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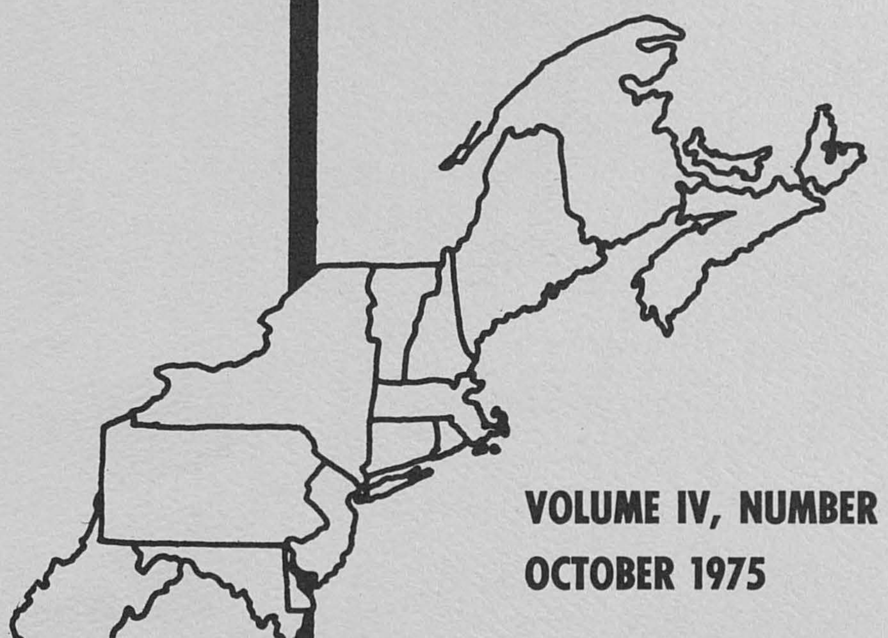

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LAND TREATMENT OF MUNICIPAL WASTEWATER: A COOPERATIVE APPROACH TO MANAGEMENT

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Introduction

Problem

Communities across the country are faced with the legal requirements to reduce water pollution from domestic and industrial wastes discharged into streams and rivers. Approximately 7½ billion gallons of wastewater were produced daily in the United States in 1972. This volume is estimated to quadruple over the next 50 years [3].

Zero discharge of pollutants to navigable waters by 1985 has been established as a national wastewater management goal. Federal and State laws have been passed to regulate water pollution. The Amendments to the Federal Water Pollution Control Act of 1972, Public Law 92-500, require secondary treatment of wastewater by July 1, 1977.

Communities are closely evaluating alternative treatment methods to determine the most cost-effective ways to comply with water quality requirements. The alternatives for advanced wastewater treatment are land treatment, advanced biological treatment, and physical-chemical treatment. The land treatment alternative is receiving increased attention. Specific provisions on land treatment became a part of Federal legislation in the Water Pollution Act Amendments of 1972, the first Federal laws specifically encouraging land treatment and reclamation and authorizing Federal construction grants to State and local agencies to assist in the establishment of such treatment systems.

Land treatment is the application of wastewater to land, usually following primary and secondary treatment. The soil and agricultural crops or forest products then adsorb and filter nitrates, phosphates, and other elements from the wastewater. Remaining water drains through the soil profile to recharge the groundwater or to return via underdrains to the waterways. Data on the "living filter" concept has been collected at Pennsylvania State University since 1963 [6, 8]. Muskegon County, Michigan has received national attention for its wastewater irrigation project, where a land treatment system will eventually treat the industrial and municipal wastewater from approximately 160,000 people [1, 7]. The land treatment concept has been extensively evaluated by the U.S. Army Corps of Engineers. In 1971, it undertook five pilot wastewater management studies for the metropolitan areas of Boston, Detroit, Cleveland, Chicago, and San Francisco. These studies evolved into an urban studies program covering many of the major metropolitan areas of the United States. Both the pilot studies and the urban studies program evaluate land treatment as an alternative for wastewater treatment [13, 14].

Land treatment affects farmers and the agricultural community through its requirements for land, a basic factor of agricultural production. The amount of land required varies with the treatment system objectives and with the volume of wastewater. For example, estimates of the land needed to treat the total wastewater volume from Southeastern Michigan range from 760,000 acres to 1,955,000 acres [15]. Smaller regions or communities require less land. In a recent survey of communities using land treatment, approximately 90 percent used 1,000 acres or less [9]. Communities evaluating land treatment are faced with the problem of acquiring land rights. Both communities and farmers are confronted with determining the impacts on their respective goals of the options for transferring land rights and managing land treatment systems.

Purpose

A land treatment wastewater management system requires rights to acreage controlled by the existing landowners. A body responsible for wastewater treatment requires rights insuring access to the land. The present landowner may or may not wish to provide the required access. A number of options exist for transferring land rights and managing land treatment systems. Each of these options impact differently on the respective goals of the parties involved.

The focus of this paper is to give special attention to a wastewater cooperative as a particular option for the establishment and management of a land treatment system. Its relationship to other options and its application in Germany is explored. The concept is then applied to a wastewater management proposal for Southeastern Michigan.

Acquisition and Management Options

An important distinction is made between options to obtain access to land for treatment purposes and the options available for the management of the farming operation at the treatment sites. Acquisition options are alternatives to acquire control over a resource while the management options are means to obtain services or behavioral actions. The acquisition options include fee simple property rights, less than fee simple property rights, such as easements, and contractual agreements involving no real property interest, such as a lease. Acquisition options for wastewater treatment purposes are similar to those used for other public purposes such as the preservation of open space and agricultural land on the fringe of metropolitan areas. A number of management options can be exercised in conjunction with these acquisition options, particularly for the fee simple and contractual acquisition options. Management options with fee simple acquisition include purchase and manage, purchase and leaseback, and purchase and resale on condition. Easements are the most common ways to acquire real property interests other than fee. Management options that can be used in conjunction with contractual agreements include lease contracts, transfer of development rights, and wastewater cooperatives. Each of the acquisition options has characteristics which influence the distribution of costs and benefits of land treatment to the landowners, the wastewater authority, and to other members of society. An alternative, attractive because of the ease with which it can be adopted to the local economic and social structure, is the wastewater cooperative.

Wastewater Cooperative

Concept

Group action through a cooperative effort is a familiar concept in American agriculture. Although farmers form cooperatives to purchase production supplies and sell their crops, these cooperative ventures are not generally extended to land use. It has been suggested that increasing partnerships and greater cooperative action will be necessary for farmers to function in an environment of contractual systems of control [2].

A cooperative venture in wastewater management would probably be more cognizant than an outside agency of the well-being of the rural community, as it would build upon the existing economic and social organization. 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 freedom of individual decision making. Farmers tend to place a high degree of emphasis on "freedom". However, the history of the cooperative movement indicates mutual gains from cooperation on input purchases and commodity sales exceeds any perceived loss of freedom.

German Experience

A use of cooperatives for land treatment is an alternative to the two party contractual arrangements often existing between an individual farmer and wastewater authority. Such a cooperative approach is used in Braunschweig, Germany. The Sewage Utilization Association of Braunschweig was organized in 1954 to expand the activities of a sewage farm operating in the area since the 1890s. The association combines the resources of the city and 550 farmers controlling 10,400 acres of land to treat approximately 8 mgd. of raw sewage using a land treatment irrigation system. The total Braunschweig area is divided into four districts of comparable size. Policy decisions are made by a committee of five farmers and four city representatives. The cost of the system is divided; farmers pay 25 percent and the city 75 percent. The water cost to the farmers is about $30/acre-foot. There is an average annual rainfall deficit of 2" for the area's principal crops of potatoes, sugar beets and small grains, so farmers are interested in obtaining additional water [10].

Southeastern Michigan Application

The concept of a wastewater cooperative was applied to a land treatment system proposed in the Southeastern Michigan Wastewater Management Study, completed by the Detroit District U.S. Army Corps of Engineers in 1974. This study developed long-range wastewater management plans for Southeastern Michigan. Its objective was to identify the present and future water pollution problems of the Southeastern Michigan study area and to design and evaluate the feasibility and consequences of alternatives for solving the problems. In the process of developing the plans, the needs and objectives related to water pollution problems in Southeastern Michigan were defined, treatment systems and related components were designed, alternative plans were formulated, and their impacts were assessed and evaluated [15].

The regional impact on agricultural production and cost sharing of the proposal was estimated. A wastewater cooperative organization is assumed formed to consolidate and coordinate negotiations with the wastewater authority. Rather than individual contractual agreements between an individual farmer and the wastewater authority, bargaining over distribution of irrigation costs and returns is assumed. A total of about 102,000 acres was involved, 72,500 of which remain in private ownership. The impacts of alternative cost sharing arrangements were estimated by aggregating the costs and returns of the total system. The expected benefits were allocated according to several criteria for the distribution of annual total costs, annual capital costs, and annual operating costs.

Construction and operating and maintenance costs for a system to irrigate the projected acreage of approximately 72,000 acres were estimated based on costs for individual modules. Each irrigation module covers 4 square miles and consists of 16 160-acre center pivot systems. Estimates of annual total costs for the entire system of 28 modules, based on data from consulting engineers, are $9.3 million; of which $5.5 million is capital cost and $3.8 million are operation and maintenance costs [4].

Crop production changes for the total irrigation system were estimated using alternative yield sets and rotations to account for uncertainties associated with the effect of wastewater application on crops. Estimates of alternative levels of total production from the entire irrigation project are presented in Table 1. The yield sets

Table 1
Estimates of Regional Production from a Land Treatment Proposal
Under Alternative Rotation and Yield Assumptions, Southeast Michigan

Crop	Acres	Unit	Production Yield Set[1]			Index of Production Yield Set[1]		
			Y_3	Y_4	Y_5	Y_3	Y_4	Y_5
			- - - - 1,000 units - - - -					
Corn	25,400.	bu	2,794.0	3,810.0	4,775.2	100.00	136.36	170.91
Soybeans	25,400.	bu	812.8	889.0	1,117.6	100.00	109.37	137.49
Wheat	7,200.	bu	360.0	432.0	540.0	100.00	120.00	149.99
Alfalfa	14,500.	ton	43.5	72.5	89.9	100.00	166.67	206.65
Total	72,500.							
Corn	29,000.	bu	3,190.0	4,350.0	5,452.0	100.00	136.36	170.91
Soybeans	29,000.	bu	928.0	1,015.0	1,276.0	100.00	109.37	137.49
Wheat	14,500.	bu	725.0	870.0	1,087.5	100.00	120.00	149.99
Total	72,500.							
Corn	29,000.	bu	3,190.0	4,350.0	5,452.0	100.00	136.36	170.91
Soybeans	14,500.	bu	464.0	507.5	638.0	100.00	109.37	137.49
Drybeans	14,500.	cwt	232.0	290.0	362.5	100.00	125.00	156.25
Wheat	14,500.	bu	725.0	870.0	1,087.5	100.00	120.00	149.99
Total	72,500.							

[1] Yield sets are below. Y_3 is without irrigation, Y_4 and Y_5 are with irrigation.

Crop	Unit	Yield Set		
		Y_3	Y_4	Y_5
		units/acre		
Corn	bu	110	150	188
Soybeans	bu	32	35	44
Drybeans	cwt	16	20	25
Wheat	bu	50	60	75
Alfalfa Hay	ton	3.0	5.0	6.2

reflect no irrigation and positive yield response to wastewater irrigation. The absolute and relative production changes vary with the crop and assumption sets used. Corn production increased as much as 71 percent. The greatest relative increase was for alfalfa, 106 percent.

Regional production requirements for major commodities from Southeastern Michigan shown in Table 2 are normative estimates of regional shares of national requirements for food and fiber. These were estimated in the Great Lakes Basin Framework Study and the Southeastern Michigan Water Resources Study and serve as benchmarks for comparison with production with wastewater irrigation.

Table 2
Aggregated Production from a Land Treatment Project as a Share of Regional Production Requirements under Alternative Yield and Rotation Assumptions, Southeastern Michigan

Crop	1980 Regional[1/] Requirements (1000 units)	Yield Per Acre[2/]	Rotation[3/]		
			R_1	R_2	R_3
			---% of Requirements---		
Corn	24,537 bu.	110	11.4	13.0	13.0
		150	15.5	17.7	17.7
		188	19.5	22.2	22.2
Soybeans	11,833 bu.	32	6.9	7.8	3.9
		35	7.5	8.6	4.3
		44	9.4	10.8	5.4
Dry Beans	910 cwt.	16	- -	- -	25.5
		20	- -	- -	31.9
		25	- -	- -	39.8
Wheat	10,286 bu.	50	3.5	7.0	7.0
		60	4.2	8.5	8.5
		65	5.2	10.6	10.6
Alfalfa Hay	495 tons	2.0	8.9	- -	- -
		5.0	14.6	- -	- -
		6.2	18.2	- -	- -

1/ (Great Lakes Commission, 1972).

2/ From Table 1.

3/ R_1 - 35% corn, 35% soybeans, 10% wheat, 20% alfalfa
R_2 - 40% corn, 40% soybeans, 20% wheat
R_3 - 40% corn, 20% soybeans, 20% dry beans, 20% wheat

The aggregate contribution of production from the land treatment project to regional requirements under alternative assumptions is also summarized in Table 2. Production estimates under three rotation assumptions are presented as a percentage of individual crop requirements. Dry beans from the project contribute the largest share of regional requirements, 25-40 percent. The contribution of soybeans is the least, 4-9 percent. If the most optimistic yield, Y_5, is realized on a rotation with 40 percent corn, the additional production of 2.3 million bushels represents 9 percent of the 1980 requirements. The contribution to regional corn production from the project area will increase from 13 percent without irrigation to 22 percent with irrigation.

Estimates of total revenues based on alternative assumptions of yields, prices, and rotations vary between $10.2 and $25.4 million without irrigation, and between $13.3 and $40.5 million with irrigation, depending upon the data sets used (Table 3).

The viability of the formation of a wastewater cooperative is strongly influenced by the proposed cost sharing arrangements with the wastewater authority. The data in Table 4 shows the net benefits to the cooperative with alternative irrigation cost sharing agreements. If a conservative yield and price set is assumed for all rotations, (Y_4P_1), the cooperative realizes net benefits only when the wastewater authority pays 75 percent of the total annual costs. If greater yield increases result (Y_5P_1), the cooperative realizes positive benefits with all cost sharing arrangements except when it pays the total cost of the irrigation system.

The sensitivity of net revenues from regional production to alternative cost sharing arrangements, rotations, yields, and prices is indicated in Table 4. The data is summarized in Table 5, where the total revenue increases from irrigation are arrayed against irrigation cost combinations to identify where costs exceed returns. The irrigation costs are arrayed from highest (total annual cost) to the lowest (25 percent of total annual cost). In between these extremes are annual capital costs, 50 percent of total annual cost, and annual operating costs. The largest cost exceeded by revenues from alternative data combinations is identified. For example, with yield set Y_4 and price level P_2, a maximum of 50 percent of total irrigation costs are offset by increased revenues with rotation R_3. If rotation R_2 is used, there will be positive net returns only after 25 percent of total costs are paid. Under assumptions of yield set Y_5 and price set P_3, positive revenues remain after paying total annual irrigation costs.

Table 3
Total Revenue and Change in Total Revenue with Irrigation, Alternative Crop Rotations, Yields, and Prices, Regional Land Treatment Project 1/

Crop Rotation		Acres	Y3P1	Y4P1	Y5P1	Y3P2	Y4P2	Y5P2	Y3P3	Y4P3	Y5P3
			Revenue with Alternative Yield and Price Sets								
			dollars								
R1	Corn	25,400.	4,582.2	6,248.4	7,831.3	6,985.0	9,525.0	11,938.0	9,779.0	13,335.0	16,713.2
	Soybeans	25,400.	3,348.7	3,662.7	4,604.5	4,064.0	4,445.0	5,588.0	6,502.4	7,112.0	8,940.8
	Wheat	7,200.	849.6	1,019.5	1,274.4	1,080.0	1,296.0	1,620.0	1,800.0	2,160.0	2,700.0
	Alfalfa	14,500.	1,435.5	2,392.5	2,966.7	1,740.0	2,900.0	3,596.0	2,175.0	3,625.0	4,495.0
	Total	72,500.	10,216.0	13,323.1	16,676.9	13,869.0	18,166.0	22,742.0	20,256.4	26,232.0	32,849.0
	Change			3,107.1	6,460.9		4,297.0	8,873.0		5,975.6	12,592.6
R2	Corn	29,000.	5,231.6	7,134.0	8,941.3	7,975.0	10,875.0	13,630.0	11,165.0	15,225.0	19,082.0
	Soybeans	29,000.	3,823.4	4,181.8	5,257.1	4,640.0	5,075.0	6,380.0	7,424.0	8,120.0	10,208.0
	Wheat	14,500.	1,711.0	2,053.2	2,566.5	2,175.0	2,610.0	3,262.5	3,625.0	4,350.0	5,437.5
	Total	72,500.	10,766.0	13,369.0	16,764.9	14,790.0	18,560.0	23,272.5	22,214.0	27,695.0	34,727.5
	Change			2,603.0	5,998.9		3,770.0	8,482.5		5,481.0	12,513.5
R3	Corn	29,000.	5,231.6	7,134.0	8,941.3	7,975.0	10,875.0	13,630.0	11,165.0	15,225.0	19,082.0
	Soybeans	14,500.	1,911.7	2,090.9	2,628.6	2,320.0	2,537.5	3,190.0	3,712.0	4,060.0	5,104.0
	Dry Beans	14,500.	3,906.9	4,883.6	6,104.5	4,640.0	5,800.0	7,250.0	6,960.0	8,700.0	10,875.0
	Wheat	14,500.	1,711.0	2,053.2	2,566.5	2,175.0	2,610.0	3,262.5	3,625.0	4,350.0	5,437.5
	Total	72,500.	12,761.2	16,161.7	20,240.8	17,110.0	21,822.5	27,332.5	25,462.0	32,335.0	40,498.5
	Change			3,400.5	7,479.7		4,712.5	10,222.5		6,873.0	15,036.5

1/ Yield is specified in Table 1.
Prices are:

Crop	Unit	Price Set		
		P_1	P_2	P_3
		$/unit		
Corn	bu	1.64	2.50	3.50
Soybeans	bu	4.12	5.00	8.00
Dry Beans	cwt	16.84	20.00	30.00
Wheat	bu	2.36	3.00	5.00
Alfalfa Hay	ton	33.00	40.00	50.00

Table 4
Changes in Annual Total Revenue and Net Revenue for a Regional Wastewater Irrigation Project with Alternative Assumptions on Rotation, Yield, Price, and Irrigation Cost Sharing

		Net Revenues After Deduction of:				
Alternative Data Sets[1]	Change in Total Revenue with Irrigation	Total Irrigation Costs (9,304)	Capital Costs (5,511)	50% of Total Cost (4,652)	Operating Cost (3,783)	25% of Total Cost (2,326)
	1,000 dollars					
$R_1Y_4P_1$	3,107	-6,197	-2,404	-1,545	-676	781
$R_1Y_5P_1$	6,461	-2,843	950	1,808	2,678	4,134
$R_1Y_4P_2$	4,297	-5,007	-1,214	-355	514	1,971
$R_1Y_5P_2$	8,873	-431	3,362	4,221	5,090	6,547
$R_1Y_4P_3$	5,976	-3,328	464	1,324	2,192	3,650
$R_1Y_5P_3$	12,593	3,288	7,082	7,940	8,810	10,266
$R_2Y_4P_1$	2,603	-6,701	-2,908	-2,049	-1,180	277
$R_2Y_5P_1$	5,998	-3,305	488	1,346	2,216	3,672
$R_2Y_4P_2$	3,770	-5,534	-1,741	-882	-13	1,444
$R_2Y_5P_2$	8,482	-822	2,972	3,830	4,700	6,156
$R_2Y_4P_3$	5,481	-3,823	-30	829	1,698	3,155
$R_2Y_5P_3$	12,514	3,210	7,002	7,862	8,730	10,188
$R_3Y_4P_1$	3,400	-5,904	-2,110	-1,252	-382	1,074
$R_3Y_5P_1$	7,480	-1,824	1,968	2,828	3,696	5,154
$R_3Y_4P_2$	4,712	-4,592	-798	60	930	2,386
$R_3Y_5P_2$	10,222	918	4,712	5,570	6,440	7,896
$R_3Y_4P_3$	6,873	-2,431	1,362	2,221	3,090	4,547
$R_3Y_5P_3$	15,036	5,732	9,526	10,384	11,254	12,710

1/ Data Sets Combine Rotation, Yield, and Price Information from Tables 1 and 3.

Table 5
Irrigation Costs Offset by Revenue
Increases, Wastewater Cooperative

Rotation	Yield and Price Sets[1/]					
	Y_4P_1	Y_5P_1	Y_4P_2	Y_5P_2	Y_4P_3	Y_5P_3
	Irrigation Costs Offset[2/]					
R_1	5	2	4	2	2	1
R_2	5	2	5	2	3	1
R_3	5	2	3	1	2	1

1/ Yields and prices are from Tables 1 and 3; Revenues and Irrigation costs are from Table 3.

2/ Numbers indicate net revenues remaining after the following annual irrigation costs are paid.
1. Total costs
2. Capital costs
3. 50 percent of total costs
4. Operating costs
5. 25 percent of total costs

Summary and Conclusion

Land application is receiving increased attention as a technology for improved treatment of wastewater. One of the problems in establishing such a system, especially for large metropolitan areas, is the acquisition and management of land for treatment purposes. Options which transfer resource control from landowners to a wastewater authority can disrupt the existing agricultural community and inject inequities in the distribution of the cost of public policy, in this case wastewater treatment using land.

A wastewater cooperative is an organizational form built upon an existing tradition in agriculture which enables the ownership and management functions to remain with the existing farmers. Such a cooperative has been successfully used in Germany since 1954. The concept of a wastewater cooperative was applied to a proposed land treatment system for Southeastern Michigan.

Total production and revenue changes were estimated for a land treatment system using alternative assumptions on yield response, prices, and irrigation cost sharing arrangements. The production from 72,500 privately owned acres of land was estimated. The impact on regional production requirements was relatively small, with the greatest impact occurring in corn production.

The effect of alternative cost sharing agreements was estimated, assuming a cooperative would be formed to serve as a bargaining unit for the farmers and the wastewater authority and to serve as a central clearing house for management decisions. If a conservative yield and price set are assumed, there are net revenues to the co-operative only if 75 percent of the total annual costs are paid by the wastewater authority. When higher yields or prices are achieved, net revenues are realized under all cost sharing arrangements, and under the most optimistic assumptions, net revenues remain for the cooperative after paying the total cost of the irrigation system.

The concept of a wastewater cooperative has been successfully applied in Germany, and offers potential for application in the United States. Additional research is needed to identify important factors influencing wastewater cooperative formation, its optimum characteristics, and ways in which a cooperative would integrate the goals of farmers and wastewater authority. In particular, more data is needed on the influence of cost sharing and federal subsidies for capital expenditures on the selection of the land treatment alternative.

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