title is acquired by the wastewater authority. Easement acquisition and contractual arrangements have less impact as the farmer continues to farm, influenced only by the terms of the easement or contract.

With fee simple transfer of title, the impact on the farmer is influenced by the management option selected by the community. The impact is less severe when the farmer can remain on the land under a tenancy or employment arrangement rather than relocating. A lease arrangement affords a former owner the greatest stake in the operation, particularly if the former owner shares in successes as well as in failures.

Contractual arrangements between the farmer and the community should be reviewed on a regular basis. The initial agreement should indicate agreement over the distribution of benefits and costs, but changes in the underlying factors would require a regular review of contractual terms.

Communities

Fee simple acquisition gives a community complete ownership of the land, but at a high cost, particularly for large systems. But, such acquisition enables a community to unilaterally plan to meet its primary objective of wastewater treatment and renovation. With other than fee simple acquisition, the treatment goals of the community and the income goals of the farmers are likely to require more land to treat wastewater and maintain agricultural production simultaneously.

Fee simple acquisition provides a community greater flexibility in planning for multipurpose land use, such as parks and open space.

Real property interest other than fee may be obtained through the use of easements. Title to the treatment site would be retained by the current owner and the community acquires only those property rights necessary to carry out the particular management practices and controls required by the land treatment system. Easements do not remove land from the local property tax base.

Even when land remains in private ownership, the large amount of acreage required for high wastewater volumes suggests that land treatment is most applicable for smaller communities or to treat only a part of the total wastewater volume of a large metropolitan area.

COMMUNITY EXPERIENCES WITH LAND TREATMENT SYSTEMS

This study addresses the long-term experiences of communities with land treatment systems. Ten communities were selected by EPA for a detailed study. Selection criteria included long-term continuous operation of the system, availability of current and historical data on the operation of the system, ability to monitor current land treatment sites, geographical dispersion, and type of system. Sites were not selected on the basis of the economic and institutional characteristics, which are the focus of this study. The communities selected by EPA are:

Rapid infiltration	Slow rate (irrigation)
Lake George, N.Y.	Dickinson, N. Dak.
Hollister, Calif.	Roswell, N. Mex.
Vineland, N.J.	San Angelo, Tex.
Milton, Wis.	Tooele, Utah
	Mesa, Ariz.
	Camarillo, Calif.

This report focuses on communities which use effluent for crop irrigation. (Thus, only two rapid infiltration systems--Vineland and Lake George--were studied here since such systems were owned and managed by municipalities with no linkages between agricultural production and treatment management. Hollister, Calif., and Milton, Wis., were not considered in this report.) Issues of control, management, and responsibilities are more complex in crop irrigation cases than with rapid infiltration and overland flow systems where land is typically owned and managed by the community. Much less land is needed in the latter two systems, and agricultural production is of little importance to the total operation.

A case study approach was used to obtain insights from municipal officials, farmers, and landowners of potential use by other communities considering land treatment. Community experiences with effluent irrigation are described, including a brief community profile, an exploration of the evolution of the system, and a discussion of current operations. The farming operations and interactions between the city and farmer are described, focusing on the costs of the systems and the contracts used to govern the use of effluent in agriculture.

Camarillo, California

Camarillo is a coastal community situated in Ventura County, northwest of Los Angeles on the agriculturally rich Oxnard Plain. Its climate is Mediterranean or dry subtropical with warm dry summers and cool moderately rainy winters, with rainfall primarily in January and February. Average annual rainfall for the past 100 years was approximately 43 centimeters (cm) [17 inches (in)]. The 1980 population of Camarillo was approximately 37,500. Agriculture continues to be important in the economic life of the community. Major manufactured products include magnetic tape and recorders, fiberboard cartons, business forms, aerospace metals, and precision machines. Military bases, State hospitals, and schools provide most of the nonmanufacturing employment (8).

System History and Operation

The Camarillo Sanitary District was formed in April 1955 (under the Sanitary District Code of 1923) to construct a replacement for the existing cesspool system. In 1955, the city obtained an option to purchase land for construction of the sewage collection system and treatment plant. A bond issue was authorized in 1956 to raise revenue to buy land and construct a sewage disposal facility. In September 1957, $675,000 of bonds were sold for that purpose. The present system began operation in 1958. One major incentive for use of effluent on the land at the inception of the project was that it was a source of irrigation water. There was no water available from beneath the ground nor from the nearby irrigation district. Initially, the California State Health Department officials would not allow effluent applications to the land. However, as water quality improved and demand for water increased, restrictions were relaxed.

The present treatment system consists of primary and secondary clarification, with effluent discharge to a chlorine chamber, then to holding ponds, with eventual irrigation of cropland and a nearby cemetery or discharge in Conejo creek. Sludge undergoes anaerobic digestion, is dried on sludge beds, and is stored for eventual reuse on a nearby sod farm. The present treatment plant has a design capacity of 208 l/s (4.75 mgd), which may be reached within the next two decades.

Farming Operation

Effluent is applied through surface irrigation to 192 ha (475 ac), of which 81 ha (200 ac) are doublecropped. Truck crops are raised; single crops are dry beans and peppers, while broccoli and tomatoes are typically doublecropped. The current operator has farmed the land since 1966. He respects the regulatory power of the California State Health Department, and closely follows specified guidelines for effluent use. For example, effluent is not applied after the tomatoes start to change color. It is never applied on lettuce or root crops. Broccoli can be irrigated as soon as its heads are above the water level.

The farmer controls the application of the wastewater to the land. He owns the pipes, and starts the pumps at the storage lagoons according to the water needs of his crops. Pumping and maintenance costs are paid by the city. The fertilizer content in the effluent is recognized by the farmer, but no adjustments are made in the fertilizer practices.

The biggest drawback experienced by the farmer due to effluent use was soil crusting. Without adequate rains to break up the crust, effluent water could not be used effectively. There were also problems with sprinkler head plugging and increased pipe corrosion due to the wastewater. However, without the effluent, the high cost of water from the irrigation district could force him out of farming.

City-Farmer Interaction

Effluent is applied to agricultural land governed by two agreements. The landowner has an agreement with the city over water use, and also has a separate lease agreement with a local farmer covering his use of the land. The farmer pays cash rent of between $495 and $680 per ha ($200-275 per ac), depending upon the quality of the land. The better quality land is doublecropped.

The land currently under agreement with the city handles the present flow, but will not handle the design flow of 208 l/s (4.75 mgd) which is expected to be met within the next 10 to 20 years. The city must file a plan with the California Water Quality Control Board as soon as 75 percent of the plant capacity is reached.

The city is renegotiating the lease with the landowner to clarify the quantities of water involved. The landowner has a total of 324 ha (800 ac) available, but only 192 ha (475 ac) are presently used for wastewater irrigation. Plans are to expand on the present treatment site to provide sufficient water for the entire 324 ha (800 ac). As this is not enough land for the total projected flow, the city will determine where the remainder of the water will be used.

Key provisions specified in the 1955 agreement between the landowner and the city include:

1. Water from the sewage treatment plant is available to the landowner without charge for irrigation. A pipeline would be constructed from the treatment plant to an earthen reservoir on the landowner's property at Camarillo Sanitary District expense. Pumping costs to fill the reservoir are paid by the Camarillo Sanitary District.

2. The Sanitary District reserves absolute discretion to determine when it is safe to pump effluent. It does not guarantee a minimum flow of water, nor a continuous flow of water. It also specifies that the district shall not occupy the position of a public utility towards the landowners.

3. The landowner is responsible for maintenance and continued existence of the earthen reservoir. All claims against the District arising out of flood or other damage to crops due to overflow or washing out of the lagoon are waived.

4. The landowner provides a drainage easement to the Sanitary District to Conejo creek and permits drainage of effluent into a creek as required.

5. The landowner waives all causes of action for damage to crops, or other real personal property, arising from the use of effluent water.

6. The District agrees to lay sewage and effluent pipes at least 76 cm (30 in) below the surface. Any breakage to these due to farming activities would be paid by the landowner.

7. Should any of the areas near the treatment plant become residential in character, and effluent irrigation become offensive to neighbors, or should become a public nuisance, or if effluent irrigation should become the subject of a lawsuit, the District is immediately released from further obligations to supply the landowner with sewage effluent.

An agreement exists between the Camarillo Sanitary District and Pacific Sod Farms, Inc. for removal of dry sludge from Camarillo Sanitary District Treatment Plant. Key provisions include:

1. The Sanitary District provides an area for stockpiling sludge, will stockpile sludge at its expense, and will notify Pacific Sod Farms 1 week in advance of when dry sludge is available.

2. Pacific Sod Farms, at its expense, will treat the sludge stockpile to retard weed growth, load the dried sludge into its own hauling vehicles, and haul from the treatment plant site.

3. Pacific Sod Farms recognizes that the District does not guarantee the quantity or quality of dry sludge. It also agrees that the District may continue to supply dry sludge to local residents.

4. The consideration for the terms of the agreement is $1 per year, Pacific Sod Farms paying the District. The agreement is renewable annually, and can be cancelled by either party providing 30 days notice.

<u>Dickinson, North Dakota</u>

Dickinson, located in Stark County in southwestern North Dakota, is in farming and ranching country. Its population in 1970 was 12,400, approximately 63 percent of the total population of Stark County. Its 1980 population was about 16,000. Population growth occurs because Dickinson is a regional center of economic activity and because of energy-related expansion. A population of around 28,000 has been projected by the year 2000.

System History and Operation

The first waste treatment system for the community was a trickling filter with sludge digestion built by the Works Progress Administration in 1938. This underdesigned system developed capacity problems in 1945-46. It was revamped in 1957 as a two-cell lagoon system, with discharges into the Heart River, which were permissible at the time. It was at this time that utilization of effluent for irrigation began.

A lagoon treatment system was selected because of the influence of a strong advocate of lagoon systems and because of relatively low cost and land availability. The city purchased 48 ha (120 ac) of prime agricultural land from a local farmer for the lagoon site. The seller, as part of the agreement of sale, requested the use of the water from the lagoons. He was well aware of the water's value as he had been irrigating with water from the Heart River since the early forties. The city agreed to provide the farmer irrigation water for the city-owned 7-hectare (18-acre) field adjacent to the treatment plant.

The city-owned land was leveled for flood irrigation, which began in 1960. In addition to the land flooded, sprinkler irrigation was used on 20 ha (50 ac). By 1966, 53 ha (130 ac) were irrigated with lagoon water. The area irrigated had expanded to 101 ha (250 ac) by 1976, with all increases on privately owned land.

The city has considered the construction of a secondary wastewater treatment plant to handle projected growth, but ruled out that alternative due to high construction costs and long-term maintenance costs. The existing system will be expanded by the addition of an aeration cell prior to the primary and secondary cell. A third cell will be added to provide additional area for most of the winter storage required (180 days). Discharges from this system into the Heart River could be made after 1980, if flow volumes exceeded the amounts that could be used by crop irrigation.

Farming Operation

Wastewater use from the Dickinson treatment lagoon is integrated into a single diverse farming operation of approximately 546 ha (1,350 ac), including irrigated pasture, hay land, and dryland farming. All pasture and forage produced on acreage receiving effluent is fed to livestock. In addition to water from the lagoon, water for 73 ha (180 ac) is purchased from the Heart River Irrigation Association at a fixed cost of \$3.70 per ha (\$1.50 per ac) for a maximum of 1,850 cubic meters (1.5 acre-feet) per year.

Timing of effluent application to crops is the farmer's decision. In the earlier periods of the system operation, the city controlled application times and rates. However, this resulted in applications that were too great, resulting in crop damage and water seepage. The farmer has rights to all the excess water in the lagoon and has agreed to take all water to avoid discharges to the Heart River.

The present system is a combination of flood and sprinkler systems. Sprinklers are favored over flooding, due to better water distribution. Annual application rates from sprinklers are 51 to 61 cm (20-24 in). The city pays the pumping costs to the distribution points within each field. The farmer has access to the city-owned pumps and starts them whenever water is needed.

City-Farmer Interaction

The operation of the system was discussed with the city engineer, the treatment plant operator, the farmer, and city auditor. All emphasized the importance of mutual respect and understanding for land application to succeed. Good relationships are necessary for successful day-to-day operations. This group makes the following recommendations to others planning a land application system:

1. A long-range plan should be developed between the community and the farmer. The city should look at its projected growth and land requirements and develop a plan with the farmer to use the water in an efficient manner. A 50-year plan was suggested to guide all involved parties.

2. It is vital that the farmer, treatment plant operator, and city engineer clearly understand each other's operation, especially the constraints under which each operates. Such understanding was aided in Dickinson's case by the appreciation on the part of the city officials for agriculture and the role of water in its operation.

3. The need for mutual understanding was considered more important than having all details explicitly outlined in legal contracts.

4. Working arrangements should be stated more clearly in contracts, particularly for the benefit of city officials not directly involved in operational details. Such documentation would insure continuity if

the city engineer or other key people left, or if for some other reason smooth working relationships dissolved.

One of the results of the sale of land to the city for initial lagoon construction in 1957 was an agreement for the city to provide water to the farmer for agricultural operations. Terms of this first agreement may have been established in a verbal contract, but the first formal lease agreement found in this investigation was not initiated until 1969.

The contract has four major elements: the term, a paragraph on construction of the irrigation project, a paragraph on the use of water, and a cancellation clause. The formal lease of 1969 sets forth the conditions wherein the city leases to the farmer 7.3 ha (18 ac) for 5 years, automatically renewable for an additional 5 years unless the land was needed for sewage lagoon purposes. In this lease agreement, the farmer agrees to develop an irrigation system utilizing water from the sewage lagoon. The city contributes a flat amount to the construction of the irrigation system. The use paragraph covers use of water on the prescribed city-owned land as well as on adjoining land of the lessee, as needed to prevent discharge into the Heart River. The cancellation clause protects the city from default on any of the provisions by the farmer. There is no reciprocal protection clause for the farmer.

In 1972, an agreement was entered into by the city and farmer to insure that the city would be able to continue to drain water upon land adjacent to the lagoon owned by the farmer. This would be land in addition to the city-owned land previously leased to the farmer.

The main purpose of the agreement was to insure that the city would have a place to discharge effluents, other than the Heart River, until the city had completed construction of adequate treatment facilities. The term of the agreement was a maximum of 5 years. A key paragraph indicated that the farmer agreed to continue to allow the city to spread water on his land. The city was to furnish all energy costs for pumping water, whether the irrigation is done by the city or by the farmer. The city agreed to furnish labor when irrigation was required to drain excess amounts of water. The farmer agreed to let the city irrigate at any time, subject to compatibility with farming operations. If at any time the water discharge from the lagoons became harmful to the grass or land, the farmer had the right to dilute it by utilizing water from the Heart River.

In anticipation of increased wastewater flow, the city entered into an agreement with the farmer to make excess wastewater available solely and exclusively for the farmer's use upon his land adjacent to the lagoons. The farmer in turn agreed to take all excess wastewater.

Conditions of this agreement include:

1. The city is the sole and exclusive judge of when excess wastewater is available.

2. If effluent use is found to damage the land, the farmer's obligation to take water is terminated. However, the city shall not be liable for damage or deterioration to land.

3. The city provides a suitable pump at the wastewater lagoon site and provides all energy costs for such pump operations. The farmer agrees to furnish all pipe and other materials and labor to receive the excess wastewater from the pump.

Mesa, Arizona

Mesa is located in the Salt River Valley 26 km (16 mi) east of Phoenix. The climate is dry, with annual rainfall of approximately 18 cm (7 in). Population growth in Mesa has exploded in the last 25 years. Population was about 17,000 in 1950, 63,000 in 1970, 118,000 in 1980, and projected to be 270,000 by the year 2000.

System History and Operation

Prior to 1949, Mesa's sewage treatment was provided by a septic tank located at the present treatment plant site. Effluent from the plant was discharged into the Salt River. Two primary settling basins, and one primary and one secondary digester were constructed in 1949, with discharge going to the Salt River. A 6.9-ha (17-ac) oxidation pond was added in 1955 which met the city's needs until 1960 when plant flow reached the design capacity of 98 l/s (2.25 mgd). The second phase of the expansion program began in 1960, consisting of two more settling basins, a large primary and secondary digester, trickling filter, and a secondary settling basin. Present treatment plant facilities are designed for an average flow of 219 l/s (5 mgd), with peak load capacity of 350 l/s (8 mgd).

Effluent from the 4.8-ha (12-ac) oxidation pond is pumped to a city-owned site of 65 ha (160 ac) for crop irrigation. There is no chlorination prior to irrigation. Tailwater from the irrigation activities is discharged into the Salt River. Sludge is dried on adjoining beds for up to 90 days prior to being buried or stacked in the desert. Only limited use has been made of sludge, primarily on highway right of ways.

Mesa treats wastewater in its own plant, as well as relying upon a regional treatment plant, the 91st Avenue Wastewater Treatment Plant in Phoenix. This plant is jointly owned by seven communities, along with the pipeline which discharge to the Salt River outfall. Most of the industrial wastes of Mesa are discharged to the Phoenix system. The effluent treated in the Mesa plant is thus almost entirely municipal sewage. All of the water treated at the Mesa plant is used for crop irrigation. The alternative to irrigation is discharge to the dry riverbed of the Salt River where it would percolate into the groundwater.

Mesa owns a 438-l/s (10-mgd) share of the treatment capacity at the 91st Avenue Wastewater Treatment Plant. Mesa's separate plant has a 144-l/s (3.3-mgd) biological treatment capacity with a 219-l/s (5-mgd) hydraulic capacity scheduled for standby status in 1980. Mesa has rights to discharge an average daily flow of 1,183 l/s (27 mgd) to the Salt River outfall. Mesa's 438-l/s (10-mgd) share of the pipeline to the city plant will be utilized by the early eighties, requiring either an expansion of the existing plant or construction of another plant, either separately or as a joint venture with the city of Tempe.

Farming Operation

Effluent has been applied to city-owned land since about 1957. Serious management problems in the early stages occurred due to rapid turnover of the farm managers. The present farmer has operated the treatment farm for about 6 years, and is the first to manage the land intensively.

Primary crops are wheat, corn, and sorghum which are chopped and sold to local dairies as silage. Wheat and barley crops have produced a total of 44.8 metric tons per hectare (mt/ha) [20 tons/ac] in two winter cuttings. A corn/sorghum mix in the summer averages 56 mt/ac (25 tons/ac). Sorghum alone yields about 26.9 mt/ha (12 tons/ac).

The farmer owns and maintains the pumps. The city pays for electricity for pumps and provides the water at no charge. No fertilizer or pesticide is applied.

The city-owned land could not be operated profitably with purchase of regular irrigation water from the Salt River. Water rights exist for only 10 acres. The soil is too poor to justify the purchase of the minimum amount required, 2 ac-ft per year.

City-Farmer Interaction

The city initially considered managing the farming operation directly, but later decided to lease the land to farmers, specifying that the primary objective was proper wastewater treatment. Difficulties arose due to conflicting objectives of the city (wastewater treatment) and farmers (profit maximization). Difficulties also arose from the lessee subletting land to third parties. Lessees overestimated the value of the contract with the city when they sublet the land to others. As a result, overgrazing occurred, resulting in insufficient pasture growth for treatment purposes, especially in the winter months. When these sublessees found themselves overextended, they sought financial relief from the city. They sought concessions from the city such as payment of pump costs and repairs. The city paid rather than let the system collapse. These stopgap measures failed in 1972 and all leases had to be renegotiated. Cash rent of $123 per ha ($50 per ac) was established. The city pays the power costs. Any subleasing must have prior approval by the city.

Since the early years of the system, numerous contracts have been developed to specify the terms of agreement between the city and lessees, and between lessees and sublessees. The process of this development is highlighted below, and indicates the complexities that can arise in multiparty agreements.

The first agreement between the city and a lessee was a 5-year contract developed in July 1957 for the use of 3.7 ha (9.2 ac) of land adjoining the treatment plant. The city wanted the water from the treatment plant utilized and the land it owned west of the treatment plant cultivated and improved. The lessee wanted a right of way across the city-owned land as well as the use of the effluent. Rental payment for the first year of the contract was construction of a fence around the site by the farmer. Subsequent year rental payments were $300 per year. It gave the lessee access across the treatment plant and to the irrigation sites, and gave rights to all the water at no additional charge to the lessee.

The first lease was sold in 1958. In December 1959, Mesa, the lessor, entered into a lease agreement with the new lessee for the use of additional land purchased by the city of Mesa. The city leased the land for agricultural purposes, on the basis of the highest bid. The term of the lease was for 3 years, January 1, 1960, to December 31, 1962. The acreage involved was to be determined each year by the city engineer and the lessee. The lessee had the option to extend the lease for 5 years, with the right to another 5-year extension if the first option was exercised. Under this agreement, the lessee agreed to level land on the premises economically feasible to level for agricultural purposes. The lessee got the newly leveled land rent free until the initial investment was recouped. After that, rent of $52/ha ($21/ac) was charged.

The agreement gave the lessee the right to sell to other parties any excess effluent water. Such parties were given the right to construct necessary pumping and transmission facilities on the city's land.

Numerous transfers of agreements between lessees and sublessees occurred between 1962 and 1972. It was in connection with these transactions that the previously mentioned difficulties occurred. The city canceled all leases in 1972 and developed a new lease.

In this agreement, approximately 38 ha (95 ac) of land were leased for a 3-year period starting on January 1, 1975, with the option to extend it for another 3 years. The rental rate was $123 per ha ($50 per ac). Any leveling work was done by the lessee, with appropriate adjustments in his rental charges to defray these expenses. The city owns the engine powering the irrigation pump and pays the operation and maintenance costs. An important clause in this agreement was that the lessee agreed not to assign the agreement, or sublet any portion of the premises, without securing the written consent of the city.

There was a supplemental agreement added in June 1975 which added 19 ha (47 ac) to the parcel of land involved, bringing the total to 57.5 ha (142 ac). This supplemental agreement also increased the annual cash rent to $128 per ha ($52 per ac) to include the applicable sales tax.

Roswell, New Mexico

Roswell, located in the southeastern part of the State, is the county seat and population center of Chaves County. The population of Roswell grew from 7,000 in 1920 to 34,000 in 1970 and to about 40,000 in 1980. It is a semiarid region with an average rainfall of 17.8 cm (7 in), requiring irrigation for agricultural crop production. The county is entirely grassland with the exception of the Roswell-Lake Arthur corridor, which contains most of the cultivated lands. Nearly 33 percent of the land in the county is federally owned.

Water has been one of the most important factors in the area's development. A large artesian belt is the county's most outstanding phenomenon. Flowing artesian water was discovered in 1891, resulting in rapid irrigation development. One well drilled in 1931 was the largest artesian well in the world, with an initial flow of 582 l/s [9,225 gallons per minute (gpm)]. Overuse of the artesian water began to deplete the supply, resulting in public regulation over the past 30 years. There is now an annual limitation on pump water use of 3 feet per acre plus 0.5-foot carriage loss.

Agriculture is the most important industry in Chaves County, with mining (primarily crude oil and natural gas) the second most important economic activity. It is one of the few counties in New Mexico in which both crops and livestock are produced in significant amounts. The main agricultural activities are livestock production of both range and feedyard stock and cultivation of cotton, hay, and sorghum. Alfalfa and sorghum are grown on contract basis for livestock feeders, who typically do not raise their own forage crops. Alfalfa hay raised in the Roswell area is of very high quality, with a protein content as high as 22 percent. Much of this hay is sold to dairies or cattle feeders in western Texas.

Water is the limiting factor for crop production in the area. Approximately 39,670 ha (98,000 ac) or 2.5 percent of the total land area in the county is cultivated. All cultivated land is irrigated and is found in the corridor between Roswell and Lake Arthur in the Pecos Valley. Farm size ranges between 4 and 1,620 ha (10-4,000 ac), with 81 ha (200 ac) the average farm size. Each acre with rights is allotted 3 ft/ac/yr (3,700 cubic meters) of water. This water scarcity, combined with the soil alkalinity, influences the crops grown.

System History and Operation

The early sewage treatment system, started in the thirties, was an Imhoff tank at the end of a sewage outfall line 8 km (5 mi) out of town. Secondary treatment in the form of a trickling filter was added in 1944. Plant capacity was expanded in 1961 and again in 1974. The 1974 expansion consisted of an oxidation ditch and chlorination added to the trickling filter process.

The present treatment process consists of the following: preaeration, primary settling, trickling filter, oxidation ditch, final settling, and chlorination. The effluent is discharged into an outfall pipeline to the Pecos River. Water for agricultural irrigation is drawn from the outfall line.

The volume treated is approximately 175 l/s (4 mgd) of typical domestic effluent. Effluent is delivered from the outfall line through metered outlets to six or seven farmers who purchase the water on a contractual basis. There are no additional costs to the city associated with providing this water to the farmers, other than the maintenance of the meters.

Details are sketchy on how the land treatment system evolved. Serious saltwater encroachments of the underground aquifers occurred due to droughts and drawdowns in the early fifties. A farmer recognized effluent as an additional source of water, both for direct use and for mixing with the more saline ground water. Land for a municipal treatment plant was made available in exchange for rights to the effluent. The early informal agreement evolved into a contract whereby the farmer paid a fixed amount ($975 per year) to take up to a specified quantity of water, 481,065 cubic meters (390 ac-ft/yr). Similar agreements were made with other users of the effluent. However, in recent years, the number using the water has decreased. One of the primary irrigators has not used the full amount of water specified in the contract because of adequate rainfall during the growing season.

Given the semiarid climate of the Roswell area, storage facilities could have been constructed along the outfall line to impound effluent for use during times of critical dryness. But, this has not been done.

Farming Operation

Effluent is applied to a 115-ha (285 ac) farm, of which 74.8 ha (185 ac) were irrigated with ground water and 28.3 ha (70 ac) were irrigated with effluent. Effluent was sometimes mixed with ground water because of the high salinity content of the ground water.

Annual application rates of the effluent were about 1.2 to 1.8 m (4-6 ft). The farmer followed the same fertilization program for crops receiving effluent as those irrigated with ground water, though he had an implicit awareness of the value of nutrients in the effluent. Silage is sold to a local dairy. Corn silage yields are approximately 38 mt/ha (17 tons/ac), and alfalfa hay yields about 13.4 mt/ha (6 tons/ac).

City-Farmer Interaction

Agreements exist between the city and farmers located along the outfall line governing water use for irrigation. These are 5-year leases with an annual review. All leases were reviewed in 1976, the end of the 5-year period. The contracts are viewed by the city as a means of protecting their interests. There are no contracts with several users, primarily because the city cannot establish that there were easements of record for the discharge pipe across the land in question. Court attempts to settle this have been unsuccessful and the city has dropped the issue.

The city is interested in increasing revenues from the sale of water. In the fiscal year 1976-77, only $4,000 was received from irrigation contracts, while total operating costs for the entire treatment system were $150,000. Contract payments from the farmers are based upon monthly meter readings completed by the treatment plant operator.

The city's interest in obtaining more revenues from water sales makes it reluctant to enter into long-term agreements with farmers for fear of precluding future profitable opportunities. State and Federal water quality regulations were other issues identified as impeding the development of long-term agreements. Uncertainties regarding these agreements preclude long-term commitments which might have to be dissolved if more stringent regulations are imposed.

The lease agreements between the city and the farmers contain eight paragraphs. The first and second paragraphs specify the annual amount of water that will be made available for a specified acreage for which a legal description is provided. The second also specifies that water may be taken from the sewage outfall line only at metered points and that taking of water from any other point constitutes a termination of the agreement. Paragraphs three and four specify the type of measuring meter to be used and make the farmers responsible for meter malfunctions due to tampering or interference.

Paragraph five provides a means to adjust the amount of water to be used annually by plus or minus 10 percent of that specified in paragraph one. A 10-percent increase in water taken through the meter will be sold at the rate of $2.50 per acre-foot. Unmetered water will cost $3.50 per acre-foot.

Paragraph six provides for renegotiation of the contract for an additional 5-year term contingent upon agreement on a price per acre-foot.

An important provision of paragraph seven excuses the city from any liabilities associated with inability to deliver water as promised. It also specifies that all costs, save the installation of measuring meters by the city, shall be borne by the farmer.

Paragraph eight specifies a mechanism for termination of the contract for the city, that is, a 6-month written notice is required for termination, which would become effective at the end of the annual crop growing season.

<u>Tooele, Utah</u>

Tooele, the county seat of Tooele County which is Utah's second largest county, is located 33 miles southwest of Salt Lake City. The city population grew from about 12,500 people in 1970 to about 14,300 in 1980. Approximately 60 percent of the county's population is in the city.

Tooele is 1,539 m (5,050 ft) above sea level, with an average annual temperature of 11 degrees Celsius (C) [51 degrees Fahrenheit (F)]. The average July temperature is 24 degrees C (74 degrees F), and the average January temperature is -4 degrees C (25 degrees F). Average rainfall is 42 cm (16.5 in).

The largest employer, the Tooele Army Depot, one of the Army's major logistical commands, employs about 4,500 people. The largest manufacturing employer is Anaconda Copper.

Tooele County has approximately 202,400 ha (500,000 ac) in farms, about 11 percent of the county's total acreage. Approximately 82 percent of the land in the county is publicly owned. Average farm size is 1,012 ha (2,500 ac) and the average farm value is $150,000. Major products are livestock and livestock products, alfalfa hay, and grain.

System History and Operation

Municipal sewage treatment in Tooele began in the thirties with central collection facilities connected to a septic tank. The grandfather of the current landowner using the effluent recognized the value of the water from the septic tank and used it to irrigate corn.

Prior to construction of the present treatment plant, the city entered into an agreement covering the use of excess water flowing from the municipal septic tank. In 1952, a landowner granted the city the right to construct and maintain an open ditch over and across real property, in exchange for the use of excess overflow water. This ditch transported water from the treatment plant to a distribution point on the landowner's farm. The landowner agreed to take care of surplus water once it reached the farm, and to save the city from all responsibility of any problems resulting from the surplus water flowing onto the lands of any other persons. In consideration, the city provided the water free of charge.

As the city expanded, the septic tank's capacity was exceeded, and a centralized treatment plant was constructed in 1957. Treatment is provided by a trickling filter plant with a design capacity of 96 l/s (2.2 mgd). Currently about 61 l/s (1.4 mgd) are treated. Effluent from the plant travels to a holding pond, through an earth-lined ditch 1 mile in length, and then through two small reservoirs before being applied to the land. The holding pond was added after problems arose due to excess suspended solid materials remaining after the treatment process.

Farming Operation

The farm receiving effluent covers approximately 486 ha (1,200 ac) of privately owned crop and pasture land. Water sources for irrigation include mountain reservoirs, effluent, and ground water. However, ground water wells have to be drilled 122 to 183 m (400-600 ft) deep, at considerable expense. Effluent has been applied on some of this land for 19 years, and on other parts for only 2 years.

Approximately 223 ha (550 ac) are irrigated with effluent from a holding pond, using both flood and sprinkler irrigation. Since the land has not been leveled, sprinkler irrigation is being used more frequently due to ponding problems with the flood irrigation. Application rates are about 76 cm (30 in) per year, with hay, grain, and forage crops being the principal crops grown. The irrigation season lasts approximately 5 months. Crops grown include 162 ha (400 ac) of hay and 61 ha (150 ac) of grain. Cattle are grazed on the fields during the winter.

The effluent provides all nutrients; no commercial fertilizer is used. Wheat yields are between 3.4 and 4.7 mt/ha [50 and 70 bushels per acre (bu/ac)]. Alfalfa hay yields about 15.7 mt/ha (7 tons/ac), as contrasted with 11.2 mt/ha (5 tons/ac) when irrigated with mountain reservoir water and 6.7 mt/ha (3 tons/ac) without any irrigation.

The farmer determines the rate of applications, which are heaviest in the fall. No crusting or noticeable changes in soil conditions have been noted where crops are grown. Some crusting was noted in the ditches. During the winter, effluent runs down the water course, seeping into the ground or filling up ponds.

City-Farmer Interaction

The farmer pays the city a fixed annual amount for the use of the water, approximately $750. However, no formal document stating the terms of this agreement was located.

The city made an agreement in 1952 to obtain rights to build a ditch for transport of excess sewage water. When the present landowner purchased that land, he acquired the same rights to the water and agreed to pay for it. Upon subsequent sale of the land, the city would have continual access to the ditches, but would have to renegotiate the terms of the agreement with the new landowner.

San Angelo, Texas

San Angelo is the county seat of Tom Green County, located in west-central Texas. The region is semiarid, receiving an average of 53 cm (20.6 in) of rainfall per year. The average temperature is 19 degrees C (66 degrees F).

The population of San Angelo was around 69,000 in 1980. The economic base of the community is diverse. Ranching and irrigated crop production are the prime agricultural activities. The town is the wholesale food distribution center for the region. There are many small (60 to 100 employees) establishments in the area, as well as some branches of national companies. Goodfellow Air Force Base is also in the area.

System History and Operation

San Angelo has used some form of land treatment since 1933. Two sites have been used. The first was used for 30 years but was abandoned in 1958 due to city expansion. The second site has been in use since 1958. Until recently, the only pretreatment before application to the land was primary sedimentation. Construction of an activated sludge secondary treatment plant began in 1976 to meet State requirements for discharges to irrigation areas accessible to the public.

Farming Operation

The city owns and operates a 300-ha (740-ac) farm on which effluent is applied for treatment and production of forage crops and livestock. As the farm is run by municipal employees, questions of leases and other issues associated with two-party agreements are not as important as in the other irrigation systems studied. The annual average flow of effluent is 219 to 241 l/s (5-5.5 mgd), approximately 85 percent domestic and 15 percent industrial. Effluent is applied to agricultural land at an annual rate of 1.5 to 1.8 m (5-6 ft), using a border strip irrigation method. Of the 300 ha (740 ac) in the site, 259 ha (640 ac) are irrigated, 24 ha (60 ac) are used for onsite storage, and 16 ha (40 ac) are used for onsite treatment. Crops grown in 1975 included 34 ha (85 ac) of barley, 28 ha (70 ac) of fescue, 40 ha (100 ac) of alfalfa, and 156 ha (385 ac) of coastal bermuda grass. The bermuda grass is used primarily for pasture. Estimated gross receipts from the sale of hay and grazing permits in 1975 and 1976 have been estimated at $71,000 and $58,000 respectively (20). Other estimates for 1976 suggest total revenues from crop sales and grazing leases of between $80,000 and $90,000, with a net operating profit from the farming operation of around $20,000 per year (52).

Lake George, New York

Lake George is a recreational community at the southern end of Lake George. The 1980 population of the town was around 3,400. The lake is known for the clarity of its waters and the beauty of its shoreline. Due to efforts of the Lake George Association, water quality of the lake has been maintained at a high enough level to be given an "AA" classification by the State of New York. This classification prohibits sewage discharges of any type into Lake George or any waters discharging into the lake. This allows use of Lake George as a drinking water supply requiring only chlorination prior to use (3).

The sewage treatment system for Lake George Village and adjacent areas has special conditions associated with seasonal population variations and the need to maintain lake quality. The summer population is typically three times the number of permanent residents. Legislation prohibits the discharge of any wastewater, treated or untreated, into the lake or streams discharging into the lake. The system selected to meet these conditions was a rapid infiltration system that has been in continuous operation since 1939.

The Lake George Village Sewage Plant was built in 1936 and began operation in 1939. The selection of a land treatment system evolved through an interpretation of the law prohibiting discharges to the lake as applying only to surface discharges. Thus soil system disposal (including septic tanks) of effluent was considered legal (3). This interpretation opened the way for the village to discharge secondary effluent onto the soil. The original plant was designed for 22 l/s (0.5 mgd) and included a primary settling and digestion tank, three dosing tanks, three trickling filters, two secondary settling tanks, six natural sand seepage beds, and a three-section sludge bed. Only one-third of the capacity was used in the winter due to the decreased flow (53). As flow increased, the six original sand beds were increased to 21 with a combined area of 2.6 ha (6.4 ac). The first expansion was the addition of one bed in 1947. Two were added in 1950, three in 1956, eight in 1965, and the last bed in 1970 (2).

The present system serves two sewer districts, the village of Lake George and the surrounding town of Lake George. The treatment given the combined flows consists of primary sedimentation with Imhoff type sludge digestion, secondary treatment by trickling filters, and secondary sedimentation. Final effluent is then discharged without chlorination into one of 21 sand infiltration beds. Flow varies between about 43.8 l/s (1 mgd) in the summer tourist season to 13 l/s (0.3 mgd) in the winter. The design flow is 76.7 l/s (1.75 mgd). Sludge is dried on beds and hauled to a landfill (2).

The system appears to provide high-level treatment at modest costs. Analysis of the seepage from the sand beds indicates that discharge of the secondary effluent on the sand beds is achieving the equivalent of tertiary treatment, after almost 40 years of operation (2). There is a debate over whether the system will be allowed to continue or will be forced to join a regional sewer authority and pump its sewage out of the area. The village has room to expand onto more sand beds. If the existing system is phased out in favor of the regional system, there is likely to be a sharp increase in treatment costs for each homeowner in the area.

Vineland, New Jersey

Vineland, located in southern New Jersey midway between Philadelphia and Atlantic City, has the largest land area of any city in the state, over 181 sq km (70 sq mi). Its 1980 population was 52,700, compared to 48,000 in 1970.

The Vineland treatment plant was constructed in 1901 using a septic tank concept. It was abandoned and later rebuilt in 1928 on its present location. The original concept to apply the primary effluent to broad irrigation basins was revised when the plant was reconstructed. Because of complaints about odor from nearby residents, the sewage was pumped 4 km (2.5 mi) to a sandy area where a settling tank and sludge drying beds were built. Vineland contracted with a farmer to dispose of the effluent from the settling tank on this borough-owned land for a period of 5 years. A salary was paid for the first 2 years as farming was assumed to be done at a loss because the soil was extremely poor and full of tree roots, briars, and huckleberry bushes. Compensation for the last 3 years of the contract was expected to come from the crops grown (26).

A 1946 consulting engineer report provides some additional insights into the earlier stages of the operation of the plant. At that time, the Vineland authority served 8,000 people. Problems identified were undercapacity and the need for a relief sewer. Treatment consisted of four covered septic tanks with effluent discharge to 6.5 ha (16 ac) of land where crops are grown. During harvest periods and part of the winter, effluent was discharged to adjacent woodland. Sludge was applied to a disposal field where it was plowed under after drying. Sewage was applied to land with crops at the rate of 280,590 l/ha/day (30,000 gal/ac/day). This rate was often in excess of agricultural needs.

Sewage treatment for the community of Vineland is provided by the Vineland Water and Sewer Utility and the Landis Sewerage Authority. The city utility serves the inner core of the city and the Landis Sewerage Authority serves the surrounding area. This separation of treatment systems has existed since 1947 when the State of New Jersey forced the township surrounding Vineland (Landis) to establish a treatment system. The township and the borough of Vineland merged in 1952, but the treatment systems remained separate due to differences in the system and in billing procedures.

Treatment by the Landis Sewerage Authority began in 1948. The existing system has been in operation since 1967. Previously, it was an Imhoff system with a capacity of 88 l/s to 131 l/s

(2-3 mgd). In 1975, the Landis Sewerage Authority sewage plant served approximately 19,000 people plus industry, which consists largely of food processors and contributes almost 50 percent of the total flow. The treatment facility has an average daily design flow capacity of 307 l/s (7.0 mgd). The average daily flow in 1974 was 178 l/s (4.06 mgd), with the peak flow of 241 l/s (5.5 mgd). The plant provides primary treatment with the final effluent discharged onto rapid infiltration beds. The sludge removed from the primary settling tanks is pumped to a sludge holding tank and then treated by chemical oxidation and stabilization before being pumped to open drying beds. The dried sludge cake is disposed of by landfilling on the existing plant property. The existing infiltration basins presently being utilized for disposal of the plant effluent encompass a total area of 26 ha (65 ac). After the wastewater has percolated through the soil bed, the entire area is disked to break up the solids deposits. Each bed is plowed to a depth of 12 inches every 6 months (27).

The existing treatment facility owned and operated by the Vineland Water and Sewer Utility presently serves an estimated population of 6,500 persons. There are no major industrial contributions to the Vineland plant. The average daily flow for the first 8 months of 1974 was 35 l/s (0.8 mgd), with peak flow of 66 l/s (1.5 mgd). The capacity of the plant is 66 l/s (1.5 mgd) and provides primary treatment for the wastewater before it is discharged onto rapid infiltration beds. The area of the beds is about 9.7 ha (24 ac). Sludge is discharged to drying beds twice a year, and then plowed under (23).

COMPARISON OF THE IRRIGATION SYSTEMS

The previous section described the experiences of six communities with slow rate systems and two communities with rapid infiltration systems. These communities were not selected using a statistical sampling procedure; these experiences may not then be representative of all communities that have considerable experience with such systems. However, the study of these communities has identified both unique and similar experiences with land treatment systems which can provide insights for communities considering land treatment systems.

Economic and Demographic Characteristics

The regional setting for the six slow rate land application systems is highlighted for the communities and the counties in which the respective facilities are located (table 1). The facilities are located in a wide range of community sizes. No facility is located in an extremely small community. Population sizes in 1980 ranged from 15,900 in Dickinson to

Table 1--Selected city and county characteristics, wastewater treatment areas

Item	Unit	Camarillo, California	Dickinson, North Dakota	Mesa, Arizona	Roswell, New Mexico	Tooele, Utah	San Angelo, Texas
City population (1970)	No.	19,200	12,400	62,900	33,900	12,500	63,800
City population (1980)	do.	37,500	15,900	117,800	39,700	14,300	68,626
County data:							
County	Name	Ventura	Stark	Maricopa	Chaves	Tooele	Tom Green
Population (1980)	No.	528,000	24,000	1,293,000	51,100	26,000	77,300
Population per square mile	do.	202.1	15	106	7	3.1	40
Population change (1970-80)	Pct.	40	23	34	18	21	9
Urban population	do.	92.2	63.9	93.4	78.3	71.7	52.4
Percentage of labor force unemployed	do.	5.9	4.6	6.0	6.7	10.0	14.0
Percentage labor force	do.						
in manufacturing	do.	17.7	5.5	20.3	8.5	11.3	11.6
Percentage of population in farming	do.	1.8	17.7	1.0	5.8	3.0	2.0
Annual rainfall	In.	17	23.5	7	7	16.5	20.6

Sources: 1970 and 1980 Census of Population.

117,800 in Mesa. Population density ranged from 3.1 people per square mile in Tooele to 106 in Mesa. Thus, in terms of population characteristics, the communities are rather dissimilar.

Few similarities are apparent in terms of economic activity in the respective areas. For example, Maricopa County (Mesa) has over 20 percent of its population engaged in manufacturing and 1 percent in farming, while Stark County (Dickinson) has 5.5 percent of its population in manufacturing activities and 17.7 percent in farming.

Since wastewater irrigation in the six communities is closely tied to agricultural activity, comparative agricultural data for the respective counties and States were collected to determine if there were any common characteristics which may have encouraged development of the land application facilities. Two types of comparisons can be made using the data in table 2. First, proportionate land used in the counties and States can be compared. Second, the relative contribution of a county to the State's agricultural output can be identified. Use of agricultural land in the respective counties is similar to statewide land use. In general, a higher proportion of farmland is irrigated in the counties in which the land application systems are located. This may help explain the use of the land application in these communities, since local farmers are already aware of the value of water for irrigation. The relative aridness of the areas as shown by the data on annual rainfall (table 1) helps substantiate this hypothesis. The county share of the market value of all farm products produced in the respective States is proportional to the respective land areas for four of the communities. Exceptions are Mesa and Roswell which have a much greater share of the value of output than their share of farmland would indicate and which reflect the importance of irrigation.

Wastewater Pretreatment

The wastewater in each of the communities receives the equivalent of at least secondary wastewater treatment before being applied to the land. Details on plant size and type of treatment are presented in table 3. The range of facility sizes is relatively narrow (1-5 mgd). These facility sizes correspond with previous economic research results which concluded that land application is more economically advantageous than other advanced wastewater treatment systems for communities treating less than 438 l/s (10 mgd) (31, 61).

Site Acquisition and Management

Fee simple acquisition and contracts were the most frequent methods used by the communities (plus four other examples) to acquire land (table 4). No cases were found of easement use.

Table 2--Comparison of county and State agricultural characteristics

Characteristic	Camarillo, California (Ventura Co.)	Dickinson, North Dakota (Stark Co.)	Mesa, Arizona (Maricopa Co.)	Roswell, New Mexico (Chaves Co.)	Tooele, Utah (Tooele Co.)	San Angelo, Texas (Tom Green Co.)
	Percent					
Percentage of land area in farms:						
County	36.3	1/ 100+	32.4	69.1	10.9	1/ 100+
State	35.7	97.4	52.6	60.2	21.5	85.0
Percentage of farmland in cropland:						
County	33.3	66.9	28.6	4.0	8.2	21.5
State	31.5	68.2	4.2	4.9	17.2	27.9
Percentage of farmland which is irrigated:						
County	21.2	0	24.1	3.2	2.9	1.8
State	20.3	.1	3.1	1.8	9.1	.5
Percentage of State market value of all farm products coming from the county	3.5	2.0	43.1	17.6	1.3	.7
Percentage of State market value of crops coming from the county	4.9	1.1	43.3	11.5	.7	.5
Percentage of State market value of livestock in coming from county	1.8	3.0	43.2	19.4	1.4	.8
Percentage of the State's farmland in the county	1.2	2.0	5.0	5.8	4.3	.7

1/ Statistical enumeration techniques in the census data resulted in higher estimates of land in farms than for land in the county. Joint ownership and land rental are two possible reasons for this phenomenon.

Source: 1974 Census of Agriculture.

Table 3--Comparison of pretreatment systems

Characteristic	Unit	Camarillo, California	Dickinson, North Dakota	Mesa, Arizona	Roswell, New Mexico	Tooele, Utah	San Angelo, Texas
Type of pretreatment		Activated sludge	Lagoon	Trickling filter	Trickling filter	Trickling filter	Activated sludge
Design flow	l/s	208	105-127	219	219	96	232
	mgd	4.75	2.4-2.8	5.0	5.0	2.2	5.3
Average daily flow	l/s	118	44-66	219	175	61	219
	mgd	2.70	1.0-1.5	5.0	4.0	1.4	5.0
Peak daily flow	l/s	149	79	219	219	61	350
	mgd	3.4	1.8	5.0	5.0	1.4	8.0

Table 4--Options used by selected communities for land acquisition and management

Location	Type of waste	Site area	Acquisition option	Management option
		Hectares (ac)		
Muskegon County, Michigan	Wastewater and sludge	4,290 (10,600)	Fee simple title	Managed by county
Braunschweig, Germany	Wastewater and sludge	4,210 (10,400)	Contract	Wastewater cooperative
Bakersfield, California	Wastewater	972 (2,400)	Fee simple	Leaseback to farmer; cash rent
Lubbock, Texas	Wastewater and sludge	1,619 (4,000)	Fee simple and contract	Leaseback of city owned land to single farmer who uses water on city owned land, his own land, and sells water to other farmers and an electric utility
San Angelo, Texas	Wastewater	300 (740)	Fee simple	Managed by municipal employees
Dickinson, North Dakota	Wastewater	101 (250)	Contract	Cash lease for water sale to farmer
Tooele, Utah	Wastewater	486 (1,200)	Contract	Cash lease for water sale to farmer
Mesa, Arizona	Wastewater	65 (160)	Fee simple	Leaseback for cash rent
Camarillo, California	Wastewater	192 (475)	Contract	Landowner provides land in exchange for water and leases land to a third party
Roswell, New Mexico	Wastewater	115 (285)	Contract	Cash lease for Water sale to farmer

Leases are the most frequently used management option. Leases are used to manage farming on city-owned land, as in the case of Mesa, and to govern the sale of water for application to privately owned land, as in the cases of Tooele and Dickinson.

No situation clearly emerges where one acquisition or management option is more likely to be used than another. Fee simple acquisition might be expected to be used more frequently by smaller communities due to smaller land needs and fewer problems associated with community opposition. Conversely, one might expect contracts and leases would be more likely to be used by larger communities. However, of the communities shown in table 4, the large sites are owned by the city, except for Braunschweig. While one of the smaller sites is owned by the city (Mesa), most small sites are owned by farmers who contract with the city for water. Large systems need more controls which suggest some pressure for ownership of a least part of the system. Smaller systems need less land and may easily be able to negotiate leases.

The fact that no clear pattern emerges highlights the uniqueness of each land application system and the difficulty of generalizing from one location to another. While concepts and guidelines provide some general assistance, the particular mix of technical, economic, legal, regulatory, social, and political factors operating at each site had the greatest influence on which management and acquisition option was selected. For example, the large Muskegon, Mich., land treatment system developed out of the combination of special water quality needs, a positive approach by county officials toward establishing the system and handling public opposition, large areas of sparsely settled, relatively nonproductive land, and support from research grants.

Farming Operations

The wastewater irrigation systems studied here evolved to their present status over a period of years. Although the starting points and evolutionary process differed, there are some similarities in the farming operations. Two common characteristics are shared by the agricultural operations of the six communities: cost sharing and underutilization of water available (table 5). In each case, the city is responsible for getting the water to the application site and each farmer pays something to the city (either through rights to land or cash) for the wastewater. San Angelo is an exception since the city manages the farm. Only a portion of the available wastewater is applied to the land, ranging between 20 percent in Roswell and 60 percent in San Angelo.

Table 5--Selected data on the agricultural operations

Characteristic	Units	Camarillo, California	Dickinson, North Dakota	Mesa, Arizona	Roswell, New Mexico	Tooele, Utah	San Angelo, Texas
Year irrigation began		1958	1957	1957	1944	1957	1933
Irrigated area:							
	ha	192	101	60	28.3	223	259
	ac	475	250	147	70	550	640
Initial purchase price:							
	Dol./ha	---	865	3,520	---	124	2,025
	Dol./ac	---	350	1,425	---	50	820
Estimated value in 1976	Dol.	2,000	---	3,000	---	500	---
Annual application rate:							
	cm	102	51-61	914	122-183	76	152-183
	in	40	20-24	360	48-72	30	60-72
Crops grown		dry beans peppers broccoli tomatoes	wheat oats barley	wheat corn sorghum	corn alfalfa	alfalfa grain	hay pasture
Cost-sharing arrangements		City pays pumping costs. Landowner provides land for treatment plant in exchange for the use of the wastewater.	City pays pumping costs. Farmer provides land for the treatment plant in exchange for rights to the wasterwater.	City pays pumping costs. Farmer leases land from city at $50 per acre.	6 to 7 farmers take water from outfall line, pay between $2.50 and $3.50 acre foot of water.	City provides water via outfall ditch on user's land. Farmer pays $750/year for effluent.	Annual net receipts of $20,000 from farm operation.

--- = Not available

Economic analysis suggests a farmer will compare the marginal costs and benefits in determining whether or not to use wastewater for irrigation. In such cases, a farmer will irrigate with effluent if expected benefits from wastewater irrigation exceed expected costs. The primary benefit to a farmer from wastewater irrigation is the additional yield due to irrigation. For example, the entire production at the Camarillo site was attributed to effluent irrigation as it was the only available source of water. A variety of costs to the farmer will influence the decision to participate. The application costs need to be considered. Do they differ from the costs of applying typical irrigation water due to such problems as clogging of sprinkler heads or corrosion of the irrigation pipe? A second important cost is the fee for the irrigation water. A farmer must determine if water of equivalent quality is available at a lower cost. If land rental is tied to the use of the irrigation water, as is the case in Mesa, these costs must be considered jointly when evaluating alternative sites for renting cropland. The farmer must also consider potential inconveniences associated with the use of wastewater. It is continuously available in a fixed quantity. If storage is not available, as is the general case with the systems under consideration, irrigation is determined as much by water availability as by crop needs.

Finally, some risks may be associated with the use of wastewater for irrigation. Possible contaminants in the wastewater may harm the individuals applying the wastewater, the crops grown on the irrigation site, or the soil at the site. The risk of soil contamination can be passed to the city through clauses in the contracts or by public ownership of the land, as in Mesa and San Angelo. Since the systems in this report have been operating for long periods of time, one might conclude that these risks are considered minimal.

Reflections on the Operation of the Systems

Community officials and farmers in the six communities generally agreed that there was a need for a longrun planning horizon to be taken into consideration when developing the systems. In many instances, systems have expanded piecemeal as the community has grown and as the volume of wastewater has increased, necessitating larger areas for land treatment. A factor repeatedly stressed for system success was the need for good working relationships between the community and the landowner. Such relationships were considered more important than the existence of tight legal contracts.

One conclusion of the investigation is that the effluent was used for irrigation in a suboptimal economic manner. It was generally recognized that effluent was a valuable source of water and nutrients which helped increase the crop yields.

Few of the farmers, however, were actually measuring the differences in a quantitative sense. Similarly, the city engineers or others responsible for the operation of the system recognized that there was an economic value in the use of the effluent. But they had not established procedures to charge the landowners or farm operators for the entire value received. They were more concerned with fulfilling their primary responsibility of properly treating the wastewater. In several communities, the city representatives seemed to have an implied goal of increasing the charges for the wastewater. They were thus hesitant about entering into long-term agreements for the use of the water because of anticipation that the value of water for nonagricultural uses would one day surpass the value in agricultural uses, as well as increase in value for agricultural uses.

Another factor identified as working against the establishment of long-term contracts was uncertainty over the future directions of EPA regulations on land treatment systems. Several communities were hesitant to enter into a long-term arrangement tying up land and capital in a land treatment system which might provide a treatment level below standards that might become required by EPA.

No distinct pattern was identified from the communities studied with respect to the choice for land acquisition and management methods. Considerable variation exists in both the management and acquisition options used, and there was no obvious reason why one method was selected over another. Major influences on the systems' evolution included site-specific technical factors; economic issues; the political, legal, regulatory and social environment; and initiative and risk-taking attitudes of local officials.

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