TECHNICAL REPORT

COST-EFFECTIVE COMPARISON OF LAND APPLICATION AND ADVANCED WASTEWATER TREATMENT

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY ·

NOVEMBER 1975

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER PROGRAM OPERATIONS

WASHINGTON, D.C. 20460

MCD-17

NOTES

To order this publication, MCD-17, Technical Report, Cost-Effective Comparison of Land Application & Advanced Wastewater Treatment.

Write to:

General Services Administration (8FSS)
Centralized Mailing List Services
Bldg. 41, Denver Federal Center
Denver, CO 80225

Please indicate the MCD number and title of publication.

EPA-430/9-75-016

TECHNICAL REPORT

COST-EFFECTIVE COMPARISON OF LAND APPLICATION AND ADVANCED WASTEWATER TREATMENT

BY

Charles E. Pound

Ronald W. Crites

Robert G. Smith

Belford L. Seabrook, P.E.

Project Officer

NOVEMBER 1975

prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER PROGRAM OPERATIONS

WASHINGTON, D.C. 20460

MCD-17

FOREWORD

This report is intended to be used for general cost comparisons of advanced wastewater treatment and land application systems. The curves shown in the figures are presented only for comparative purposes and should not be used to estimate costs of specific alternatives in facilities plans.

The sensitivity of total costs of land application systems to variations in design factors is illustrated for irrigation systems in Figure 2. The three conditions chosen represent the variations that may be encountered in design and are not intended to be regional stereotypes.

Variations in application rates, storage periods, and interest rates were also studied independently for irrigation, overland flow, and infiltration-percolation systems. The resulting curves exhibited only slight cost variations and therefore were not included in this report.

CONTENTS

	Page
INTRODUCTION	1
APPROACH	2
COST COMPARISON OF AWT AND LAND APPLICATION SYSTEMS - FIGURE 1	6
COST COMPARISON OF AWT AND IRRIGATION SYSTEMS UNDER VARIABLE SITE CONDITIONS - FIGURE 2	8
VARIATION OF COST WITH CONVEYANCE DISTANCE AND FLOW CAPACITY - TABLE 4	11
LAND PRICE RESULTING IN EQUAL TOTAL COSTS OF AWT AND LAND APPLICATION SYSTEMS - FIGURE 3	12
FEDERAL AND LOCAL SHARE OF TOTAL COSTS - FIGURE 4	14
COST COMPONENT TABLES	16
EXAMPLES	20
REFERENCES	25

TABLES

No.		Page
1	AWT Systems	2
2	Effluent Quality Comparison for Land Treatment and AWT Systems	3
3	Site Conditions for Land Application Systems	4
4	Conveyance Cost VS Flow Capacity	11
5	Component Costs for AWT Systems	16
6	Component Costs of Irrigation Systems Under Condition 1	17
7	Component Costs of Irrigation Systems Under Condition 2	17
8	Component Costs of Irrigation Systems Under Condition 3	18
9	Component Costs for Overland Flow Systems	19
10	Component Costs for Infiltration-Percolation Systems	19
11	Cost Comparison for Example 1	22
12	Cost Comparison for Case A	23
13	Cost Comparison for Case B	24

FIGURES

1	Costs of AWT and Land Application Systems	7
2	Costs of AWT and Irrigation Systems Under Variable Site Conditions	9
3	Land Price Resulting in Equal Total Costs of AWT and Land Application Systems	13
4	Federal and Local Share of Total Present Worth Costs of AWT-4 and Irrigation Systems	15

COST-EFFECTIVE COMPARISON OF LAND APPLICATION AND ADVANCED WASTEWATER TREATMENT SYSTEMS

INTRODUCTION

Numerous misconceptions regarding the economic feasibility of land application systems are involved in the controversy over the role of land treatment processes used in place of conventional advanced wastewater treatment (AWT). The relative importance of costs for preapplication treatment, conveyance, storage, application, and land must be assessed for each case. Depending on local conditions, a long conveyance distance or a high land price may be economically justifiable when the alternatives are compared in the cost-effectiveness analysis.

The objectives of this report are to illustrate the sensitivity of land application system costs to variations in major design factors and to compare these costs with those for conventional AWT systems. Four figures showing cost curves have been produced for this purpose, and some major implications from the analysis of these curves are listed. The component costs for the curves are presented in tables to illustrate their relative magnitudes and to allow replacement, additions, or deletions of cost components. Two examples are included to illustrate the potential use of the curves and tables.

Two other comparisons are made in addition to variations in design factors. First, land price is shown in Figure 3 in curves that represent equivalent total costs of AWT and land application systems. These curves can be used to determine the upper limits of land prices that would be feasible for various cases, or they can be used to determine the upper limits of flow for which land application systems would be comparable in cost to AWT systems for a given land price.

Second, the effect of federal grants was compared for an irrigation system and an AWT system in Figure 4. The local and federal shares were computed assuming land to be eligible for grants except for use as a preapplication treatment or storage site.

APPROACH

To compare typical costs of land application and AWT, the technical reports, *Costs of Wastewater Treatment by Land Application* [1] and *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems* [2], have been used. Four AWT systems have been developed as shown in Table 1. The effluent quality expected from these four systems, from the three land application systems, and from activated sludge and aerated lagoon systems is shown in Table 2.

Table 1. AWT SYSTEMS

System	Constituents removed	Processes used
AWT-1	NH_3-N	Biological nitrification
AWT-2	Total-N	Biological nitrification-denitrification
AWT-3	Phosphorus and SS	Tertiary, two-stage lime coagulation, and filtration
AWT-4	Total N, P, and SS	Tertiary, two-stage lime coagulation, filtration, and selective ion exchange

Table 2. EFFLUENT QUALITY COMPARISON FOR LAND TREATMENT AND AWT SYSTEMS

System	Effluent quality parameter, mg/l					
	BOD	SS	NH_3-N	NO_3-N	Total N	P
Aerated lagoon	35	40	10	20	30	8
Activated sludge	20	25	20	10	30	8
Irrigation	1	1	0.5	2.5	3	0.1
Overland flow	5	5	0.5	2.5	3	5
Infiltration-percolation	5	1	--	10	10	2
AWT-1	12	15	1	29	30	8
AWT-2	15	16	--	--	3	8
AWT-3	5	5	20	10	30	0.5
AWT-4	5	5	--	--	3	0.5

Comparing the effluent qualities and pairing off land application and AWT systems it appears that:

- Irrigation and AWT-4 produce effluents of similar quality
- Overland flow and AWT-2 produce effluents of similar quality
- Infiltration-percolation produces an effluent comparable in quality to AWT-1 and AWT-3

In estimating the effluent qualities in Table 2 for land application systems it was assumed that preapplication treatment would consist of biological oxidation using aerated lagoons. The quality of effluent from land application processes is approximately the same whether the wastewater applied is from primary or secondary treatment according to Reed [3].

The site conditions for the three land application systems are given in Table 3. A comparison of system costs for irrigation (Condition 2), overland flow, and infiltration-percolation with the AWT costs is shown in Figure 1.

Table 3. SITE CONDITIONS FOR LAND APPLICATION SYSTEMS

Parameter	Irrigation			Overland flow	Infiltration-percolation
	Condition 1[a]	Condition 2[b]	Condition 3[c]		
Conveyance distance, miles	1	5	10	5	5
Storage period, weeks	1	10	20	5	1
Application rate, in./wk	3	2	1.5	6	12
Land price, $/acre	1,000	2,000	4,000	2,000	2,000
Crop revenue, $/acre	400	300	150	100	--
Underdrain spacing, ft	none	200	100	--	--
Tailwater return, % of applied effluent	0	10	30	--	--

a. Condition 1 represents a climate with mild winters, nearby site with well-drained loamy soil. Application is by center pivot sprinkling.

b. Condition 2 represents a climate with moderately cold winters, moderately well-drained soil underlain by poorly drained subsoil. Application is by center pivot sprinkling.

c. Condition 3 represents a cold climate, a distant site with poor drainage and rolling terrain necessitating application by solid set sprinkling and surface runoff control.

COMPARISON DATA

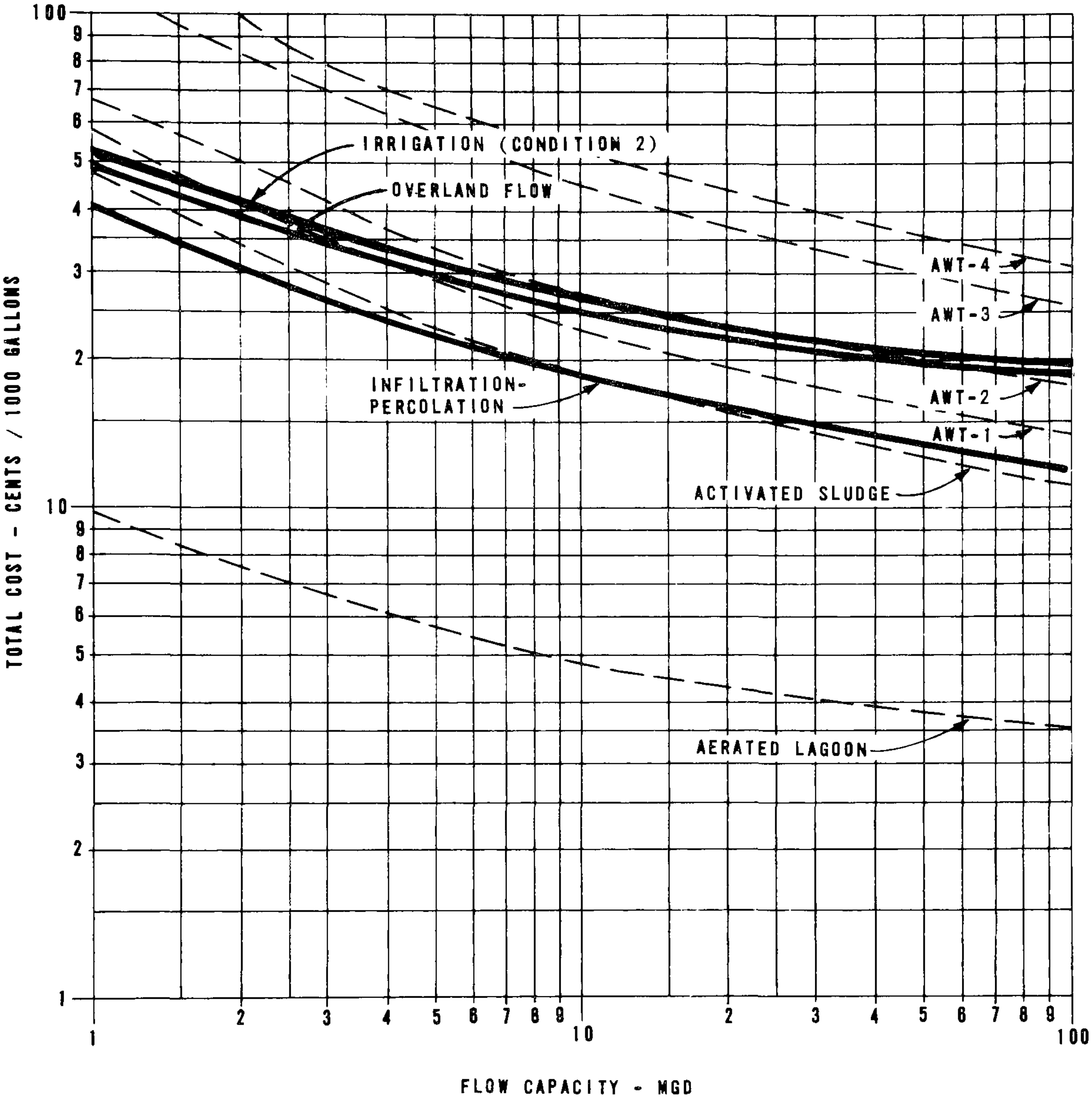
COST COMPARISON OF AWT AND LAND APPLICATION SYSTEMS - FIGURE 1

Basis of Costs

1. EPA Treatment Plant Cost Index - 177.5
2. Interest rate - 5-5/8 percent
3. Recovery period - 20 years
4. Pretreatment using headworks, aerated lagoon, chlorination, and administration and laboratory facilities
5. Pumping station with 150 feet total head
6. Unlined storage reservoir with embankment protection
7. Conveyance by force main
8. Costs not included - water rights, relocation, easements

Implications

1. In general, land application systems exhibit less economy of scale than AWT systems. Thus, land application systems tend to be more cost effective at lower flow capacities when compared to a given AWT system. For example, both irrigation and overland flow under the stated design conditions have a progressively lower total cost than AWT-1 as flow capacities decrease below about 3 mgd and a progressively higher total cost as flow capacities increase beyond 3 mgd.
2. Under the stated conditions, infiltration-percolation is the lowest cost land application system. Overland flow and irrigation are nearly equal and exhibit a relatively constant cost differential with respect to infiltration-percolation and to one another.
3. All three land application systems under the stated conditions are significantly more cost effective than AWT-3 or AWT-4 (although effluent qualities will vary) at flow capacities at least through 100 mgd.



NOTE: CONDITION 2 REPRESENTS A CLIMATE WITH MODERATELY COLD WINTERS, MODERATELY WELL-DRAINED SOIL UNDERLAIN BY POORLY DRAINED SUBSOIL. APPLICATION IS BY CENTER PIVOT SPRINKLING.

FIGURE 1. COSTS OF AWT AND LAND APPLICATION SYSTEMS

4. Infiltration-percolation, under the stated conditions, is cost competitive with activated sludge secondary treatment.

5. Irrigation (Condition 2) and overland flow are cost competitive with AWT-1 and AWT-2.

COST COMPARISON OF AWT AND IRRIGATION SYSTEMS UNDER VARIABLE SITE CONDITIONS - FIGURE 2

Basis of Costs

1. EPA Treatment Plant Cost Index - 177.5

2. Interest rate - 5-5/8 percent

3. Recovery period - 20 years

4. Irrigation site conditions - see Table 3

5. Pretreatment using headworks, aerated lagoon, chlorination, and administration and laboratory facilities

6. Pumping station with 150 feet total head

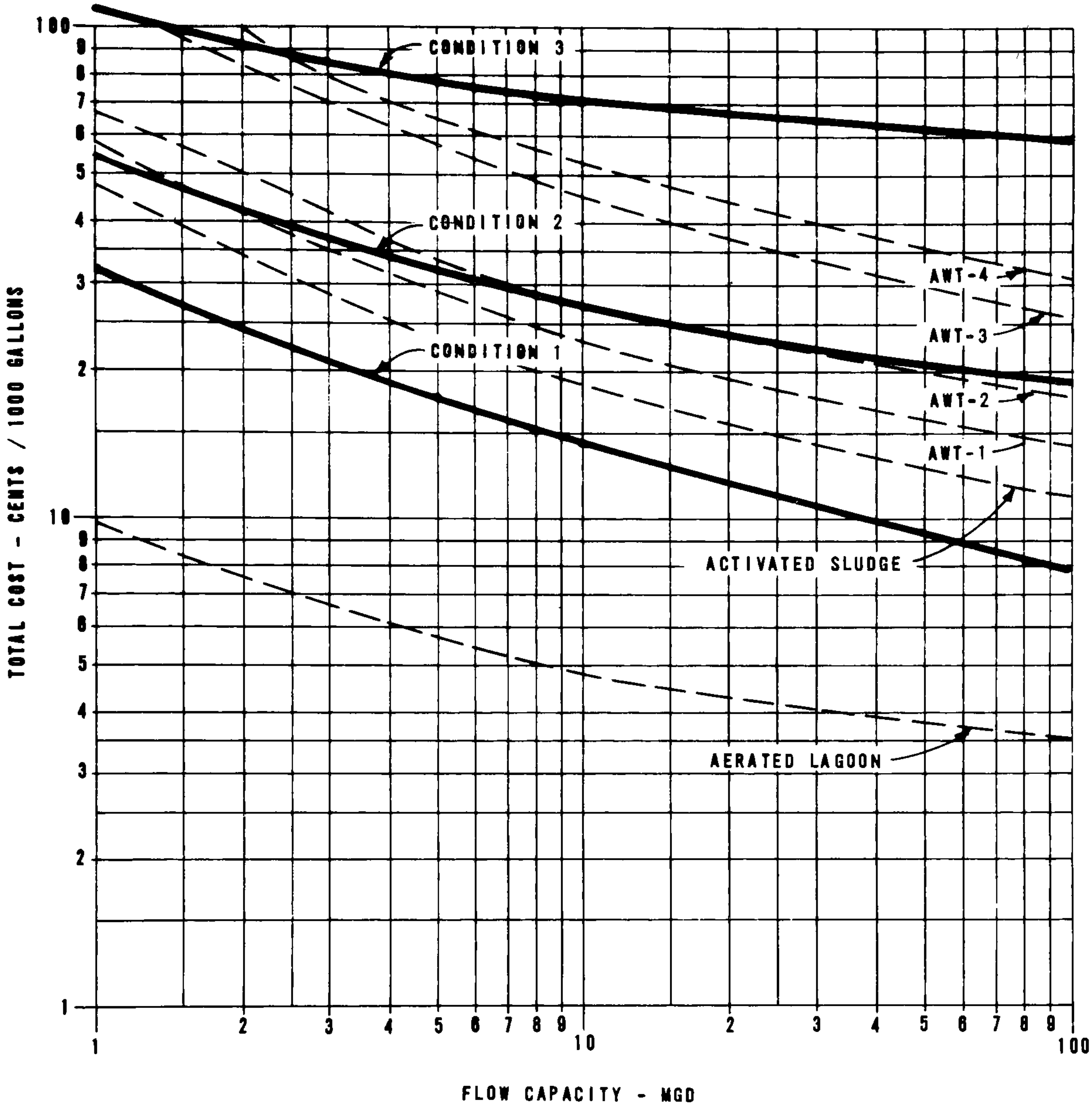
7. Unlined storage reservoir with embankment protection

8. Conveyance by force main

9. Costs not included - water rights, relocation, easements

Implications

1. Differences in site condition variables can result in a cost variation of over 300 percent for an irrigation system. Overland flow and infiltration-percolation are also subject to similar cost variations with site conditions although less extreme than irrigation because of fewer cost component variables.



NOTE: CONDITION 1 REPRESENTS A CLIMATE WITH MILD WINTERS, NEARBY SITE WITH WELL-DRAINED LOAMY SOIL. APPLICATION IS BY CENTER PIVOT SPRINKLING.

CONDITION 2 REPRESENTS A CLIMATE WITH MODERATELY COLD WINTERS, MODERATELY WELL-DRAINED SOIL UNDERLAIN BY POORLY DRAINED SUBSOIL. APPLICATION IS BY CENTER PIVOT SPRINKLING.

CONDITION 3 REPRESENTS A COLD CLIMATE, A DISTANT SITE WITH POOR DRAINAGE AND ROLLING TERRAIN NECESSITATING APPLICATION BY SOLID SET SPRINKLING AND SURFACE RUNOFF CONTROL

FIGURE 2. COSTS OF AWT AND IRRIGATION SYSTEMS UNDER VARIABLE SITE CONDITIONS

2. As conditions become more favorable for irrigation, the total costs exhibit more economy of scale, with the cost curves tending to have a shape similar to the AWT system cost curves.

3. Under a combination of unfavorable conditions (Condition 3) irrigation appears to be economically competitive with AWT-3 and AWT-4 only at flows less than about 3 mgd.

4. Under Condition 2, irrigation is decidedly more cost effective than either AWT-3 or AWT-4 at all flows less than 100 mgd and is competitive with AWT-1 and AWT-2 at flows less than about 20 mgd.

5. Under Condition 1, irrigation is significantly more cost effective than activated sludge at all flows less than 100 mgd.

6. Revenue produced from the sale of the crop is very important to the total costs, especially under Conditions 1 and 2.

VARIATION OF COST WITH CONVEYANCE DISTANCE AND FLOW CAPACITY - TABLE 4

Basis of Costs

1. EPA Treatment Plant Cost Index - 177.5

2. Interest rate - 5-5/8 percent

3. Recovery period - 20 years

4. Conveyance by force main

5. Costs not included - water rights, relocation, easements

Table 4. CONVEYANCE COST VS FLOW CAPACITY
Cents per 1,000 Gallons

Distance miles	Average flow, mgd							
	1	3	5	10	20	30	50	70
1	1.8	0.8	0.6	0.4	0.3	0.2	0.2	0.1
3	5.4	2.4	1.8	1.2	0.9	0.8	0.6	0.5
5	9.2	4.0	3.0	2.0	1.5	1.3	1.0	0.9
10	18.3	8.0	6.0	4.0	3.0	2.5	2.0	1.7
20	36.6	16.0	12.0	8.0	6.0	5.0	4.0	3.4
30	54.9	24.0	18.0	12.0	9.0	7.5	6.0	5.1
50	92.0	40.0	30.0	20.0	15.0	12.5	10.0	8.5
100	184	80	60	40	30	25	20	17

Implication

1. The total cost of land application systems is very sensitive to conveyance distance at low flow capacity but becomes less sensitive as flow capacity increases. For example, the cost of conveyance for a 1-mgd irrigation system (Condition 2) would represent 11 percent of the total cost at 3 miles of transmission, but would increase to 29 percent at 10 miles and to 45 percent at 20 miles. The same conveyance distances for a 50-mgd system would represent only 3, 9, and 16 percent of the total cost, respectively.

LAND PRICE RESULTING IN EQUAL TOTAL COSTS OF AWT AND LAND APPLICATION SYSTEMS - FIGURE 3

Basis of Costs

1. EPA Treatment Plant Cost Index - 177.5
2. Interest rate - 5-5/8 percent
3. Recovery period - 20 years
4. Irrigation site (Condition 2)
5. Pretreatment using headworks, aerated lagoons, chlorination, and administration and laboratory facilities
6. Pumping station with 150 feet total head
7. Unlined storage reservoir with embankment protection
8. Conveyance by force main
9. Costs not included - water rights, relocation, easements

Implications

1. In general, the lower the flow capacity of the land application system, the higher the price that can be paid for land and still be economically competitive with AWT systems.
2. In areas where land costs are low ($1,000 per acre or less) irrigation (Condition 2) would be more cost effective than AWT-4, AWT-3, and AWT-2. Similarly, irrigation would be more cost effective than AWT-1 at flows less than about 10 mgd. Overland flow, under similar conditions, would be more cost effective than AWT-2 at flows less than about 50 mgd.

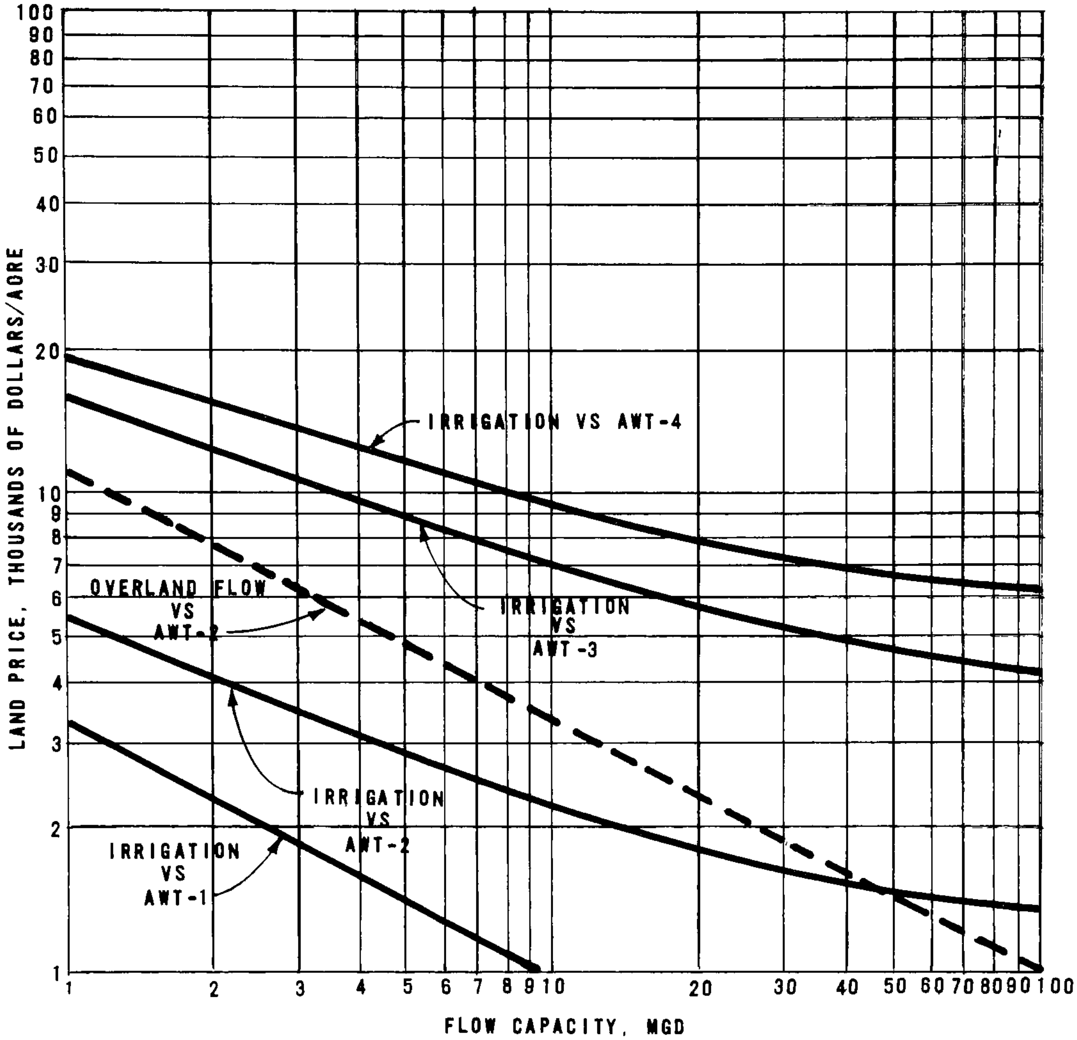


FIGURE 3. LAND PRICE RESULTING IN EQUAL TOTAL COSTS OF AWT AND LAND APPLICATION SYSTEMS

FEDERAL AND LOCAL SHARE OF TOTAL COST - FIGURE 4

Basis of Costs

1. EPA Treatment Plant Cost Index - 177.5
2. Federal grant funding at 75 percent of eligible construction cost
3. Interest rate - 5-5/8 percent
4. Recovery period - 20 years
5. Irrigation site (Condition 2)
6. All land costs for irrigation except storage site are considered eligible
7. Pretreatment using headworks, aerated lagoons, chlorination, and administration and laboratory facilities
8. Pumping station with 150 feet total head
9. Unlined storage reservoir with embankment protection
10. Conveyance by force main
11. Costs not included - water rights, relocation, easements

Implications

1. The federal share of total costs represents a much larger percentage of the total cost for land application systems than for AWT systems. For example, the federal share of a 10-mgd irrigation system represents about 70 percent of the total cost, while the federal share for the same size AWT-4 system represents about 35 percent of the total cost. This difference results from the fact that the majority of the costs associated with land application systems are capital costs of which the federal share is 75 percent. In addition, the operating and maintenance costs, which are paid entirely out of the local share, are lower for land applications relative to AWT systems and these costs are reduced further through revenues from crops.

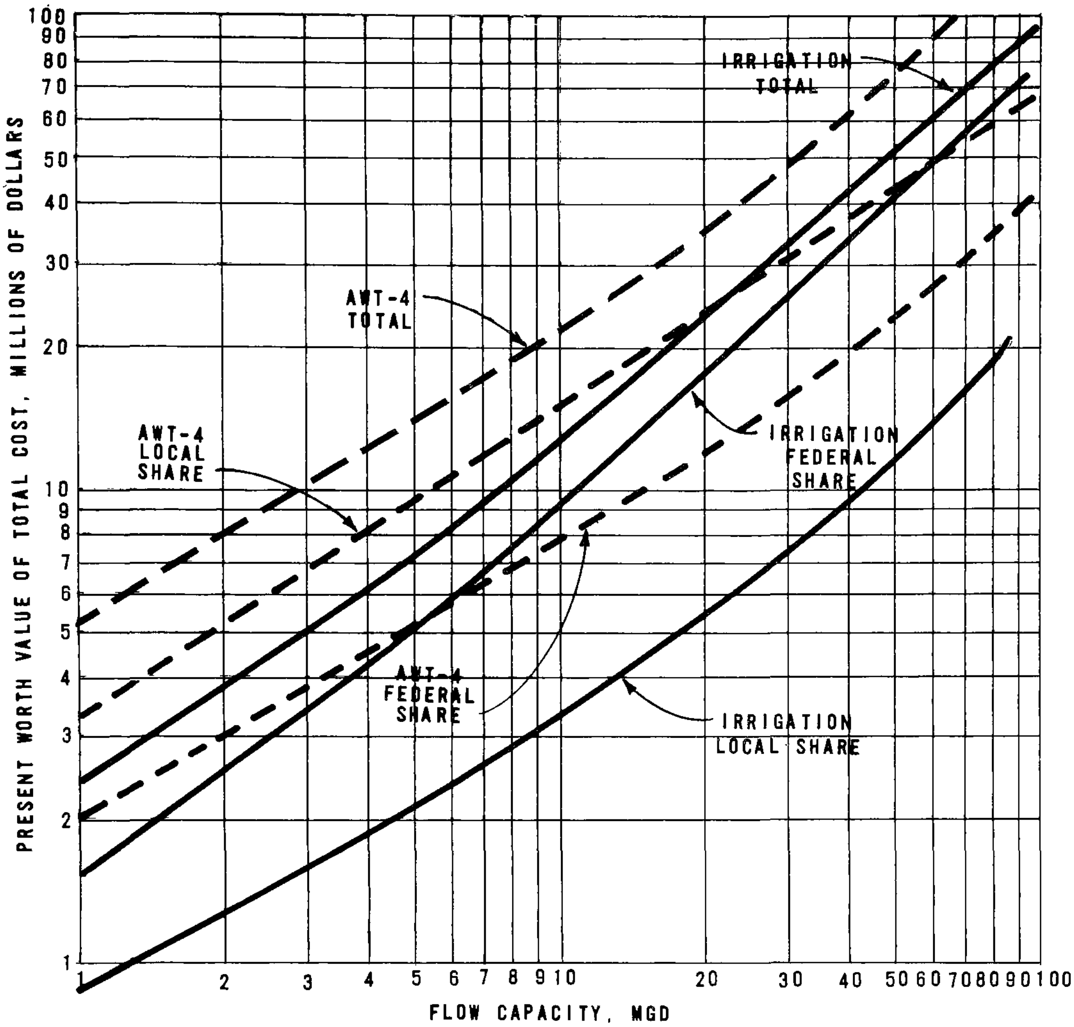


FIGURE 4. FEDERAL AND LOCAL SHARE OF TOTAL PRESENT WORTH COSTS OF AWT-4 AND IRRIGATION SYSTEMS

2. For land application systems and AWT systems of equal total costs, the local share of the land application system cost will generally be lower than the local share of the AWT system cost. From this standpoint local agencies may tend to look more favorably on land application systems when total costs appear to be equal.

COST COMPONENT TABLES

To allow manipulation of system costs and further sensitivity analyses as desired, the cost components of all the systems are given in Tables 5 through 10. The sources of these costs are the EPA reports [1,2]. The exception to this is the cost for sludge disposal, which is estimated at $30 per ton for 1-mgd secondary systems and $20 per ton for 100-mgd systems [4].

Table 5. COMPONENT COSTS FOR AWT SYSTEMS
Cents per 1,000 Gallons

Process	Curve designation [2]	Average flow, mgd					
		1	3	5	10	50	100
Headworks	AA	2.7	1.4	1.1	0.8	0.6	0.4
Primary	A1	6.7	3.2	2.4	1.7	0.9	0.8
Activated sludge	C1	19.0	12.0	9.1	7.0	4.5	4.0
Disinfection	R	2.8	1.9	1.6	1.3	1.0	1.0
Sludge digestion	L1	4.1	1.9	1.4	1.0	0.6	0.6
Sludgy drying	O1	6.0	3.8	3.2	2.6	1.9	1.8
Sludge disposal	--	3.7	3.5	3.3	3.1	2.8	2.5
Administration	--	3.2	1.7	1.3	0.9	0.4	0.3
Subtotal		48.2	29.4	23.4	18.4	12.7	11.4
AWT-1							
Nitrification	G2	11.0	6.8	5.6	4.5	3.2	2.8
Total		59.2	36.2	29.0	22.9	15.9	14.2
AWT-2							
Nitrification	G2	11.0	6.8	5.6	4.5	3.2	2.8
Denitrification	H	9.4	6.2	5.3	4.4	3.6	3.6
Total		68.6	42.4	34.3	27.3	19.5	17.8
AWT-3							
Lime addition	F2	12.0	6.0	4.8	3.4	1.8	1.5
Filtration	D	11.0	7.9	6.7	5.3	3.2	2.5
Sludge drying	O7	9.8	6.3	5.3	4.4	3.2	2.9
Recalcination	Q3	24.0	17.0	14.0	12.0	7.3	7.0
Incineration	P5-L1	6.7	3.8	2.9	2.0	1.0	0.8
Total		111.7	70.4	57.1	45.5	29.2	26.1
AWT-4							
AWT-3		111.7	70.4	57.1	45.5	29.2	26.1
Ion exchange	I	14.0	11.0	9.8	8.5	6.5	5.9
Total		125.7	81.4	66.9	54.0	35.7	32.0

Table 6. COMPONENT COSTS OF IRRIGATION SYSTEMS UNDER CONDITION 1

Variable	Unit	Average flow, mgd					
		1	3	5	10	50	70
Effective flow	mgd	1.02	3.05	5.1	10.2	51	71.4
Field area	acres	90	270	450	900	4,500	6,300
Total area	acres	170	440	750	1,400	5,200	8,700
Costs							
Pretreatment	¢/1,000 gal.	9.9	6.7	5.7	4.7	3.9	3.5
Pumping	¢/1,000 gal.	6.8	5.0	4.2	3.8	2.9	2.6
Conveyance	¢/1,000 gal.	1.8	0.8	0.6	0.4	0.2	0.1
Application system							
Capital	¢/1,000 gal.	8.8	6.3	6.0	5.8	4.9	4.6
Operation and maintenance	¢/1,000 gal.	11.0	8.5	7.9	7.1	5.3	5.2
Storage	¢/1,000 gal.	0.7	0.5	0.5	0.4	0.3	0.3
Land	¢/1,000 gal.	2.6	2.3	2.3	2.2	1.9	1.9
Crop revenue	¢/1,000 gal.	(9.9)	(9.9)	(9.9)	(9.9)	(9.9)	(9.9)
Total	¢/1,000 gal.	31.7	20.2	17.3	14.5	9.5	8.3

Table 7. COMPONENT COSTS OF IRRIGATION SYSTEMS UNDER CONDITION 2

Variable	Unit	Average flow, mgd					
		1	3	5	10	50	70
Effective flow	mgd	1.24	3.7	6.2	12.4	62	87
Field area	acres	170	510	850	1,700	8,500	11,900
Total area	acres	275	750	1,200	2,200	10,500	14,000
Tailwater, 10%	mgd	0.1	0.3	0.5	1.0	5.0	7.0
Costs							
Pretreatment	¢/1,000 gal.	9.9	6.7	5.7	4.7	3.9	3.5
Pumping	¢/1,000 gal.	6.8	5.0	4.2	3.8	2.9	2.6
Transmission	¢/1,000 gal.	9.2	4.2	2.8	2.0	1.0	0.7
Application system							
Capital	¢/1,000 gal.	11.6	9.3	8.8	8.1	7.9	7.6
Operation and maintenance	¢/1,000 gal.	13.0	10.2	9.7	8.9	8.0	7.9
Underdrain							
Capital	¢/1,000 gal.	2.5	2.3	2.3	2.3	2.3	2.3
Operation and maintenance	¢/1,000 gal.	1.3	0.9	0.8	0.7	0.5	0.5
Tailwater return							
Capital	¢/1,000 gal.	0.5	0.2	0.2	0.1	0.1	0.1
Operation and maintenance	¢/1,000 gal.	0.1	0.1	0.1	0.1	--	--
Storage	¢/1,000 gal.	3.5	2.9	2.8	2.4	2.2	2.1
Land	¢/1,000 gal.	8.5	7.7	7.4	6.8	6.5	6.2
Crop revenue	¢/1,000 gal.	(13.7)	(13.7)	(13.7)	(13.7)	(13.7)	(13.7)
Total	¢/1,000 gal.	53.2	35.8	31.1	26.2	21.6	19.5

Table 8. COMPONENT COSTS OF IRRIGATION SYSTEMS UNDER CONDITION 3

Variable	Unit	Average flow, mgd					
		1	3	5	10	50	70
Effective flow	mgd	1.6	4.9	8.1	16.2	81	114
Field area	acres	280	840	1,400	2,800	14,000	19,600
Total area	acres	390	1,100	1,800	3,400	15,000	21,000
Tailwater, 30%	mgd	0.3	0.9	1.5	3.0	15	21
Costs							
Pretreatment	¢/1,000 gal.	9.9	6.7	5.7	4.7	3.9	3.5
Pumping	¢/1,000 gal.	6.8	5.0	4.2	3.8	2.9	2.6
Conveyance	¢/1,000 gal.	18.3	8.4	5.7	4.1	2.0	1.4
Application system							
Capital	¢/1,000 gal.	25.5	23.2	23.2	22.0	22.0	22.0
Operation and maintenance	¢/1,000 gal.	16.0	14.0	13.0	12.0	11.3	11.0
Underdrain							
Capital	¢/1,000 gal.	6.3	6.3	6.5	6.5	6.5	6.5
Operation and maintenance	¢/1,000 gal.	3.8	2.8	2.6	2.4	1.8	1.8
Tailwater return							
Capital	¢/1,000 gal.	0.7	0.3	0.2	0.2	0.1	0.1
Operation and maintenance	¢/1,000 gal.	0.2	0.2	0.1	0.1	0.1	0.1
Storage	¢/1,000 gal.	6.2	5.5	5.3	4.9	4.5	4.4
Land	¢/1,000 gal.	24.0	22.6	22.2	20.9	18.5	18.5
Crop revenue	¢/1,000 gal.	(11.5)	(11.5)	(11.5)	(11.5)	(11.5)	(11.5)
Total	¢/1,000 gal.	106.2	83.5	77.2	70.1	62.1	60.4

Table 9. COMPONENT COSTS FOR OVERLAND FLOW SYSTEMS

Cost component	Unit	Average flow capacity, mgd					
		1	3	5	10	50	70
Effective flow	mgd	1.2	3.7	6.2	12.4	62	81
Field area	acres	53	159	265	530	2,650	3,710
Total area	acres	130	360	570	1,100	4,900	6,500
Costs							
Pretreatment	¢/1,000 gal.	9.9	6.7	5.7	4.7	3.9	3.5
Pumping	¢/1,000 gal.	6.8	5.0	4.2	3.8	2.9	2.6
Conveyance	¢/1,000 gal.	9.2	4.2	2.8	2.0	1.0	0.7
Application system							
Capital	¢/1,000 gal.	11.6	8.9	7.9	6.5	6.0	5.8
Operation and maintenance	¢/1,000 gal.	7.5	5.8	5.4	4.8	3.9	3.8
Storage	¢/1,000 gal.	2.3	1.6	1.4	1.2	0.9	0.9
Land	¢/1,000 gal.	4.0	3.8	3.6	3.4	3.0	2.8
Crop revenue	¢/1,000 gal.	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)
Total	¢/1,000 gal.	49.8	34.5	29.9	24.9	20.1	18.6

Table 10. COMPONENT COSTS FOR INFILTRATION-PERCOLATION SYSTEMS

Cost component	Unit	Average flow capacity, mgd					
		1	3	5	10	50	70
Effective flow	mgd	1.02	3.05	5.1	10.2	51	71.4
Total area	acres	46	135	220	440	2,100	3,000
Costs							
Pretreatment	¢/1,000 gal.	9.9	6.7	5.7	4.7	3.9	3.5
Pumping	¢/1,000 gal.	6.8	5.0	4.2	3.8	2.9	2.6
Conveyance	¢/1,000 gal.	9.2	4.2	2.8	2.0	1.0	0.7
Application system							
Capital	¢/1,000 gal.	6.8	4.3	3.6	3.0	2.1	2.0
Operation and maintenance	¢/1,000 gal.	6.0	4.4	3.8	3.2	2.2	1.9
Storage	¢/1,000 gal.	0.7	0.5	0.5	0.4	0.3	0.3
Land	¢/1,000 gal.	1.4	1.4	1.4	1.4	1.4	1.4
Total	¢/1,000 gal.	40.8	26.5	22.0	18.5	13.8	12.4

EXAMPLES

The use of the comparative cost curves and the cost tables is illustrated in the following hypothetical examples.

Example No. 1

Requirements. A new regional wastewater treatment facility is to be constructed to provide a flow capacity of 10 mgd and to meet the following effluent quality requirements for surface water discharge:

BOD	- 20 mg/l
SS	- 20 mg/l
Total N	- 3 mg/l
P	- No limit

Alternatives. A review of Table 2, showing the expected effluent quality resulting from various methods of treatment, indicates that three methods of treatment (AWT-2, overland flow, and irrigation) would be possible selections that would achieve the desired degree of treatment. The alternatives considered in this case are described below:

Alternative A - Construct an AWT-2 treatment facility that would provide conventional primary treatment, secondary treatment by activated sludge, and nitrogen removal by biological nitrification-denitrification.

Alternative B1 - Construct headworks and an aerated lagoon as pretreatment for land application. Construct an overland flow system on a site located 3 miles from the pretreatment site. The important site conditions and preliminary design criteria are as follows.

Soil type - clay
Application rate - 6 inches per week
Storage period - 5 weeks
Topography - rolling
Land cost - $1,000 per acre

Alternative B2 - Construct pretreatment facilities as in Alternative B1. Construct an irrigation system on same site as B1. The site conditions are somewhat unfavorable for irrigation and this is reflected in the preliminary design criteria listed below.

Application rate - 1.5 inches per week
Storage period - 10 weeks
Underdrain interval - 100 feet
Tailwater return - 30 percent
Application system - solid set spray
Land cost - $1,000 per acre

Alternative C - Construct pretreatment facilities as in Alternative B. Construct an irrigation system on a site more favorable for irrigation, located 5 miles from the pretreatment site. The important site characteristics and preliminary design criteria are listed below:

Soil type - sandy loam
Topography - flat
Application system - center pivot spray
Application rate - 3 inches per week
Storage period - 10 weeks
Land cost - $3,000 per acre
Underdrain interval - none
Tailwater return - none

Cost Comparison. The total cost of each of the alternatives in cents per thousand gallons is determined in Table 11, using the cited figures and tables.

Table 11. COST COMPARISON FOR EXAMPLE 1

Alternative	Cost component	Cost ¢/1,000 gal.	Source
A	AWT-2	27.0	Figure 1
	Total	27.0	
B1	Overland flow	24.9	Table 9
	Conveyance adjustment	-(2.0)	Table 9
		+1.2	Table 4
	Land cost adjustment	-(3.4)	Table 9
		+(3.4 x 1/2)	Table 9
	Total	22.4	
B2	Irrigation	70.1	Table 8
	Conveyance adjustment	-(4.1)	Table 8
		+2.0	Table 4
	Storage adjustment	-(4.9)	Table 8
		+2.4	Table 7
	Land cost adjustment	-(20.9)	Table 8
		+(20.9 x 1/4)	Table 8
	Total	49.8	
C	Irrigation	14.5	Table 6
	Conveyance adjustment	-(0.4)	Table 6
		+2.0	Table 4
	Storage adjustment	-(0.4)	Table 6
		+2.4	Table 7
	Land cost adjustment	-(2.2)	Table 6
		+(2.2 x 3)	Table 6
	Total	22.5	

Conclusions. The lowest cost alternatives are B1 and C. Since the two alternatives are approximately equal at this level of cost comparison, a more detailed cost estimate and comparison is indicated. One cost component to evaluate carefully is that of crop revenue, since this component represents a substantial reduction in the total cost of Alternative C (see Table 6).

Example No. 2

Requirements. An existing 20-mgd activated sludge plant is required to upgrade its effluent quality to meet the following criteria:

BOD - 10 mg/l

SS - 10 mg/l

N - 3 mg/l

P - 0.5 mg/l

Alternatives. It is evident from a review of Table 2 that the only methods of treatment capable of providing the necessary degree of treatment are AWT-4 and irrigation. In this example, the cost of AWT-4 is compared with that of irrigation under varying conditions of conveyance distance (Case A) and land costs (Case B). Since secondary treatment is existing, activated sludge or aerated lagoon will not be necessary.

Case A - Consider a moderately favorable site for irrigation, a distance of 5 miles away from the existing treatment plant site. How much can be paid for land and have the irrigation system competitive with the AWT-4 system?

Table 12. COST COMPARISON FOR CASE A

Treatment method	Cost component	Cost ¢/1,000 gal.	Source
AWT-4	AWT-4	44.0	Figure 1
	Existing activated sludge adjustment	-(16.0)	Figure 1
	Total	28.0	
Irrigation	Irrigation system	24.0	Figure 1
	Aerated lagoon adjustment	-(4.3)	Figure 1
	Land cost	-(6.7)	Table 7
	Subtotal	13.0	
	Amount available for land = (28.0-13.0)	15.0	
	Total area, acres	4,300	Table 7
	Allowable cost/acre $= \frac{20\text{ mgd }(15¢/1,000\text{ gal.})(10^3)}{(0.0154)\ (4,300\text{ acres})}$	4,500	

Conclusions. Under the assumed site conditions for the irrigation system, as much as $4,500 per acre could be paid for land and have the irrigation system competitive with AWT-4.

Case B - Consider a moderately favorable irrigation site at a cost of $2,000 per acre. How far away from the existing treatment plant could the site be and have the irrigation system competitive with AWT-4?

Table 13. COST COMPARISON FOR CASE B

Treatment method	Cost component	Cost ¢/1,000 gal.	Source
AWT-4	From Case A	28.0	Figure 1
Irrigation	Irrigation system	24.0	Figure 1
	Aerated lagoon adjustment	-(4.3)	Figure 1
	Conveyance cost	-(1.7)	Table 7
	Subtotal	18.0	
	Amount available for conveyance = (28.0 - 18.0)	10.0	--
	Allowable distance, miles	33	Table 4

Conclusions. Under the assumed site conditions for the irrigation system, wastewater could be conveyed as far as 33 miles and have irrigation be competitive with AWT-4. Special conditions such as river or highway crossings and easements may add substantial costs and reduce this distance somewhat.

REFERENCES

1. Pound, C.E., R.W. Crites, and D.A. Griffes. Costs of Wastewater Treatment by Land Application. EPA-430/9-75-003. Office of Water Program Operations, Environmental Protection Agency. June 1975.

2. Van Note, R.H., et al. A Guide to the Selection of Cost-Effective Wastewater Treatment Systems. EPA-430/9-75-002. Office of Water Program Operations, Environmental Protection Agency. July 1975.

3. Reed, S.C., et al. Pretreatment Requirements for Land Application of Wastewaters. (Presented at the Second ASCE National Conference on Environmental Research, Development, and Design. University of Florida. July 20-23, 1975.)

4. Process Design Manual for Sludge Treatment and Disposal. Environmental Protection Agency. EPA-625/1-74-006, October 1974.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978 — 777-066/1112 REGION NO. 8