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THE COST OF LAND APPLICATION OF WASTEWATER: A SIMULATION ANALYSIS
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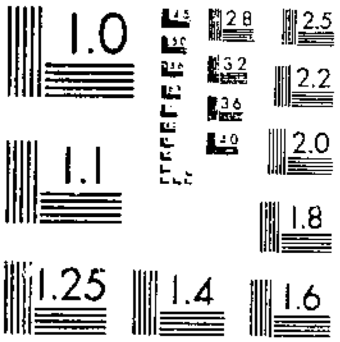

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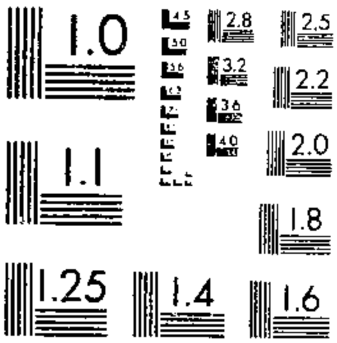

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THE COST OF LAND APPLICATION OF WASTEWATER: A SIMULATION ANALYSIS

C. EDWIN YOUNG

ECONOMIC RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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THE COST OF LAND APPLICATION OF WASTEWATER: A SIMULATION ANALYSIS. C. Edwin Young, Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1555.

ABSTRACT

Land treatment of wastewater is a cost effective method for advanced treatment of municipal sewage. Costs of land treatment of wastewater are analyzed using a computer simulation model. Six alternative techniques for land application are examined. Variations in costs are studied using cost estimates and cost elasticity estimates. Assuming that the soil requirements are met, infiltration basins are the least cost technique for land application. Center pivot irrigation is the least cost irrigation alternative examined. Analysis of treatment economies of size indicates that most of the advantages to increasing facility size have been realized after facility size reaches 10 million gallons per day.

Keywords: Wastewater, Land treatment of wastewater, Costs, Simulation, Cost elasticities, Municipal sewage

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Washington, D.C. 20250 November 1976

CONTENTS

SUMMARY

A computerized model is developed to analyze costs of applying municipal sewage effluent to land. The cost analysis compares six alternative land application technologies: solid-set irrigation, center pivot irrigation, border strip irrigation, ridge and furrow irrigation, overland flow, and infiltration basins. Each technology is assumed capable of providing the required level of waste treatment. The analysis consists of developing a cost model, estimating costs for each technology, and simulating alternative prices and assumptions.

Cost estimates are prepared for each of the six land application technologies. Annual, average, fixed, operating, and farming cost estimates are presented in Appendix tables 1 through 5. Under the assumed price relationships, the least cost irrigation technique is center pivot while solid-set is the most expensive. Border strip and ridge and furrow irrigation are the highest cost options for small facilities (less than 0.5 million gallons per day). Overland flow costs range between center pivot and solid-set irrigation costs, while infiltration basin costs are $0.10/1,000 gallons less than center pivot irrigation costs.

Economies of size are examined for average total costs as well as the components. Most of the advantages to increasing facility size have been realized after facility size reaches 10 MGD (million gallons per day). As facility size increases from 0.5 to 10 MGD, average total costs per unit of volume fall by over 50 percent, while from 10 to 100 MGD they fall by less than 15 percent. Average land costs are relatively constant for all facility sizes. Average labor costs are the only component of average operating costs subject to economies of size and only up to a facility size of 5 MGD. The model assumes that there are no economies of size in the farming operation; therefore, average net crop revenue (alfalfa) equals $0.094/1,000 gallons for the irrigation alternatives and $0.047/1,000 gallons for the overland flow alternative.

The effect of variations in individual assumptions and parameters on costs is analyzed using cost estimates and cost elasticities. The impact of variations in capital subsidies, application rates, storage costs, crop selection, zero-one control variables, effluent recovery costs, and requirements for land surface alterations are analyzed using cost estimates. Cost elasticities are estimated for the design flow, application rate, storage, transmission distance, reserve land, sewer and sewage treatment plant construction costs, land costs, discount rate, discount period, wage rate, materials costs, electric rate, chlorine price, and crop (alfalfa) price. The sewer construction cost index, capital subsidies, design flow, storage, application rate, and crop selection variables have the largest impact on cost variations.

THE COST OF LAND APPLICATION OF WASTEWATER: A SIMULATION ANALYSIS

C. Edwin Young
Agricultural Economist

INTRODUCTION

Land application of sewage effluents is one technique for high level treatment which, under certain conditions, can be the most cost effective alternative. Costs of land application are evaluated in this report using a computerized cost model. Results of the cost analysis and the computer model will be useful to municipal planners, consultants, government agencies, and researchers.

With the passage of the 1972 Amendments to the Federal Water Pollution Control Act (P.L. 92-500), municipalities have two new incentives to consider the use of land application: official encouragement and subsidies. The amendments encourage wastewater treatment which results in the construction of revenue producing facilities providing for (1) recycling of potential sewage pollutants through agricultural and forestry production, (2) reclamation of wastewater, and (3) ultimate disposal of sludges in a manner not harmful to the environment. Also included under the law was a subsidy providing for 75 percent of initial construction costs. The subsidy has a provision to cover land costs for land application systems. Prior to passage of the 1972 Amendments, Federal subsidies were not available for purchasing land, a factor detrimental to land treatment systems (*2*).[1]

Land treatment (or land application) refers to the controlled discharge of partially treated sewage effluents onto land to remove contaminants from the water. The soil and agricultural crops or forests adsorb and filter nitrates, phosphates, organics, and other elements from the effluent. For a complete description of the design and operation of land application systems, see (*6*).

Previous Studies of the Costs of Land Application Systems

For communities to evaluate land application as a treatment alternative, cost information on the components of the system is needed. Ideally, the cost analysis should compare and evaluate alternative technologies for land application. It should also compare land application technologies with alternative wastewater treatment systems.

Few studies on the cost structure of wastewater treatment are available, especially on land treatment. Two studies compared land application with conventional treatment technologies using multiple regression analysis (*14*, *15*). They found that land application costs are less sensitive to factor price increases than are conventional treatment costs. Reserve capacity imposes greater penalties on conventional treatment costs than on land treatment costs.

Several authors present models to analyze land treatment costs. Seitz and Swanson (*11*) developed a model which includes a cost function for land treatment, a cost function for an alternative treatment method, a crop yield function, a damage function for land treatment, and a damage function for alternative treatment techniques. The use of either engineering or statistical cost data in a simulation model for land treatment was discussed by Young and Christensen (*16*). A simulation model can be used to study tradeoffs between the production factors.

Data on system costs are included in four recent studies conducted for the Environmental Protection Agency (EPA). The first provides a general description of the land treatment process (*9*). Cost estimates for 1-MGD (million gallons per day) sprinkler irrigation, overland flow, and infiltration basin facilities are presented. The second reports on a survey of land disposal facilities by the American Public Works Association (*12*). Costs for several of the surveyed communities are presented. A joint study sponsored in cooperation with the Council on Environmental Quality compares the components of costs for alternative tertiary treatment technologies including land application (*3*). The final report by Pound, Crites, and Griffes presents data and a methodology for estimating system costs for applying sewage effluents to land (*10*). Because of the comprehensiveness of its methodology, this report was chosen as the base for developing a cost simulation model. Its methodology,

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[1] Italicized numbers in parentheses refer to references listed on pp. 15-16.

and the development of an expanded simulation model, are discussed in a later section.

Objectives

Objectives of this report are:

1. To develop an operational computer cost model for analysis of alternative techniques for land application of wastewater based on the Pound, Crites, and Griffes (PCG) methodology.
2. To determine which inputs and assumptions have the greatest influence on average and marginal treatment costs.
3. To develop a basic cost model for future economic analyses of land treatment.

The analysis will be divided into three sections. The first will develop and describe a computer model to estimate costs of land application. The second will summarize cost estimates for six land application techniques. The final section will examine the cost structure of the six alternatives by simulating alternative sets of prices and assumptions.

COST OF LAND APPLICATION OF WASTEWATER (CLAW) MODEL

A model capable of predicting system costs under varying assumptions is needed to analyze wastewater treatment costs. This type of model was developed using the 1975 Pound, Crites, and Griffes report as a point of departure (*10*). Development and use of the computer model is described in this section.

Model Development

The computer model developed in this section is based on the Pound, Crites, and Griffes (PCG) stage II detailed planning cost model. The PCG methodology, as illustrated in figure 1, is composed of five basic operations: preapplication treatment, transmission, storage, application systems, and effluent recovery.

The model developed in this report is referred to as Cost of Land Application of Wastewater (CLAW) model. The CLAW model, appearing in Appendix A, is written in Fortran IV. Although based on the PCG methodology, CLAW facilitates cost estimation for a variety of assumptions. A flow diagram illustrating the model is presented as Appendix figure 1.

In developing CLAW, graphically presented data in the PCG model were converted to mathematical equations. The technique for estimating costs based on the figures presented in the PCG model consisted of fitting straight line segments to each of the curves presented. Each curve was divided into a set of linear segment. Since the objective was cost estimation, segment en points were not constrained to particular points. Th variables in the mathematical functions are commo logarithms. For example, the capital cost curve fo aerated lagoons (*10*, fig. 16) was translated into equa tions by dividing it into three segments: $MGD<0.6$ $0.6 \leq MGD<2.0$, and $MGD \geq 2.0$. Respective equation for lagoon capital costs are:

$$C16 = 1.5911 + 0.3129 \times (X1 - 0.6990) \qquad \text{(1}$$
$$C16 = 1.7404 + 0.5371 \times (X1 - 0.2218) \qquad \text{(2}$$
$$C16 = 2.0212 + 0.7209 \times (X1 - 0.3010) \qquad \text{(3}$$

where:

$C16$ = log of capital costs

$X1$ = log MGD

If aerated lagoon pretreatment is selected, estimates fo capital costs are derived from equations 1 through 3 depending on facility design size measured by MGD (mil lion gallons per day). If the design size is a 1-MGD plant, equation 2 will be used. C16 will equal 1.8595 The estimate for construction costs will be the antilog of C16 or $72,000.

The remaining figures in the PCG methodology are tied together in CLAW with a series of assumptions using option control variables. For example, if the option control variable, CLEAR, is set equal to 0, the grass only curve for Field Preparation, figure 24 in the PCG model, is selected. If CLEAR = 1, the site is assumed to be covered with brush and trees. If CLEAR = 2, it implies that the site is heavily wooded.

Use of the PCG model is difficult for individuals not trained in engineering. Engineering relationships such as pipe diameter for effluent transmission and the relationship between peak daily flow and average flow are not specified. Nonengineers generally are not aware of the relationships. Pipe size for effluent transmission is determined as follows in the CLAW model. If the gravity flow option is selected, pipe diameter is determined using the Manning equation. Pipe diameter for the force main option is based on the Hazen-Williams equation.[2] The force main option compares a 50-foot pumping head with a 150-foot pumping head and selects the least cost option. Peak daily flow (PDF) is estimated at 125-percent of average daily flow (MGD) (*4*).

The CLAW model estimates initial costs, annual costs, and average costs ($/1,000 gallons). Initial cost estimates for land and construction can be examined separately. Annual and average cost estimates can be generated for total, operating, capital, labor, materials, power, and net farming costs.

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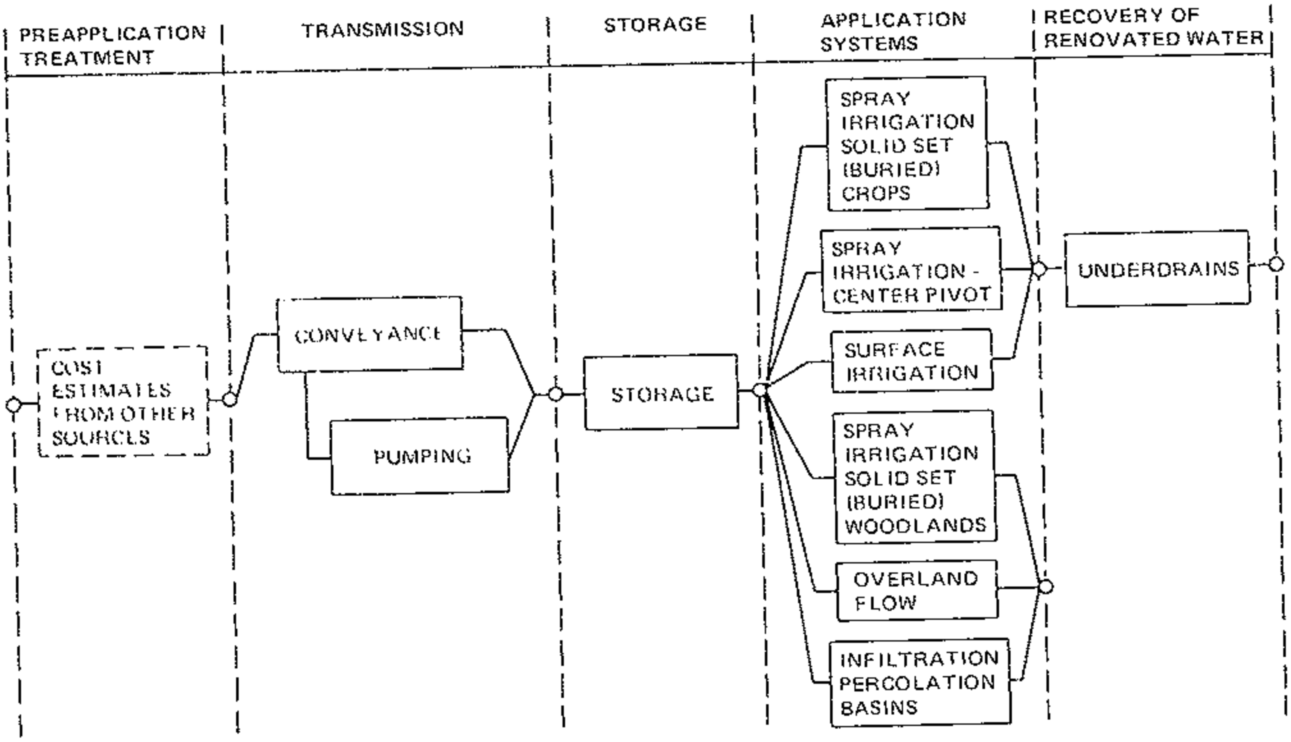
[2] Use of the Manning and the Hazen-Williams equations is described in (*13*).



SOURCE (*10*)

Figure 1. Flow diagram of land treatment options

Three special features of CLAW not found in the PCG model are the ability to analyze alternative pretreatment techniques, storage periods, and levels of construction subsidy.[3] Pretreatment technologies other than lagoon treatment can be used in CLAW. If a pretreatment technique such as trickling filter is used, the annual capital, labor, and materials costs can be substituted for the preliminary treatment and lagoon treatment portions of the CLAW model. This permits examination of land treatment as an extension or a tertiary treatment technique to be used by existing wastewater treatment facilities. Variable periods of storage can be studied.

The CLAW model permits analysis of direct discharge of the partially treated effluent to streams during periods of high dissolved oxygen in streams, such as during the winter. Thus, if a municipality can discharge its wastes directly into the stream for a portion of the year, the estimated costs of land treatment for the remainder of the year can be determined. The inclusion of the subsidy for construction costs facilitates analysis of the impact on community costs of alternative Federal and State subsidy levels. For example, a recent article discusses a proposal to reduce the Federal subsidy for construction costs from 75 to 55 percent (*5*). Additionally, if a State such as Pennsylvania provides an additional 10-percent subsidy for the construction of a treatment facility, this subsidy can be included in the cost estimates. Alternatively, the costs to national taxpayers can be compared to the costs to the local community by comparing alternative subsidized and unsubsidized cost estimates.

The CLAW user must recognize some inherent weaknesses, one of which is the extrapolation of California crop yield and cost of production data to the entire country. It is highly unlikely that agricultural practices and yields in California are realistic estimates for other U.S. regions. Crop yield varies with application rate, climate, and soil type. Agricultural data from land treatment experiences across the nation should be used to supplement the California data.[4] The California values

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[3] The special features of CLAW are examined in detail in the simulation analysis.

[4] It is anticipated that the CLAW model will be extended to incorporate agricultural data from other land treatment experiences.

were incorporated into CLAW to maintain comparability with the PCG model. Variation in net crop revenues will change the cost estimates for each technology, but will not influence relative cost differences between technologies.[5]

A second limitation of CLAW is the assumption that input use does not change as prices change. For a given size and type of facility, such as a 1-MGD center pivot system, the capital-labor ratio is assumed constant regardless of the ratio of relative prices. The cost estimates may be biased upward since lower priced inputs cannot be substituted for higher priced ones. For example, in those areas where labor costs are lower, it may be advantageous to use a laborer to regulate which sprinklers are being used rather than an automated system (substitution of labor for capital).

Use of the Model

The CLAW model is developed so that by specifying a set of 37 price and treatment option parameters, total and average cost estimates can be generated. The user of the model can specify physical relationships such as facility size and the type of land application technology to be used. Six land application technologies are available: solid-set irrigation, center pivot irrigation, border strip irrigation, ridge and furrow irrigation, overland flow, and infiltration basins. The use of options such as chlorination of the effluent prior to applying it to land can be controlled by the user to reflect alternative regulatory constraints. The crop to be grown on the irrigation site can also be varied.

In addition to the physical variables which are necessary for the use of CLAW, different input prices can be used. For example, different wage rates and electricity rates can be used. Different values for the EPA sewer construction cost index can be specified to examine capital costs. Since a land treatment site can be used for several years, two important variables are the local bond rate or discount rate and the discount period.

For a description of the data cards necessary to utilize the CLAW model, see Appendix B, Sec. 1. Names of other variables, given in Appendix B, Sec. 2, are intermediate names which do not need to be fully discussed in this report since they are not needed for using the model. They are presented so that future users of CLAW can modify the computer program.

Use of the CLAW model is uncomplicated. Assume that the values of the variables are those specified in Appendix B, Sec. 1. Costs for constructing and operating a 1 MGD solid-set irrigation facility are illustrated in table 1, an example of a computer printout from the CLAW program. Examination of table 1 reveals that with an application rate of 2 inches per week and 12 weeks of storage, 168 acres will be required for the land treatment system. If the crop grown is alfalfa with a price of $49.00 per ton, an average net crop revenue of $0.09/1,000 gallons is available to offset a portion of the total treatment costs. Average total treatment costs (0.64/1,000 gallons) are the sum of average construction costs ($0.52/1,000 gallons), average land costs ($0.03/1,000 gallons), and average operating costs ($0.18/1,000 gallons) less average net crop revenue ($0.09/1,000 gallons). A second example cost estimate using CLAW is shown in table 2. Assume a 75-percent subsidy for constructing a 5-MGD center pivot irrigation system. The average total cost estimate to the community is $0.11/1,000 gallons. Average capital (construction plus land) costs to the local municipality are $0.08/1,000 gallons with the 75-percent subsidy. Net crop revenue is $0.09/1,000 gallons; average operating costs are $0.12/1,000 gallons.

COST ESTIMATES USING CLAW

The CLAW model can be used to simulate cost estimates for alternative price and technology assumptions. Assuming price and control values specified in Appendix B, Sec. 1, cost estimates for the six land treatment alternatives were generated. Average and annual cost estimates for the six alternatives are presented in Appendix tables 1 through 5. Annual cost estimates are presented in Appendix table 1. Average costs in $/1,000 gallons appear in Appendix table 2. Various components of fixed costs, operating costs, and farming costs are presented in Appendix tables 3, 4, and 5.

Based on assumptions specified earlier, the least cost irrigation alternative for land application is a center pivot system (App. table 2). Sprinkler or solid-set irrigation is the most expensive alternative for facilities larger than 1 MGD. Operating or variable costs are lower for sprinkler irrigation than for the other irrigation alternatives. The solid-set alternative may be the best alternative when labor is difficult to obtain and may provide a higher level of treatment. Solid-set irrigation spreads the effluent more evenly across the treatment site, generally resulting in a higher degree of treatment.

Border strip irrigation and ridge and furrow irrigation are the most expensive options for smaller facilities (less than 0.5 MGD). This result is contrary to expectations. It was anticipated that these technologies would have a higher operating cost component and a lower capital cost component than the other irrigation technologies, thus permitting smaller facilities to substitute lower cost materials for higher cost ones, resulting in lower total costs. This result may be due in part to the use of engineered cost estimates rather than cost estimates based on actual systems. In light of these cost estimates, proposals for border strip and ridge and furrow irrigation should

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[5] [illegible] options [illegible] and [illegible] sensitivity analyses.

Table 1–Estimated costs for a 1-MGD solid-set irrigation facility

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                                        ASSUMPTIONS
AVERAGE FLOW      =      1.00        WEEKS NOT IRRIGATING=     12.0         WEEKS STREAM DIS.   =   0.00
MILES EFF.TRANS. =      2.00        ELEVATION DIFFERENCE=     30.0         PUMP.HEAD EFF.DIST.=     50.
PRICE OF LAND     =     1000.        INTEREST RATE       =   0.0600        DISCOUNT PERIOD     =     20.
WAGE RATE         =      6.00        PRICE OF CHLORINE   =    0.060        PRICE OF ELECT.     =  0.030
SCCI              =    248.70        STPCI               =   232.50        WPI                 =  140.0
APPLICATION RATE =      2.00        ACRES IRRIGATED     =    168.0
FEDERAL SHARE OF CONSTRUCTION COSTS=0.00
LAGOON PRETREATMENT
PRE-APPLICATION CHLORINATION
PUMP HEAD EFF. TRANS.  =  50.        PIPE SIZE           =        9.
SITE CLEARING--BRUSH AND TREES
SOLID SET IRRIGATION
 3.MONITORING WELLS   30.FEET DEEP
CROP=ALFALFA HAY                PRICE OF CROP=   49.00
          ***************************************************************************
                                        SYSTEM COSTS
INITIAL CONSTRUCTION COSTS =    2190011.                      ANNUAL LABOR COSTS      =     37276.
ANNUAL CONSTRUCTION COSTS  =     190936.                      ANNUAL MATERIALS COSTS  =     11323.
AVERAGE CONSTRUCTION COSTS =      0.5231                      ANNUAL ELECTRIC COSTS   =     15300.
INITIAL LAND COSTS         =     190857.                      ANNUAL CHLORINE COSTS   =       900.
ANNUAL LAND COSTS          =      12072.                      ANNUAL OPERATING COSTS  =     64799.
AVERAGE LAND COSTS         =      0.0331                      AVERAGE OPERATING COSTS =    0.1775
INITIAL CAPITAL COSTS      =    2380868.                      ANNUAL FARMING COSTS    =     31706.
ANNUAL CAPITAL COSTS       =     203008.                      ANNUAL CROP REVENUE     =     65865.
AVERAGE CAPITAL COSTS      =      0.5562                      AVERAGE NET CROP REVENUE=    0.0936

ANNUAL TOTAL COSTS         =     233648.                      AVERAGE TOTAL COSTS     =    0.6401
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Table 2 Estimated costs for a 5-MGD center pivot facility with a 75-percent subsidy

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*****************************************************************************************************************
*****************************************************************************************************************
                                                   ASSUMPTIONS
AVERAGE FLOW        =      5.00          WEEKS NOT IRRIGATING=      12.0           WEEKS STREAM DIS.   =   0.00
MILES EFF.TRANS.    =      2.00          ELEVATION DIFFERENCE=      30.0           PUMP.HEAD EFF.DIST.=    50.
PRICE OF LAND       =     1000.          INTEREST RATE       =    0.0600           DISCOUNT PERIOD     =    20.
WAGE RATE           =      6.00          PRICE OF CHLORINE   =     0.060           PRICE OF ELECT.     =  0.030
SCCI                =    248.70          STPCI               =    232.50           WPI                 =  140.0
APPLICATION RATE    =      2.00          ACRES IRRIGATED     =     840.1
FEDERAL SHARE OF CONSTRUCTION COSTS=0.75
LAGOON PRETREATMENT
PRE-APPLICATION CHLORINATION
PUMP HEAD EFF. TRANS.  =  50.            PIPE SIZE           =       16.
SITE CLEARING--BRUSH AND TREES
CENTER PIVOT
 3.MONITORING WELLS   30.FEET DEEP
CROP=ALFALFA HAY                 PRICE OF CROP=   49.00
             ****************************************************************************************************
                                                   SYSTEM COSTS
INITIAL CONSTRUCTION COSTS =    1514224.                            ANNUAL LABOR COSTS       =      111335.
ANNUAL CONSTRUCTION COSTS  =     132018.                            ANNUAL MATERIALS COSTS   =       32590.
AVERAGE CONSTRUCTION COSTS =      0.0723                            ANNUAL ELECTRIC COSTS    =       82801.
INITIAL LAND COSTS         =     235071.                            ANNUAL CHLORINE COSTS    =        4500.
ANNUAL LAND COSTS          =      21335.                            ANNUAL OPERATING COSTS   =      231227.
AVERAGE LAND COSTS         =      0.0117                            AVERAGE OPERATING COSTS  =      0.1267
INITIAL CAPITAL COSTS      =    1749294.                            ANNUAL FARMING COSTS     =      158530.
ANNUAL CAPITAL COSTS       =     153352.                            ANNUAL CROP REVENUE      =      329325.
AVERAGE CAPITAL COSTS      =      0.0840                            AVERAGE NET CROP REVENUE=       0.0936

ANNUAL TOTAL COSTS         =     213784.                            AVERAGE TOTAL COSTS      =      0.1171
*****************************************************************************************************************
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be thoroughly analyzed, since the combination of high costs and a potential uneven effluent distribution may result in a lower level of treatment at a higher cost.

The other two land application techniques, overland flow and infiltration basins, cannot be compared directly with the four irrigation techniques. They require specific soil characteristics and are designed for limited crop production with overland flow and no crop production with infiltration basins. Overland flow requires a relatively impermeable soil while infiltration basins require a permeable soil. Cost estimates for overland flow are between those for the center pivot and the solid-set irrigation alternatives. Cost estimates for infiltration basins are approximately $0.10/1,000 gallons less than the cost estimates for similar sized solid-set irrigation facilities.

Costs of different sized facilities can be compared using Appendix table 2. Examination of average cost ($/1,000 gallons) estimates reveals economies of size relationships for the six alternatives. After facility size reaches approximately 10 MGD, most of the advantages to increasing facility size have been realized. As size increases from 10 MGD to 100 MGD, average operating costs decrease approximately $0.02 to $0.025/1,000 gallons. Average capital costs decrease approximately $0.035 to $0.05/1,000 gallons. The economies of size relationships are quite important. Evaluations of smaller waste treatment facilities should recognize that per unit costs are greater for small systems. If facility size increases from 0.1 MGD to 0.5 MGD, average costs fall by over 70 percent. As facility size increases from 0.5 to 10 MGD, costs fall by over 50 percent. A size increase from 10 MGD to 100 MGD results in less than a 15-percent decrease in per unit costs. The average cost structure can be further analyzed by looking at the average costs of the various components (App. tables 3, 4, and 5).

Average fixed costs are depicted in Appendix table 3. Average land costs are relatively constant for all facility sizes. The small decrease in average land costs from 0.1 to 5 MGD is due to the land requirements for lagoon construction. Smaller lagoons require relatively more perimeter land per unit of wastewater treatment capacity. Cost estimates based on engineering data cannot account for diseconomies of size in acquiring large blocks of land. Larger systems may also require additional land due to variations in topography and soil type. Examination of this type of problem requires data from actual experience to evaluate any impact. Economies of size exist for construction costs, where average costs range from $1.75 to $0.20/1,000 gallons. As facility size increases from 5 MGD, the rate of decrease in average construction costs is slow. From 0.1 to 0.5 MGD, average construction costs fall by more than $1.00/1,000 gallons, and from 0.5 MGD to 5 MGD they fall by more than $0.30/1,000 gallons.

Few economies of size exist for operating costs, especially as facility size exceeds 1 MGD (App. table 4) Average power and chlorine costs are relatively constant for all facility sizes. Average materials costs are generally constant for facilities larger than 1 MGD. Average labor costs decrease quite rapidly from 0.1 to 5 MGD and then level off. Economies of size for labor costs reflect the indivisibility of labor. A 1-MGD facility is necessary to fully utilize a skilled treatment plant operator. For smaller communities (0.1 to 0.5 MGD), the police chief, the city clerk, or some other city official often operates the sewage treatment plant as part of the job. For these individuals to operate the facility adequately, relatively more time per unit of treatment will be required, thus resulting in additional labor costs.

Appendix table 5 shows how crop revenues can offset treatment plant costs. This table is based on growing alfalfa hay at $49 per ton. The average farming costs in Appendix table 5 are approximately $0.09/1,000 gallons for the four irrigation techniques and $0.04/1,000 gallons for the overland flow technique.[6] The farming costs include planting, cultivation, and harvesting. The average revenue from the sale of the crop is presented in the second set of figures. While these values will not completely offset costs of a land application facility, they will significantly reduce net cost of the system. Average revenues are approximately $0.18/1,000 gallons for the irrigation alternatives and $0.09/1,000 gallons for overland flow leaving an average net revenue of $0.09/1,000 gallons for irrigation and $0.05/1,000 gallons for overland flow.

SENSITIVITY ANALYSIS

Components of the cost structure of land treatment technologies were analyzed in the preceding discussion. Effects of individual assumptions and parameters on total costs are analyzed in the following two sections. The first examines changes in average cost estimates as CLAW model assumptions change. Cost elasticities for continuous variables such as wages and electricity rates are estimated in the second section. Several variables such as application rate, storage, and transmission distance are analyzed in both sections.

Cost Variation

The cost structure for wastewater treatment was analyzed by varying assumptions for key variables and

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[6] No crop is grown in conjunction with infiltration basins. The variety of crops that can be used with overland flow is limited by the higher application rate (4 inches/week). It is most likely that a forage crop will be grown.

estimating the changes in operating, capital, and total costs. Variables analyzed in this manner include capital subsidies, application rate, storage costs, transmission distance, crop selection, option control variables,[7] effluent recovery costs, and requirements for alterations in the land surface.

Capital Subsidies

CLAW was used to evaluate the impact of alternative subsidy levels on capital expenditures for solid-set irrigation (App. table 6).[8] The level of subsidy ranges from 0 to 90 percent of all capital expenditures for four facility sizes: 0.5, 1, 5, and 10 MGD. Total costs for a 1-MGD solid-set facility are $0.64/1,000 gallons with no subsidy for capital expenditures. If the current 75-percent Federal subsidy is included, costs to the local municipality are reduced 66 percent to $0.23/1,000 gallons. Total costs for a 10-MGD facility fall by 71 percent. Larger facilities receive a greater percentage reduction in costs from the subsidy than smaller ones since capital costs comprise a larger percentage of the total costs for larger facilities.

Application Rate

One of the most important variables influencing system costs is the rate at which the wastewater is applied to the land, generally measured in acre inches per week. The effect on average costs of varying the application rate from 1 to 4 inches per week for a solid-set irrigation system was estimated (App. table 7). Average total costs, average capital costs, and average operating costs fall as the application rate increases for systems from 0.5 to 10 MGD. Average total costs fall by $0.18/1,000 gallons as the application rate increases from 1 to 4 inches per week. Average operating costs fall by $0.04 to $0.05/1,000 gallons for each of the four facility sizes considered. On the other hand, average capital costs decrease considerably more ($0.20 to $0.30/1,000 gallons of wastewater). Thus average total costs decrease with increases in the application rate due to decreased capital costs.

Average crop revenue falls quite rapidly as the application rate increases from 1 to 4 inches per week. Assuming a constant yield of 8 tons per acre of alfalfa,[9] average net crop revenue is $0.187/1,000 gallons at 1 inch per week and only $0.047/1,000 gallons at 4 inches per week. The decrease in average net revenue is a result of the smaller acreage irrigated at the higher application rate. The high average net crop revenue at low application rates conceivably could offset capital and operating costs. Average total cost estimates in Appendix table 7 show that this does not occur. Average total costs could be lower at lower application rates if average capital costs did not rise as rapidly as they do. Inclusion of capital subsidies (App. table 6) significantly reduces the total costs to the municipality. Therefore, it may be possible for a community with a 75- or 85-percent subsidy for capital expenditures to operate at a lower application rate and have a lower net cost to the community.[10]

Storage

The third planning variable is the length of storage time. Storage facilities may be needed for periods when irrigation is impossible due to heavy rainfall, freezing weather, equipment breakdowns, or power failures. For example, the land application facility at Muskegon, Michigan, can store wastewater for up to 5 months per year for a flow of 30 MGD (*8*).

Storage costs can be a major component of land application costs. In addition to the direct lagoon costs, storage increases application costs, since a larger land area is required during the months that irrigation occurs, holding the application rate constant. The increased land area implies increases in irrigation equipment and maintenance and labor requirements. Estimates of the costs of storing wastewater for up to 25 weeks per year are illustrated in table 3. For a 1-MGD solid-set irrigation system with no storage, the average total costs are $0.45/1,000 gallons. Storage for 20 weeks per year increases costs to almost $0.76/1,000 gallons. Storing wastewater for 20 weeks increases average total treatment costs by $0.31/1,000 gallons.

One alternative to storing the wastewater is to use the stream's assimilative capacity and discharge the effluent to a nearby stream during periods when it cannot be applied to the land. During colder periods of the year, the lower water temperatures increase the dissolved oxygen

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[7] Option control variables refer to variables that control the type of treatment used. Examples are chlorination, type of effluent transmission, site preparation, fencing, monitoring wells, and effluent recovery.

[8] Solid-set irrigation costs are used as examples throughout this bulletin. Many U.S. regions will be limited to using solid-set irrigation due to the physical contour of the land. When physical constraints do not exist, other application techniques should be examined. Although the magnitudes of the cost estimates will vary, the relative cost differences for the other technologies will be similar to those for solid-set irrigation.

[9] Insufficient data are available to determine yield differences associated with different application rates. Preliminary evaluation of the data from The Pennsylvania State University Wastewater Renovation Project indicates that crop yield remains relatively constant as the application rate changes (7).

[10] The renovative ability of a land application system is greater at lower application rates (*8*); therefore, the true social cost of a system may actually be lower at lower application rates.

Table 3—Effluent storage costs for solid-set irrigation assuming a constant application rate

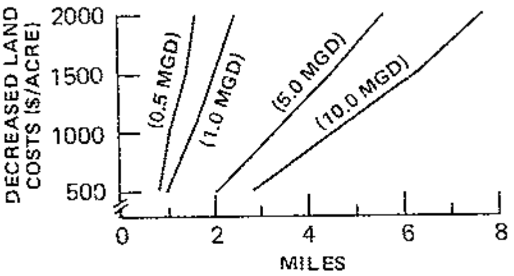
Weeks of storage	Facility size (MGD)			
	0.5	1.0	5.0	10.0
	Dollars per 1,000 gallons			
0	0.6447	0.4537	0.2640	0.2299
5	0.7540	0.5451	0.3343	0.2971
10	0.8291	0.6149	0.4001	0.3630
15	0.9031	0.6858	0.4696	0.4320
20	0.9842	0.7[illegible]	0.5439	0.5058
25	1.0713	0.8403	0.6264	0.5874

capacity of streams; therefore, a given wastewater loading depletes a lower proportion of a stream's dissolved oxygen. Also, stream flow is higher in the winter in many areas since evapotranspiration is generally lower.

The effect on costs of substituting stream discharge of effluent for storage in a land application system was analyzed using data in Appendix table 8. Sullivan et al. reports that Hillsboro, Oregon, uses winter discharge of partially treated effluent in conjunction with a land treatment operation (*12*). If a 1-MGD facility stores its effluent for 20 weeks, the associated costs of storing and treating the wastewater are $0.76/1,000 gallons. If the municipality can discharge its wastewater to a stream for 10 weeks per year, its costs will be reduced to $0.62/1,000 gallons, an 18-percent reduction in total costs. The cost reduction results from a reduction in the size of the storage facility needed and from a reduction in the amount of wastewater applied to the land during the remainder of the year. Stream discharge can impact costs more significantly than crop revenue. For example, the 10 weeks of stream discharge reduces average total costs by $0.14/1,000 gallons compared to $0.09/1,000 gallons for average net crop revenue. The ability of a municipality to discharge its secondary effluent to a stream for part of the year and to use a land application system for tertiary treatment during the remainder of the year needs additional analysis.

Transmission Distance

The impact of transmission distance on average total costs is illustrated in Appendix table 9. Average costs for a 1-MGD facility increase by over $0.03/1,000 gallons if effluent is pumped 3 miles instead of 2. For a 10-MGD facility, they increase less than $0.01/1,000 gallons. There are economies of size associated with pumping costs. For a 10-MGD facility to pump its effluent 10 miles rather than 2, its average costs increase by $0.07/1,000 gallons. An important trade-off is transportation costs compared to land costs. Transport costs, land costs, and facility size can be analyzed using figure 2. For example, a 1-MGD treatment system can pump its wastewater 2 miles in order to obtain a savings in land costs of $1,500 per acre. For the same savings in land costs, a 10-MGD facility can pump its wastes over 6.5 miles, or 4.5 miles farther than the smaller facility. Economies of size in pumping permit larger land treatment facilities to pump their wastes farther than smaller communities for similar savings in average land costs.[11]



MGD = MILLION GALLONS PER DAY
SOURCE: ADAPTED FROM (*7*)

Figure 2. Land Price—Transportation Distance Breakeven Points for Spray Irrigation

Crop Selection

Crop selection significantly influences net costs of a land application system. Distinctions between individual crop renovative abilities are not included in CLAW. The crop revenue estimates are based on the assumption that each crop is capable of providing the desired degree of renovation for a given application rate. Average net revenues have been estimated for the six crops included in CLAW (table 4). Average net revenue is the difference between average revenue and average farming costs. Highest net crop revenues are for alfalfa, corn silage, and grain sorghum (about $0.094/1,000 gallons). Reed canary grass is the least profitable (−$0.045/1,000 gallons). The sale of reed canary grass does not offset the planting and harvesting costs, when it is assumed that reed canary grass has a positive value of $20 per ton.[12]

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[11] Land acquisition is likely to be less critical for smaller facilities. They require smaller contiguous areas of land than larger facilities. Also, smaller communities are most likely to be located in agrarian settings where lower priced land is more likely to be available.

[12] Reed canary grass has inherent advantages for use in land application systems. The renovative ability of reed canary grass is quite high. Reed canary grass is capable of adsorbing large quantities of water without suffering noticeable variations in quality. Therefore, reed canary grass may be an attractive alternative when high land costs necessitate higher application rates.

Table 4—Average net crop revenue from irrigation

Crop	Average net crop revenue
	Dollars per 1,000 gallons
Alfalfa hay	0.0936
Reed canary grass	−0.0454
Barley	0.0596
Corn silage	0.0959
Cotton	0.0263
Grain sorghum	0.0940

Option Control Variables

Treatment and operation variables such as chlorination, site cover, fencing, monitoring, effluent recovery, and excavation are controlled using option control variables. For example, if effluent chlorination occurs prior to application to the land, the chlorination variable (I1) is set equal to zero. The influences of the assumptions are illustrated in Appendix tables 10, 11, and 12. Appendix table 10 deals with changes in the control variables related to solid-set irrigation, but which also apply to the center pivot, overland flow, and infiltration basin systems. Solid-set irrigation is used as an example. Effluent recovery cost estimates from solid-set irrigation and overland flow systems are in Appendix table 11. Land leveling costs for overland flow and for surface irrigation are presented in Appendix table 12.

With the exception of gravity transmission of the effluent and the degree of site clearing, changes in the values of the option control variables exert a minor influence on system costs (App. table 10). Elevation differences determine the use of gravity transmission rather than force main transmission. Gravity transmission can be used only when the elevation of the land application site is lower than where the wastewater originates. In the case of a heavily wooded site, it may be more advantageous to the municipality to irrigate the woodland if average site clearing costs exceed the decrease in average net revenue from fiber production versus crop production.

Recovery of the effluent from land application systems adds significantly to system costs. Construction of underdrains for solid-set irrigation systems can increase costs $0.20 to $0.50/1,000 gallons, while recovery wells add $0.02 to $0.03/1,000 gallons. When overland flow is used, the effluent must be collected after flowing over the land surface since there is little infiltration and percolation. Two alternative collection methods, open ditch and gravity pipe, are compared in Appendix table 11. The cost difference between the two options is approximately $0.01/1,000 gallons for each of the facility sizes considered. Chlorination of overland flow effluent adds $0.02 to $0.04/1,000 gallons to each of the treatment options.

Land treatment options which require land leveling are relatively expensive compared to solid-set or center pivot irrigation systems. If a land application technique requiring surface alterations is chosen, the use of extensive (1,400 cubic yards per acre) excavation versus normal (1,000 cubic yards per acre) excavation has little influence on system costs. Extensive excavation will add less than $0.01/1,000 gallons to average capital costs (App. table 12).

Cost Elasticities

The quantity of data generated in cost simulation of land treatment alternatives requires a summarization method. A cost elasticity, defined as a percentage change in costs divided by a percentage change in an exogeneous variable, is used to summarize the variations. The cost elasticity (E), as defined in equation 4[13], can be used to analyze small variations (less than 25 percent) in an independent variable. A cost elasticity reflects the percentage change in costs associated with a 1-percent increase in the relevant exogeneous variable.

$$E = [(C_2 - C_1) \div C_1] \div [(P_2 - P_1) \div P_1] \qquad (4)$$

where:

E = cost elasticity
P_1 = base value of variable being analyzed
P_2 = second value of variable being analyzed where P_2 = 110% of P_1
C_1 = base cost estimate for a given size of facility
C_2 = cost estimate when the variable to be analyzed rises to P_2

Estimation of a cost elasticity is a two-stage process utilizing CLAW and equation 4. To estimate the total cost-wage rate cost elasticity for a 1-MGD solid-set irrigation system, refer to Appendix table 2 for the base average total cost estimate (C_1 = $0.6432/1,000 gallons). The base wage rate from Appendix B is $6/hour. If wages rise 10 percent (P_2 = $6.60/hour), the average total cost estimate increases to $0.6572/1,000 gallons using the CLAW model. Using equation 4, the estimated cost elasticity is 0.2176. The interpretation of the cost elasticity is that a 1-percent wage increase will cause average total costs to increase by 0.2176 percent or by $0.0014/1,000 gallons.

Cost elasticities were estimated utilizing a cross-classification of 6 land application techniques, 4 cost

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[13] The cost elasticities (equation 4) which are to be estimated abstract from problems associated with estimating arc and point elasticities. Parameter estimates using an arc elasticity formula are significantly different from those using a point elasticity formula. The point elasticity formulation was chosen for simplicity. The bias imposed by the assumption does not affect the results, since relative differences are emphasized rather than absolute differences.

components, and 15 price and control parameters. Changes in 10 of the price and control variables result in changes in capital costs. Eight variables influence operating costs. Changes in four of the variables result in changes in each of the cost components considered: total, operating, capital, and construction costs. One variable, the price of alfalfa, influences only total costs. The impact of variations in the price and control variables on the cost categories are summarized in table 5. The estimated cost elasticities appear as Appendix tables 13 through 28. Examples of the cost elasticities for solid-set irrigation are provided for total costs (table 6), capital costs (table 7), and operating costs (table 8).

Table 5--Interaction of exogeneous design variables on cost components

Variable	Cost component			
	Average operating costs	Average construction costs	Average capital costs	Average total costs
Design flow	X[1]	X	X	X
Application rate	X	X	X	X
Weeks of storage	X	X	X	X
Transmission distance	X	X	X	X
Reserve land			X	X
Sewer construction cost index		X	X	X
Sewage treatment plant cost index		X	X	X
Land costs			X	X
Discount rate		X	X	X
Discount period		X	X	X
Wage rate	X			X
Wholesale price index	X			X
Electric rate	X			X
Chlorine price	X			X
Crop price				X

[1] X indicates the cost component on which the design variable impacts.

The cost elasticity discussion is divided into three sections: variables influencing capital and operating costs, variables influencing capital costs, and variables influencing operating costs. Cost elasticities for solid-set irrigation from tables 6, 7, and 8 are used as examples. The five other application techniques are contrasted to solid-set irrigation. Comparison of the application techniques is not meant to imply that they are substitutes for one another. Physical characteristics of the climate, soil, and topography limit the techniques applicable in a given situation.

Variables Influencing Both Capital and Operating Costs

Each of the major cost components -total, operating, and capital costs- changed with variations in design flow, application rate, weeks of storage, and transmission distance. Increases in the design flow and the application rate decrease costs. A greater number of weeks of storage and longer transmission distances increase costs.

Cost elasticities for changes in the design flow of a system are useful for studying economies of size. A 10-percent increase in design size for a 0.1-MGD solid-set irrigation facility results in a 6-percent decrease in the system's per unit total costs (table 6). Operating costs decrease by about 8 percent (table 8) and capital costs decrease by about 5 percent (table 7) for a 10-percent increase in design size. As facility size increases beyond 5 MGD, advantages of increases in facility size are much lower. For a 10-percent increase in design size, capital costs decrease by 1.4 percent and operating costs by 1.6 percent. The total cost elasticity for a 5-MGD solid-set facility is −0.17. Solid-set irrigation is the least sensitive technology for changes in design flow (App. table 13). Elasticities for overland flow are similar to the solid-set elasticities, while center pivot irrigation and infiltration basin elasticities are 0.02 less than the solid-set elasticities.

The application rate cost elasticities reveal that increases in the application rate cause smaller decreases in average costs for smaller facilities than for larger facilities (5 MGD or greater). The value of the solid-set total cost elasticity falls from −0.06 for a 0.1-MGD facility to −0.25 for a 5-MGD facility to −0.32 for a 100-MGD facility (table 6). Solid-set irrigation is considerably more sensitive to changes in the application rate than the other techniques. The elasticities for overland flow are 20 percent greater than the solid-set elasticities, while the center pivot, border strip, and ridge and furrow elasticities are 40 to 50 percent higher. Infiltration basins are less sensitive to variations in the application rate (E = −0.02 to −0.06).

The number of weeks the system is designed to store wastewater or effluent is a third variable affecting both operating and capital costs. The cost elasticities were estimated assuming that the wastes are stored the entire time with no direct stream discharge. Capital costs are more sensitive to the number of weeks of storage than are operating costs. A 10-percent increase in the number of weeks the wastes are stored for solid-set irrigation will result in about a 0.4-percent to 0.9-percent increase in operating costs (table 8), whereas the same change will result in about a 1.1-percent to 4.3-percent increase in average capital costs (table 7) and a 0.9- to 4.0-percent increase in average total costs (table 6). Cost elasticities for the other technologies are less than the solid-set elasticities for facilities less than 5 MGD and greater for larger facilities (App. table 15).

The distance which the effluent is transmitted from its point of origin to the final disposal site is the remaining variable affecting operating and capital costs. This distance is a minor effect for facilities larger than 5 MGD

Table 6 - Total cost elasticities for solid-set irrigation

Facility size (MGD)	Design flow	Application rate	Weeks of storage	Transmission distance	Reserve land
0.1	−0.6276	−0.0631	0.0896	0.1522	0.0018
0.5	−0.4724	−0.1242	0.1725	0.1195	0.0047
1.0	−0.3632	−0.1600	0.2222	0.0931	0.0062
5.0	−0.1734	−0.2561	0.3211	0.0468	0.0094
10.0	−0.1108	−0.2780	0.3471	0.0498	0.0103
50.0	−0.0657	−0.3133	0.3863	0.0179	0.0117
100.0	−0.0491	−0.3244	0.3992	0.0115	0.0121
	Sewer construction cost index	Sewage treatment plant cost index	Land costs	Discount rate	Discount period
0.1	0.5398	0.2503	0.0159	0.4032	−0.3567
0.5	0.6048	0.1926	0.0391	0.4281	−0.3817
1.0	0.6448	0.1691	0.0514	0.4476	−0.3901
5.0	0.7418	0.1207	0.0758	0.4944	−0.4143
10.0	0.7780	0.1048	0.0826	0.5096	−0.4230
50.0	0.8398	0.0733	0.0934	0.5359	−0.4391
100.0	0.8622	0.0618	0.0965	0.5443	−0.4446
	Wage rate	Wholesale price index	Electric rate	Chlorine price	Alfalfa price
0.1	0.2217	0.0718	0.0434	0.0011	−0.0804
0.5	0.2287	0.1322	0.0488	0.0029	−0.2041
1.0	0.2176	0.1609	0.0652	0.0037	−0.2697
5.0	0.1844	0.2150	0.0981	0.0058	−0.3978
10.0	0.1748	0.2291	0.1074	0.0063	−0.4334
50.0	0.1530	0.2506	0.1220	0.0072	−0.4881
100.0	0.1458	0.2564	0.1262	0.0074	−0.5034

Table 7 - Capital cost elasticities for solid-set irrigation

Facility size (MGD)	Design flow	Application rate	Weeks of storage	Transmission distance	Reserve land
0.1	−0.5487	−0.1002	0.1136	0.1851	0.0022
0.5	−0.4485	−0.2213	0.2200	0.1401	0.0056
1.0	−0.3192	−0.2819	0.2759	0.1055	0.0072
5.0	−0.1379	−0.4109	0.3726	0.0490	0.0100
10.0	−0.0822	−0.4401	0.3950	0.0509	0.0107
50.0	−0.0461	−0.4849	0.4260	0.0175	0.0116
100.0	−0.0325	−0.4984	0.4359	0.0111	0.0118
	Sewer construction cost index	Sewage treatment plant cost index	Land costs	Discount rate	Discount period
0.1	0.6698	0.3105	0.0198	0.5003	−0.3544
0.5	0.7233	0.2303	0.0468	0.5120	−0.4565
1.0	0.7454	0.1986	0.0595	0.5177	−0.4512
5.0	0.7911	0.1288	0.0809	0.5275	−0.4420
10.0	0.8058	0.1090	0.0859	0.5298	−0.4398
50.0	0.8350	0.0729	0.0929	0.5331	−0.4368
100.0	0.8457	0.0606	0.0946	0.5339	−0.4360

Table 8--Operating cost elasticities for solid-set irrigation

Facility size (MGD)	Design flow	Application rate	Weeks of storage	Transmission distance
0.1	–0.7886	–0.0875	0.0360	0.0129
0.5	–0.3849	–0.1401	0.0551	0.0089
1.0	–0.3166	–0.1728	0.0670	0.0065
5.0	–0.1644	–0.2484	0.0884	0.0031
10.0	–0.1209	–0.2619	0.0915	0.0029
50.0	–0.0764	–0.2754	0.0930	0.0010
100.0	–0.0658	–0.2760	0.0921	0.0006

Facility size (MGD)	Wage rate	Wholesale price index	Electric rate	Chlorine price
0.1	0.9112	0.1658	–0.2210	0.0047
0.5	0.7769	0.1748	0.1790	0.0105
1.0	0.6959	0.1712	0.2322	0.0137
5.0	0.5356	0.1612	0.3482	0.0205
10.0	0.4951	0.1557	0.3863	0.0223
50.0	0.4194	0.1479	0.4568	0.0269
100.0	0.3913	0.1457	0.4813	0.0283

(App. table 16). A 10-percent increase in the distance will result in a 0.4- or 0.5-percent increase in average total costs and average capital costs for a 5-MGD solid-set irrigation facility, while average operating costs will increase by about 0.03 percent (tables 6, 7, and 8). Changes in the transmission distance are more important for very small communities (0.1 MGD). Smaller municipalities will probably be able to find acceptable land relatively close to the wastewater source and will not need to pump the effluent long distances.

Variables Influencing Capital Costs

Six variables influence average capital costs in addition to average total costs. These variables are the price of land, the reserve land variable, the sewer construction cost index, the sewage treatment plant cost index, the discount rate, and the discount period. Increases in the price of land, the reserve land variable, the sewer construction cost index, the sewage treatment plant construction cost index, and the discount rate result in cost increases, while an increase in the discount period reduces costs. Variations in the land price and the reserve land variable influence only capital and total costs, while the other four also influence construction costs.

The two land variables, land price and reserve land, have little impact on capital and total costs, regardless of facility size (App. tables 17 and 19). The construction of the reserve land variable abstracts from the effect on different facility sizes of requiring fixed distance barriers. A fixed barrier distance imposes greater costs on smaller facilities. For example, assuming a square application site, the addition of a 100-foot barrier around a 1-MGD facility will require a 15-percent increase in land acreage, while for a 10-MGD facility only 5 percent more land will be required (App. table 18). The land price cost elasticities indicate that for small percentage increases in land costs the impact on system costs is relatively low, assuming initial land costs of $1,000 per acre. A 10-percent increase in land prices will result in a 1-percent increase in average capital costs and average total costs for the irrigation alternatives, while average capital costs and average total costs will rise by 0.5 and 0.1 percent for overland flow and infiltration basins, respectively. These results tend to confirm the findings of Carlson and Young that land prices have a minor impact on the decision to use land treatment (2).

Two reasons for the apparent unimportance of land costs are the assumed land price of $1,000 per acre and the method of annualizing land costs. If a land price of $10,000 per acre is assumed, land costs will increase in importance. The impact of land costs is reduced by the EPA requirement that the salvage value of land equal its present market value for determining annual land costs. Annual land costs become the costs of holding land.[14]

Variations in the sewer construction cost index (SCCI) provide the greatest impact of any variable on system costs. The SCCI shows the effect of changes in pumping and pipe requirements costs. Pumping or pipe installation cost reductions will have the greatest impact on land application facilities. The SCCI cost elasticities

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[14] If land values appreciate over the life of the treatment facility, annual land costs will be reduced. If the rate of appreciation of land prices is greater than the interest cost of holding land, land costs will become land revenues and will offset a portion of treatment costs.

for solid-set irrigation range from 0.54 to 0.86 for average total costs (table 6), from 0.67 to over 0.90 for average construction costs (App. table 20), and from 0.66 to 0.84 for average capital costs (table 7). The SCCI elasticities rise as facility size increases. The average capital cost elasticity for a 0.5-MGD solid-set facility is 0.72, opposed to a value of 0.83 for a 50-MGD facility. Variations in the SCCI have a lower impact on the five other land application technologies. The total cost elasticities range from 0.5 to 0.8 for center pivot irrigation and overland flow, from 0.5 to 0.7 for border strip and ridge and furrow irrigation, and from 0.5 to 0.6 for infiltration basins (App. table 20).

In contrast to the SCCI, the sewage treatment plant construction cost index (STPCI) cost elasticities fall as facility size increases. The components of the STPCI are less important as facility size increases. Cost variations for concrete structures and inplant treatment processes become less important as facility size increases. The solid-set irrigation average total cost elasticities for the STPCI fall from a value of 0.25 for a 0.1-MGD facility to 0.06 for a 100-MGD facility (table 6). The STPCI average total cost elasticities for the five other application technologies are slightly higher than the solid-set elasticities, with the highest being infiltration basins which range from 0.27 to 0.09 (App. table 21). The solid-set average total cost elasticities for the STPCI are lower than those for the SCCI (0.25 to 0.06 versus 0.54 to 0.86), since land application facilities require fewer of the typical factors of production used in conventional sewage treatment.

Estimated cost elasticities for the discount rate and the discount period are relatively constant for all facility sizes. The estimated values for the discount rate average total cost elasticities range from 0.40 to 0.55 for solid-set and center pivot irrigation and from 0.38 to 0.50 for border strip irrigation, ridge and furrow irrigation, and overland flow (App. table 22). The infiltration basin elasticity is 0.36. Variations in the discount period have a lower impact on average total costs. The average total cost elasticities range from 0.35 to 0.44 for solid-set and center pivot irrigation, from 0.33 to 0.39 for border strip and ridge and furrow irrigation, and from 0.35 to 0.41 for overland flow (App. table 23). The infiltration basin elasticity is 0.34. The lower impact of the discount period is in part due to the EPA requirement that salvage value of land equal its present market value for determining annual land costs. This regulation implies that the annual cost of land equals the present market value times the interest rate.[15] The discount period does not influence annual land costs.

Variables Influencing Operating Costs

Cost elasticities for operating costs are influenced by four price variables: the wage rate, the wholesale price index or the cost of materials, the electric rate, and the price of chlorine. The wage rate cost elasticities decrease as facility size increases, while the electric rate, wholesale price index, and chlorine price elasticities rise as facility size increases (App. tables 24, 25, 26, and 27).

Cost elasticity estimates indicate that wage variations provide the greatest impact on operating costs. The importance of wage variations declines as facility size increases. For smaller solid-set facilities (less than 1 MGD), a 10-percent increase in wage costs will result in more than a 7-percent increase in operating costs and a 2.2-percent increase in total costs (tables 6 and 8). As facility size increases, the impact of a 10-percent increase in wage rates falls to approximately a 4-percent increase in operating costs and a 1.4-percent increase in average total costs for a 100-MGD facility. The three other irrigation techniques are more sensitive to wage variations than solid-set irrigation. Total cost elasticities for center pivot irrigation range from 0.26 to 0.19, while the ridge and furrow elasticities range from 0.29 to 0.24 and the border strip elasticities are practically constant at 0.28 (App. table 24). Overland flow and infiltration basins are less sensitive, ranging from 0.21 to 0.10 and from 0.15 to 0.05, respectively.

The cost elasticities for materials costs (wholesale price index) fall slightly for average operating costs and rise for average total costs (App. table 25). The solid-set operating cost elasticities range from 0.17 to 0.15 (table 8), while the total cost elasticities rise from 0.07 for a 1-MGD facility to 0.23 for a 10-MGD facility and remains relatively constant for larger facilities (table 6). The total cost elasticities for the other three irrigation techniques are slightly higher, ranging from 0.07 to 0.33 (App. table 25). The overland flow total cost elasticities are lower, ranging from 0.06 to 0.15, while infiltration basin elasticities which are much lower fall from 0.04 to 0.03.

Operating costs include the wages and materials costs which are associated with pretreatment and with the operation of the treatment side of the land application facility. The operating costs associated with crop

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[15] $LV = LC - LC(1+i)^{-n}$ (a)

where:
LV = land value to be discounted
LC = cost of purchasing land
$(1+i)^{-n}$ = standard formula for determining the present value of an amount in n years at i
i = interest rate
n = discount period

$A = LC[1-(1+i)^{-n}]\frac{i}{[1-(1+i)^{-n}]}$ (b)

where: A = annual land cost
$\frac{i}{[1-(1+i)^{-n}]}$ Standard formula for determining the annualized value of amount in the current time period.

$A = LC\,i$ (c)

management are not included in operating cost estimates, but are accounted for in net crop revenues, thereby influencing total costs. The effect of variations of treatment plant labor and materials on average total costs can be studied by holding farming costs constant and changing the labor and materials associated with the treatment operation. The last rows in Appendix tables 24 and 25 illustrate the effect of the variations on average total costs. The rate of decrease in the total cost elasticities for wages is approximately the same as when farm wages vary, but the values of the total cost elasticities are about 0.06 less, except for the infiltration basin where they are the same. The average total cost elasticities holding farm material costs constant are relatively constant at [illegible]. Comparing this [illegible] to the materials average total cost elasticities in Appendix table 25, it can be concluded that variations [illegible] have a larger impact on farming cost[illegible]

The investment coefficients for the electrical [illegible] increase. For the 100 MGD solid-set [illegible] percent increase in the electric [illegible] increase in average [illegible] percent increase [illegible] MGD [illegible] variations [illegible] application [illegible] total cost elasticities [illegible] the elasticities of the total [illegible] (App. table 26).

Changes in the price of chlorine have a relatively small impact on [illegible] and total costs as indicated by the [illegible] cost elasticities (App. table 27). [illegible] chlorine price changes are [illegible] application facilities. It may [illegible] advanced wastewater prior [illegible] of chlorine supply will [illegible] of chlorine.

Cost elasticities for the price of the crop (alfalfa) were [illegible] average total cost. Average [illegible] the CLAW model through the average total cost equation. Average total costs equal average operating costs plus average capital costs less average crop revenue. Changes in crop revenue are important for larger facilities (over 5 MGD), where a 10-percent increase in the alfalfa price will result in a 4-percent decrease in average total costs for solid-set irrigation (App. table 28). Changes in the alfalfa price are [illegible] center pivot irrigation, surface [illegible] furrow irrigation than for solid-set [illegible]. For [illegible] MGD [illegible] the values of the cost elasticities are -0.47, -0.45 and -0.44, respectively (App. table 28). For overland flow, changes [illegible] are less important since relatively less land [illegible] is limited to forage [illegible] less crop revenue to offset the costs of the land application system. Changes in the alfalfa price do not affect average total costs for infiltration basins since no crop is grown in conjunction with an infiltration basin.

FUTURE RESEARCH USING CLAW

An objective of this analysis is to develop a basic cost model for future economic analysis of land treatment. Anticipated extensions and uses of the CLAW model include:

1. A comparison of land treatment facilities with other advanced treatment technologies.
2. The use of land treatment to upgrade existing secondary treatment facilities.
3. Development of an extensive farming model to include crop yields and farm management systems for various regions of the United States.
4. Inclusion of traveling guns and movable pipe irrigation systems in CLAW.
5. Analysis of alternatives to winter storage of effluent such as irrigation of woodlands and stream discharge of secondary effluent.
6. Comparison of alternative subsidy levels, crop yields, and prices to determine if crop revenue can offset operating costs and unsubsidized capital cost.
7. Analysis of land acquisition and lease arrangements to determine when a farmer will accept wastewater irrigation on his land.
8. Analysis of the impact of health constraints (such as barrier distances, chlorination, underdrains, and not spraying during rainfall) on facility design and costs.

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APPENDIX A
CLAW Program

```
      REAL M16,L16,LPRE,MPRE,L17,M17,L18,M18,M20,M21,L21,LI22,M22,L22,
     1L27,M27,L28,M28,P29,L29,M29,L30,M30,L31,M31,L32,M32,L33,M33,L34,I5
     2,M1,L35,M35,L36,M36,L37,M37,L38,M38,L39,M39,M40,L40,M41S,M41F,PS,
     3MGD,RAP,PCHL,PPOW,PLAND,M34,EL,PS1
      INTEGER  COVER, CLEAR
      READ(5,202) K
202   FORMAT(I5)
      DO 300 I=1,K
      READ(5,200)  MGD,SUB,TRANS,SCCI,STPCI,WPI,WAGE,PCHL,PPOW  ,RATE,
     1ACRE2,R,PLAND,YR,WEEK1,WEEK2,WELLS
200   FORMAT(13F5.2,4F2.0)
      READ(5,201)  IRRI,I1,I2,COVER,CLEAR,I3,I4,I6,ELDIF,HEAD2,WD, UNDER
     1,I5,EARTH,CROP,SCROP,A1,A2,A3
201   FORMAT(8I1,5F3.0,F4.0,F2.0,F6.2,3F10.0)
      WRITE(6,100)
100   FORMAT('2',132('*'))
      WRITE(6,138)
138   FORMAT(' ',132('*'))
      WRITE(6,101)
101   FORMAT(' ',T59,'ASSUMPTIONS')
      WRITE(6,102) MGD,WEEK1,WEEK2
102   FORMAT(' ','AVERAGE FLOW      =',F9.2,T40,'WEEKS NOT IRRIGATING=',
     1F9.1,T80,'WEEKS STREAM DIS.  =',F7.2)
      WRITE(6,104) TRANS,ELDIF,HEAD2
104   FORMAT(' ','MILES EFF.TRANS. =',F9.2,T40,'ELEVATION DIFFERENCE=',
     1F9.1,T80,'PUMP.HEAD EFF.DIST.=',F7.0       )
      WRITE(6,133) PLAND,R,YR
133   FORMAT(' ','PRICE OF LAND     =' ,F9.0,T40,'INTEREST RATE        =',
     1F9.4, T80,'DISCOUNT PERIOD     =',F7.0)
      WRITE(6,134) WAGE,PCHL,PPOW
134   FORMAT(' ','WAGE RATE         =' ,F9.2,T40,'PRICE OF CHLORINE   =',
     1F9.2,T80,'PRICE OF ELECT.     =',F7.3)
      WRITE(6,135) SCCI,STPCI,WPI
135   FORMAT(' ','SCCI              =' ,F9.2,T40,'STPCI                =',
     1F9.2,T80,'WPI                 =',F7.1)
      RAF=MGD*52/(52-WEEK1)
      X1=ALOG10(MGD)
      X6=ALOG10(RAP)
      ACRE=(MGD*1000000*(365- 7*WEEK2))/(52-WEEK1)/(27154*RATE)
      WRITE(6,103) RATE,ACRE
103   FORMAT(' ','APPLICATION RATE =',F9.2,T40,'ACRES IRRIGATED      =',
     1F9.1)
      WRITE(6,1000) SUB
1000  FORMAT(' ','FEDERAL SHARE OF CONSTRUCTION COSTS=',F4.2)
      R16=0
      CHL17=0
      M17=0
      L17=0
      C17=0
      PDF=1.25*MGD
      X3=ALOG10(PDF)
      IF(A1.GT.0.OR.A2.GT.0.OR.A3.GT.0) GO TO 19
      WRITE(6,105)
105   FORMAT(' ','LAGOON PRETREATMENT')
                                       CPRE=1.6021+0.6215*(X3 -0.3010)
      IF(MGD.LT.8.0)                   MPRE=3.1139+0.3145*(X1 )
      IF(MGD.GE.8.0.AND.MGD.LT.10.0)  MPRE=3.3979+0.6651*(X1 -0.9031)
      IF(MGD.GE.10.0.AND.MGD.LT.16.0) MPRE=3.4624+0.6842*(X1 -1.0000)
```

```
      IF(MGD.GE.16.0.AND.MGD.LT.20.0) MPRF=3.6021+0.7227*(X1 -1.2041)
      IF(MGD.GE.20.0)                  MPRF=3.6721+1.0262*(X1 -1.3010)
      IF(MGD.LT.2.0)                    HCURB=2.7782+0.3219*(X1 )
      IF(MGD.GE.2.0.AND.MGD.LT.3.0)     HCURB=2.8751+0.4497*(X1 -0.3010)
      IF(MGD.GE.3.0.AND.MGD.LT.6.0)     HCURB=2.9542+0.5850*(X1 -0.4771)
      IF(MGD.GE.6.0)                   HCURB=3.1303+0.8136*(X1 -0.7782)
      IF(MGD.LT.2.0)                   HCURM=2.5315+0.2701*(X1 )
      IF(MGD.GE.2.0.AND.MGD.LT.4.0)     HCURM=2.6123+0.3704*(X1 -0.3010)
      IF(MGD.GE.4.0.AND.MGD.LT.6.0)     HCURM=2.7243+0.5781*(X1 -0.6021)
      IF(MGD.GE.6.0.AND.MGD.LT.9.0)     HCURM=2.8261+0.6442*(X1 -0.7782)
      IF(MGD.GE.9.0)                   HCURM=2.9395+0.7694*(X1 -0.9542)
      SA= 1.429*MGD
      X9=ALOG10(SA)
      IF(SA.LT.4) A[illegible] (X9)
      IF(SA.GE.4.AND.SA.LT.20) ACRB=1.0414+0.6635*(X9-0.6021)
      IF(SA.GE.20.AND.SA.LT.80) ACRB=1.6097+0.8671*(X9-1.3010)
      IF(SA.GE.80) ACRB=[illegible]*(X9-1.9031)
      A[illegible](ACRB)
      HCRF=[illegible]*(10.**(HCURB)+ 10.**(HCURM))
      IF(MGD.LT.0.6)C16=[illegible]*(X1+0.6990)
      IF(MGD.GE.0.6.AND.MGD.LT.2.0)C16=1.7404+0.5371*(X1+0.2218)
      IF(MGD.GE.2.0)                  C16=2.0212+0.7209*(X1-0.3010)
      IF(MGD.LT.2.0)                  L16=4.1139-0.6826*(X1+0.6990)
      IF(MGD.GE.2.0)                  L16=3.4314-0.5782*(X1-0.3010)
      IF(MGD.LT.1.0)                  M16=2.9542-0.5030*(X1+0.6990)
      IF(MGD.GE.1.0)                  M16=2.6021-0.4670*(X1)
      [illegible]
      IF(IT.GT.0) GO TO 11
      WRITE(6,13[illegible])
1[illegible] FORMAT(' ','[illegible] CHLORINATION')
      IF(MGD.LT.1.0)                  C17=1.2788+0.3430*(X1+0.6990)
      IF(MGD.GE.1.0.AND.MGD.LT.4.0)C17=1.5185+0.4778*(X1)
      IF(MGD.GE.4.0)                  C17=1.8062+0.5233*(X1-0.6021)
      IF(MGD.LT.2.0)                  L17=3.5911-0.5304*(X1+0.6990)
      IF(MGD.GE.2.0)                  L17=3.0697-0.4174*(X1-0.3010)
      IF(MGD.LT.0.8)                  M17=3.3222-0.5646*(X1+0.6990)
      IF(MGD.GE.0.8.AND.MGD.LT.3.0)M17=2.9823-0.4935*(X1+0.0969)
      IF(MGD.GE.3.0)                  M17=2.6990-0.4279*(X1-0.4771)
      C17=10.**(C17)
      L17=10.**(L17)
      M17=10.**(M17)
      CHL17=MGD*750.0
11    A1=10.**CPRF + 10.**(C16) + C17
      A2=LPRF + 10.**(L16)*MGD+L17*MGD
      A3=10.**MPRF + 10.**(M16)*MGD + M17*MGD
10    IF(IT.EQ.1) GO TO 12
      S=ELDIF/(TRANS*5280)
      D=4*((MGD/(2396.39*(S**0.5)))**0.375)
      PS=FLOAT(IFIX(D*12)+1)
      X2=ALOG10(PS)
      IF(COVER.EQ.9) GO TO 13
      WRITE(6,139) PS
139   FORMAT(' ','COVER                    =          5',T40,'PIPE SIZE
     1=',F6.0)
      IF(PS.LT.10.0)                   C18  =0.7924+0.6257*(X2-0.6021)
      IF(PS.GE.10.0.AND.PS.LT.20.0)C18  =1.0414+0.8625*(X2-1.0000)
      IF(PS.GE.20)                     C18  =1.3010+1.0090*(X2-1.3010)
      GO TO 14
13    IF(PS.LT.10.0)                   C18  =0.8573+0.6448*(X2-0.6021)
      WRITE(6,140)  PS
```

```
140   FORMAT(' ','COVER                    =          9',T40,'PIPE SIZE
     1=',F9.2)
      IF(PS.GE.10.0.AND.PS.LT.20.0)C18  =1.1139+0.8231*(X2-1.0000)
      IF(PS.GE.20.0)                C18  =1.3617+1.0464*(X2-1.3010)
14    IF(PS.LT.7.0)                 M18=0.4150+0.2852*(X2-0.6021)
      IF(PS.GE.7.0.AND.PS.LT.10.0)  M18=0.4343+0.5416*(X2-0.8451)
      IF(PS.GE.10.0.AND.PS.LT.20.0)M18=0.5682+0.6485*(X2-1.0000)
      IF(PS.GE.20.0)                M18=0.7634+0.8808*(X2-1.3010)
      IF(PS.LT.7.0)                 L18=0.3010+0.1703 * (X2-0.6021)
      IF(PS.GE.7.0.AND.PS.LT.10.0)  L18=0.3424+0.4684 * (X2-0.8451)
      IF(PS.GE.10.0.AND.PS.LT.20.0)L18=0.4150+0.5850 * (X2-1.0000)
      IF(PS.GE.20.0)                L18=0.5911+0.7565 * (X2-1.3010)
      IF(PS.LT.6.0)                 C20R=0.3222
      IF(PS.GE.6.0.AND.PS.LT.10.0)  C20R=0.3222+0.3412 * (X2-0.7782)
      IF(PS.GE.10.0)                C20R=0.3979+0.4398 * (X2-1.0000)
      C18=(10.**(C18))*5280*TRANS +(10.**(C20R))*475*TRANS
      M18=(10.**(M18))*52.8*TRANS
      L18=(10.**(L18))*52.8*TRANS
      P21=0.0
      GO TO 15
13    IF(CLIFF.GT.45) CL=10.* 12.
      C21=3.2788-0.4160*(XL)
      M21=2.3974-0.0570*(XL +0.2218)
      IF(CLIFF.GE.45) GO TO 19
      D=4*(MGD/(3963.75*(((150-ELDIF)/(TRANS*5280))**0.54)))**0.380228
      PS=FLOAT(IFIX(D*12)+1)
      P21=PS
      X2=ALOG10(PS)
      IF(PS.LT.6.0)                 C20=0.8451+0.5146 * (X2-0.4771)
      IF(PS.GE.6.0.AND.PS.LT.10.0)  C20=1.0000+0.6587 * (X2-0.7782)
      IF(PS.GE.10.0.AND.PS.LT.20.0)C20=1.1461+1.0000  *(X2-1.0000)
      IF(PS.GE.20.0)                C20=1.4472+1.0628  *(X2-1.3010)
      IF(PS.LT.9.0)                 M20=0.3010+0.5094  *(X2-0.4771)
      IF(PS.GE.9.0)                 M20=0.5441+0.7844  *(X2-0.9542)
      P1=2100*MGD
      IF(PDF.LT.0.8)                         C21=1.8573+0.1689*(X3 +0.6990)
      IF(PDF.GE.0.8.AND.PDF.LT.2.0)          C21=1.9590+0.3893*(X3 +0.0969)
      IF(PDF.GE.2.0.AND.PDF.LT.7.0)          C21=2.1139+0.4200*(X3 -0.3010)
      IF(PDF.GE.7.0.AND.PDF.LT.20.0)         C21=2.3424+0.6602*(X3 -0.8451)
      IF(PDF.GE.20.0)                     C21=2.6434+0.7695*(X3 -1.3010)
      IF(PS.LT.6.0)                 C20R=0.3222
      IF(PS.GE.6.0.AND.PS.LT.10.0)  C20R=0.3222+0.3413 * (X2-0.7782)
      IF(PS.GE.10.0)                C20R=0.3979+0.4298 * (X2-1.0000)
      CC1=((10.**(C20))*TRANS*5280+(10.**(C21))*1000 +(10.**(C20R))*
     1475*TRANS)
      M1=(10.**(M20))*52.8*TRANS +(10.**(M21))*MGD
      C1=M1 *WPT/100+CC1*(R/(1-(1+R)**(-YC)))*SCCI/194.2+P1 *PPOW/0.02
19    D=4*(MGD/(3963.75*(((150-ELDIF)/(TRANS*5280))**0.54)))**0.380228
      PS=FLOAT(IFIX(D*12)+1)
      X2=ALOG10(PS)
      IF(PS.LT.6.0)                 C20=0.8451+0.5146 * (X2-0.4771)
      IF(PS.GE.6.0.AND.PS.LT.10.0)  C20=1.0000+0.6587 * (X2-0.7782)
      IF(PS.GE.10.0.AND.PS.LT.20.0)C20=1.1461+1.0000  *(X2-1.0000)
      IF(PS.GE.20.0)                C20=1.4472+1.0628  *(X2-1.3010)
      IF(PS.LT.9.0)                 M20=0.3010+0.5094  *(X2-0.4771)
      IF(PS.GE.9.0)                 M20=0.5441+0.7844  *(X2-0.9542)
      P21=6200*MGD
      IF(PDF.LT.0.8)                         C21=1.9031+0.1962*(X3 +0.6990)
      IF(PDF.GE.0.8.AND.PDF.LT.2.0)          C21=2.0212+0.3140*(X3 +0.0969)
      IF(PDF.GE.2.0.AND.PDF.LT.7.0)          C21=2.1461+0.5243*(X3 -0.3010)
```

```
      IF(PDE.GE.7.0.AND.PDE.LT.20.0)     C21=2.4314+0.6777*(X3 -0.8451)
      IF(PDE.GE.20.0)                    C21=2.7404+0.8009*(X3 -1.3010)
      IF(PS.LT.5.0)                 C20R=0.3222
      IF(PS.GE.5.0.AND.PS.LT.10.0)  C20R=0.3222+0.3413 * (X2-0.7782)
      IF(PS.GE.10.0)                C20R=0.3979+0.4398 * (X2-1.0000)
      C18=(10.**(C20))*TRANS*5280+(10.**(C21))*1000 +(10.**(C20R))*
     1475*TRANS
      M18=(10.**(M20))*52.8*TRANS +(10.**(M21))*MGD
      C2=M18*WPT/120+C18*(R/(1-(1+R)**(-YR)))*SCCI/194.2+P21*PPOW/0.02
      HEAD1=150.
      IF(C2.LT.C1)  GO TO 16
      HEAD1=50.
      C18=CC1
      M18=M1
      P21=P1
      PS=PS1
16    L18=(10.**(L21))*MGD
      WRITE(6,29) HEAD1,PS
29    FORMAT(' ','PUMP HEAD EFF. TRANS.  =',F5.0, T40,'PIPE SIZE
     1   =',F9.0)
15    PPW=3700.0*TRANS
      SC=  (FLOAT(IFIX(TRANS))+1.0)*6000.0
      FP22=0
      RC22=0
      LI22=0
      L22=0
      M22=0
      IF((WEEK1-WEEK2).LE.0)  GO TO 18
      SV = (WEEK1-WEEK2)*7*MGD
      X4=ALOG10(SV)
      IF(SV.LT.10.0)                      FP22=0.7324+0.4979*(X4+0.3010)
      IF(SV.GE.10.0.AND.SV.LT.50.0)       FP22=1.3802+0.5039*(X4-1.0000)
      IF(SV.GE.50.0.AND.SV.LT.300.0)      FP22=1.7324+0.7071*(X4-1.6990)
      IF(SV.GE.300.0)                     FP22=2.2788+0.7789*(X4-2.4771)
      IF(SV.LT.10.0)                      RC22=0.3010+0.5886*(X4+0.6990)
      IF(SV.GE.10.0.AND.SV.LT.50.0)       RC22=1.3010+0.6285*(X4-1.0000)
      IF(SV.GE.50.0)                      RC22=1.7404+0.8357*(X4-1.6990)
      IF(SV.LT.10.0)                      LI22=0.1761+0.7742*(X4+0.6990)
      IF(SV.GE.10.0.AND.SV.LT.200.0)      LI22=1.4914+0.9146*(X4-1.0000)
      IF(SV.GE.200.0)                     LI22=2.6812+1.0525*(X4-2.3010)
      IF(SV.LT.10.0)                      L22=2.6021-0.6538*(X4+0.6990)
      IF(SV.GE.10.0)                      L22=1.4914-0.6451*(X4-1.0000)
      IF(SV.LT.5.0)                       M22=2.4771-0.5973*(X4+1.0000)
      IF(SV.GE.5.0.AND.SV.LT.10.0)        M22=1.4624-0.3344*(X4-0.6990)
      IF(SV.GE.10.0.AND.SV.LT.60.0)       M22=1.3424-0.2138*(X4-1.0000)
      IF(SV.GE.60.0)                      M22=1.1761-0.1639*(X4-1.7782)
      LI22=10.**LI22
      RC22=10.**RC22
      FP22=10.**FP22
      L22=(10.** (L22))*SV
      M22=(10.** (M22))*SV
18    X5=ALOG10(ACRE)
      IF(CLEAR.EQ.0)                      C24=-0.6990+0.8413*(X5  -1.3010)
      IF(CLEAR.EQ.0)  WRITE(6,107)
107   FORMAT(' ','SITE CLEARING--GRASS')
      IF (CLEAR.EQ.1)                     C24=1.4771+0.8964*(X5  -1.7782)
      IF(CLEAR.EQ.1)  WRITE(6,108)
108   FORMAT(' ','SITE CLEARING--BRUSH AND TREES')
      IF(CLEAR.EQ.2)                      C24=1.9542+1.0000*(X5  -1.7782)
      IF(CLEAR.EQ.2)  WRITE(6,109 )
```

```
109   FORMAT(' ','SITE CLEARING--HEAVILY WOODED')
      IF(IRRI.GT.2) GO TO 30
      IF(IRRI.EQ.2) GO TO 21
      WRITE(6,110)
110   FORMAT(' ','SOLID SET IRRIGATION')
      IF(ACRE.LT.30.0)                      C27=1.6335+0.7380*(X5  -1.3010)
      IF(ACRE.GE.30.0.AND.ACRE.LT.70.0)     C27=1.7634+0.8581*(X5  -1.4771)
      IF(ACRE.GE.70.0.AND.ACRE.LT.200.0)    C27=2.0792+0.9343*(X5  -1.8451)
      IF(ACRE.GE.200.0)                     C27=2.5052+1.0393*(X5  -2.3010)
      IF(ACRE.LT.40.0)                      L27=2.1139-0.5305*(X5  -1.3010)
      IF(ACRE.GE.40.0.AND.ACRE.LT.100.0)    L27=1.9542-0.3221*(X5  -1.6021)
      IF(ACRE.GE.100.0.AND.ACRE.LT.300.0)L27=1.8261-0.2134*(X5  -2.0000)
      IF(ACRE.GE.300.0)                     L27=1.7243-0.0827*(X5  -2.4771)
      IF(ACRE.LT.200.0)                     M27=1.0792-0.1068*(X5  -1.4771)
      IF(ACRE.GE.200.0)                     M27=0.9912-0.0253*(X5  -2.3010)
      BP=0
      GO TO 22
21    IF(ACRE.LT.40.0)                      C28=1.3010+0.5260*(X5  -1.3010)
      IF(ACRE.GE.40.0.AND.ACRE.LT.100.0)    C28=1.4624+0.6161*(X5  -1.6021)
      IF(ACRE.GE.100.0.AND.ACRE.LT.300.0)C28=1.7076+0.9192*(X5  -2.0000)
      IF(ACRE.GE.300.0)                     C28=2.1461+1.0893*(X5  -2.4771)
      WRITE(6,111)
111   FORMAT(' ','CENTER PIVOT')
      IF(ACRE.LT.30.0)                      L28=2.3010-0.7095*(X5  -1.3010)
      IF(ACRE.GE.30.0.AND.ACRE.LT.90.0)     L28=2.1761-0.4650*(X5  -1.4771)
      IF(ACRE.GE.90.0.AND.ACRE.LT.200.0)    L28=1.9542-0.2622*(X5  -1.9542)
      IF(ACRE.GE.200.0)                     L28=1.8633-0.1503*(X5  -2.3010)
      IF(ACRE.LT.30.0)                      M28=1.1139-0.5267*(X5  -1.3010)
      IF(ACRE.GE.30.0.AND.ACRE.LT.70.0)     M28=1.0212-0.3209*(X5  -1.4771)
      IF(ACRE.GE.70.0.AND.ACRE.LT.200.0)    M28=0.9031-0.1272*(X5  -1.8451)
      IF(ACRE.GE.200.0)                     M28=0.8451-0.0453*(X5  -2.3010)
      IF(ACRE.LT.50.0)                      P28=0.8573-0.1990*(X5  -1.3010)
      IF(ACRE.GE.50.0.AND.ACRE.LT.300.0)    P28=0.7782-0.1018*(X5  -1.6990)
      IF(ACRE.GE.300.0)                     P28=0.6990
      C27=C28
      L27=L28
      M27=M28
      BP=(10.**P28)*ACRE
22    C34=0
      L34=0
      M34=0
      IF(UNDER.EQ.0) GO TO 25
      IF(UNDER.EQ.400) GO TO 23
      IF(ACRE.LT.100.0)                     C34=1.3424+0.9408*(X5  -1.3010)
      IF(ACRE.GE.100.0)                     C34=2.0000+1.0000*(X5  -2.0000)
      IF(ACRE.LT.100.0)                     M34=1.8261-0.2336*(X5  -1.3010)
      IF(ACRE.GE.100.0)                     M34=1.6628-0.1683*(X5  -2.0000)
      IF(ACRE.LT.50.0)                      L34=1.6812-0.7565*(X5  -1.3010)
      IF(ACRE.GE.50.0.AND.ACRE.LT.200.0)L34=1.3802-0.4423*(X5  -1.6990)
      IF(ACRE.GE.200.0)                     L34=1.1139-0.3465*(X5  -2.3010)
      GO TO 24
23    IF(ACRE.LT.200.0)                     C34=1.0000+0.5981*(X5  -1.0000)
      IF(ACRE.GE.200.0)                     C34=1.7782+0.9566*(X5  -2.3010)
      IF(ACRE.LT.100.0)                     M34=1.7243-0.4669*(X5  -1.3010)
      IF(ACRE.GE.100.0)                     M34=1.3979-0.3451*(X5  -2.0000)
      IF(ACRE.LT.60.0)                      L34=1.3010-0.7268*(X5  -1.3010)
      IF(ACRE.GE.60.0.AND.ACRE.LT.200.0)L34=0.9542-0.4887*(X5  -1.7782)
      IF(ACRE.GE.200.0)                     L34=0.6990-0.3740*(X5  -2.3010)
24    C34=10.** (C34)
      L34=10.** (L34)    *ACRE
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      M34=10.** (M34)     *ACRE
 25   BC=C34+ 10.** (C27)
      BL=L34 + 10.** (L27)*ACRE
      BM= M34 + 10.** (M27)*ACRE
      BCHL=0
      GO TO 70
 30   IF(IERT.GT.4) GO TO 4)
      REWAT=0.2*MGD
      X7=ALOG10(REWAT)
      IF(REWAT.LT.0.1)                          C35=1.2304+0.1312*(X7   +1.6990)
      IF(REWAT.GE.0.1.AND.REWAT.LT.0.4) C35=1.3222+0.2809*(X7   +1.0000)
      IF(REWAT.GE.0.4.AND.REWAT.LT.1.0) C35=1.4914+0.3571*(X7   +0.3979)
      IF(REWAT.GE.1.0.AND.REWAT.LT.2.0) C35=1.6335+0.5279*(X7   -0.0000)
      IF(REWAT.GE.2.0)                          C35=1.7924+0.7414*(X7   -0.3010)
      IF(REWAT.LT.0.07)                         L35=3.5911-0.7627*(X7   +1.6990)
      IF(REWAT.GE.0.07.AND.REWAT.LT.0.4)L35=3.1761-0.6078*(X7   +1.1549)
      IF(REWAT.GE.0.4)                          L35=2.7160-0.5119*(X7   +0.3979)
      IF(REWAT.LT.0.1)                          M35=3.1761-0.5693*(X7   +1.6990)
      IF(REWAT.GE.0.1.AND.REWAT.LT.1.5) M35=2.7782-0.4103*(X7   +1.0000)
      IF(REWAT.GE.0.5)                          M35=2.4914-0.3199*(X7   +0.3010)
      IF(REWAT.LT.0.07)                         P35=2.9494+0.1544*(X7   +1.6990)
      IF(REWAT.GE.0.07.AND.REWAT.LT.0.4)P35=3.0334+0.0604*(X7   +1.1549)
      IF(REWAT.GE.0.4)                          P35=3.0792
      IF (EARTH.EQ.759) GO TO 31
      IF(ACRE.LT.80.0)                          C25=0.8451+0.7925*(X5  -1.3010)
      IF(ACRE.GE.80.0.AND.ACRE.LT.300.0)C25=1.3222+0.9322*(X5  -1.9031)
      IF(ACRE.GE.300.0)                         C25=1.8573+1.0158*(X5  -2.4771)
      GO TO 32
 31   IF(ACRE.LT.80.0)                          C25=1.0000+0.8390*(X5  -1.3010)
      IF(ACRE.GE.80.0.AND.ACRE.LT.300.0)C25=1.5952+0.9342*(X5  -1.9031)
      IF(ACRE.GE.300.0)                         C25=2.0414+0.9916*(X5  -2.4771)
 32   IF(IERT.EQ.4)GO TO  33
      WRITE(6,112)
112   FORMAT(' ','SURFACE FLOODING')
      IF(ACRE.LT.80.0)                           C29=0.9345+0.6088*(X5  -1.3010)
      IF(ACRE.GE.80.0.AND.ACRE.LT.200.0) C29=1.3010+0.7565*(X5  -1.9040)
      IF(ACRE.GE.200.0)                          C29=1.6021+0.9327*(X5  -2.3010)
      IF(ACRE.LT.100.0)                          L29=2.5315-0.5514*(X5  -1.3010)
      IF(ACRE.GE.100.0.AND.ACRE.LT.300.0)L29=2.1461-0.3063*(X5  -2.0000)
      IF(ACRE.GE.300.0.AND.ACRE.LT.1000.0)L29=2.0000-0.1548*(X5-2.4771)
      IF(ACRE.GE.1000.0) L29=1.9191
      IF(ACRE.LT.100.0) M29=1.1461-0.1498*( 5  -1.3010)
      IF(ACRE.GE.100.0)  M29=1.0414-0.0513*(X5  -2.0000)
      GO TO 34
 33   IF(ACRE.LT.200.0) C30=0.8573+0.7659*(X5  -1.3010)
      IF(ACRE.GE.200.0) C30=1.6232+0.9391*(X5  -2.3010)
      WRITE(6,113)
113   FORMAT(' ','RIDGE AND FURROW')
      IF(ACRE.LT.30.0)                         L30=2.5315-0.5685*(X5  -1.3010)
      IF(ACRE.GE.30.0.AND.ACRE.LT.80.0) L30=2.4314-0.4134*(X5  -1.4771)
      IF(ACRE.GE.80.0.AND.ACRE.LT.200.0)L30=2.2553-0.3552*(X5  -1.9031)
      IF(ACRE.GE.200.0)                        L30=2.1139-0.1621*(X5  -2.3010)
      IF(ACRE.LT.60.0)                         M30=1.3222-0.1403*(X5  -1.3010)
      IF(ACRE.GE.60.0.AND.ACRE.LT.300.0)M30=1.2553-0.1133*(X5  -1.7782)
      IF(ACRE.GE.300.0)                        M30=1.1761
      C29=C30
      L29=L30
      M29=M30
 34   BC= 10.** (C35) + 10.** (C25) + 10.** (C29)
      BL=(10.**(L35))*MGD + (10.**(L29))*ACRE
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      RM=(10.**(M35))*MGD + (10.**(M29))*ACRE
      RP=(10.**(P35))*MGD
      RCHL=0
      GO TO 70
40    IF(IDST.EQ.6) GO TO 50
      IF (EARTH.EQ. 1400) GO TO 41
      IF(ACRE.LT.100.0)                      C26   =1.2041+0.8212*(X5-1.3010)
      IF(ACRE.GE.100.0)                      C26   =1.7782+0.9764*(X5-2.0000)
      GO TO 42
41    IF(ACRE.LT.100.0)                      C26   =1.3222+0.8310*(X5-1.3010)
      IF(ACRE.GE.100.0)                      C26   =1.9031+0.9744*(X5-2.0000)
42    IF(ACRE.LT.60.0)                      C31=1.3222+0.8427*(X5   -1.3010)
      IF(ACRE.GT.60.0.AND.ACRE.LT.200.0)C31=1.7243+1.0604*(X5   -1.7782)
      IF(ACRE.GE.200.0)                     C31=2.2788+1.1205*(X5   -2.3010)
      WRITE(6,114)
114   FORMAT(' ','OVERLAND FLOW')
      IF(ACRE.LT.40.0)                       L31=2.0000-0.5146*(X5   -1.3010)
      IF(ACRE.GT.40.0.AND.ACRE.LT.80.0) L31=1.8451-0.2964*(X5   -1.6021)
      IF(ACRE.GT.80.0.AND.ACRE.LT.200.0)L31=1.7559-0.1876*(X5   -1.9031)
      IF(ACRE.GT.200.0)                     L31=1.6812-0.1235*(X5   -2.3010)
      IF(ACRE.LT.70.0)                       M31=0.8451-0.2686*(X5   -1.3010)
      IF(ACRE.GT.70.0.AND.ACRE.LT.200.0)M31=0.6990-0.1218*(X5   -1.8451)
      IF(ACRE.GT.200.0)                     M31=0.6434-0.0317*(X5   -2.3010)
      IF(I3.EQ.1) GO TO 43
                                              C36=1.5315+0.9654*(X5   -1.6021)
      IF(ACRE.LT.100.0)                       L36=0.6532-0.5221*(X5   -1.4771)
      IF(ACRE.GT.100.0.AND.ACRE.LT.600.0)L36=0.3802-0.3868*(X5   -2.0000)
      IF(ACRE.GT.600.0)                      L36=0.0792-0.2820*(X5   -2.7782)
      IF(ACRE.LT.100.0)                      M36=0.6021-0.3046*(X5   -1.3010)
      IF(ACRE.GT.100.0.AND.ACRE.LT.300.0)M36=0.3892-0.1847*(X5   -2.0000)
      IF(ACRE.GT.300.0)                      M36=0.3010-0.0627*(X5   -2.4771)
      GO TO 44
43    IF(ACRE.LT.100.0)                      C36=0.8751+0.6812*(X5   -1.6021)
      IF(ACRE.GT.100.0.AND.ACRE.LT.400.0)C36=1.1461+0.7925*(X5   -2.0000)
      IF(ACRE.GT.400.0)                      C36=1.6232+0.9301*(X5   -2.6021)
      IF(ACRE.LT.100.0)                      M36=1.5315-0.4407*(X5   -1.4771)
      IF(ACRE.GT.100.0.AND.ACRE.LT.400.0)M36=1.3010-0.2573*(X5   -2.0000)
      IF(ACRE.GT.400.0.AND.ACRE.LT.2000.0)M36=1.1461-0.0460*(X5-2.6021)
      IF(ACRE.GT.2000.0)                    M36=1.1139
      IF(ACRE.LT.60.0)                      L36=1.3010-0.7370*(X5   -1.4771)
      IF(ACRE.GT.60.0.AND.ACRE.LT.200.0)L36=1.0792-0.4477*(X5   -1.7782)
      IF(ACRE.GT.200.0)                     L36=0.8451-0.3802*(X5   -2.3010)
44    C37=0
      L37=0
      M37=0
      CHL37=0
      IF(I4.EQ.1) GO TO 45
      REWAT= 0.75*MGD
      X7=ALOG10(REWAT)
      IF(REWAT.LT.3.0)                       C37=1.4472+0.4449*(X7    +0.5229)
      IF(REWAT.GE.3.0)                       C37=1.8921+0.5070*(X7    -0.4771)
      IF(REWAT.LT.2.0)                       L37=3.4914-0.5003*(X7    +0.5229)
      IF(REWAT.GE.2.0)                       L37=3.0792-0.4446*(X7    -0.3010)
      IF(REWAT.LT.0.8)                       M37=3.3424-0.6058*(X7    +0.6990)
      IF(REWAT.GT.0.8.AND.REWAT.LT.3.0)  M37=2.9777-0.5165*(X7    +0.0969)
      IF(REWAT.GE.3.0)                       M37=2.6812-0.4490*(X7    -0.4771)
                                             CHL37=2.8751

      C37= 10.**  (C37)
      L37=10.** (L37)
      M37=10.** (M37)
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45     BC=C37+ 10.** (C36) + 10.** (C31) + 10.** (C26)
       BL=L37*MGD +(10.** (L36))*ACRE + (10.**(L31))*ACRE
       BM=M37*MGD +(10.** (M36))*ACRE + (10.**(M31))*ACRE
       BCHL=CHL27*MGD
       BP=0
       GO TO 70
50     IF(ACRE.LT.6.0)                      C32=1.0414+0.5886*(X5  -0.3010)
       IF(ACRE.GE.6.0.AND.ACRE.LT.30.0)     C32=1.3222+0.7909*(X5  -0.7782)
       IF(ACRE.GE.30.0)                     C32=1.8751+0.9138*(X5  -1.4771)
       WRITE(6,116)
116    FORMAT(' ','INFILTRATION BASINS')
       IF(ACRE.LT.7.0)                      L32=2.6990-0.3816*(X5  -0.3010)
       IF(ACRE.GE.7.0.AND.ACRE.LT.40.0)     L32=2.4914-0.2514*(X5  -0.8451)
       IF(ACRE.GE.40.0)                     L32=2.3010-0.2089*(X5  -1.6021)
       IF(ACRE.LT.5.0)                      M32=2.1139-0.7565*(X5  -0.3010)
       IF(ACRE.GE.5.0.AND.ACRE.LT.10.0)     M32=1.8129-0.3785*(X5  -0.6990)
       IF(ACRE.GE.10.0.AND.ACRE.LT.40.0)    M32=1.6990-0.2997*(X5  -1.0000)
       IF(ACRE.GE.40.0)                     M32=1.5185-0.1354*(X5  -1.6021)
       BC=10.** (C32)
       BL=(10.** (L32))*ACRE
       BM=(10.** (M32))*ACRE
       BP=0
       BCHL=0
70                                          L33=3.3010-0.4006*(X1 +0.0458)
                                            M33=2.4624-0.0701*(X1 +0.6990)
       IF(HEAD2.EQ.150) GO TO 71
       IF(PAR.LT.0.6)                       C33  =1.6812+0.2330*(X6 +0.6990)
       IF(PAR.GE.0.6.AND.PAR.LT.2.0)        C33  =1.7924+0.3544*(X6 +0.2218)
       IF(PAR.GE.2.0.AND.PAR.LT.8.0)        C33  =1.9777+0.5370*(X6 -0.3010)
       IF(PAR.GE.8.0)                       C33  =2.3010+0.7859*(X6 -0.9031)
       P33=2100 *MGD
       IF(HEAD2.EQ.15) P33=630 *MGD
       GO TO 72
71     IF(PAR.LT.0.6)                       C33  =1.7076+0.2882*(X6 +0.6990)
       IF(PAR.GE.0.6.AND.PAR.LT.2.0)        C33  =1.8451+0.4123*(X6 +0.2218)
       IF(PAR.GE.2.0.AND.PAR.LT.8.0)        C33  =2.0607+0.5307*(X6 -0.3010)
       IF(PAR.GE.8.0)                       C33  =2.3802+0.8449*(X6 -0.9031)
       P33=6200 *MGD
72     P38=0
       C38=0
       L38=0
       M38=0
       IF(IPRI.EQ.5.OR.I5.EQ.0) GO TO 80
       REWAT=0.5*MGD
       IF(IPRI.EQ.6)  REWAT=0.75*MGD
       X7=ALOG10(REWAT)
                                          L38=3.3010-0.4363*(X7    )
                                          M38=2.3979-0.0605*(X7    )
       IF(I5.EQ.50)  GO TO 73
       WRITE(6,117)
117    FORMAT(' ','100 FT. RECOVERY WELLS')
       IF(REWAT.LT.3.0)                    C38=1.0414+0.2038*(X7   +1.0000)
       IF(REWAT.GE.3.0.AND.REWAT.LT.6.0) C38=1.3424+0.4475*(X7   -0.4771)
       IF(REWAT.GE.6.0.AND.REWAT.LT.10.0)C38=1.4771+0.6587*(X7   -0.7782)
       IF(REWAT.GE.10.0.AND.REWAT.LT.20.0)C38=1.6232+0.7975*(X7-1.0000)
       IF(REWAT.GE.20.0)                    C38=1.8633+0.9618*(X7-1.3010)
       P38=4100 *MGD
       GO TO 74
73     IF(REWAT.LT.3.0)                     C38=0.8663+0.2405*(X7+0.6990)
       IF(REWAT.GE.3.0.AND.REWAT.LT.6.0)  C38=1.1461+0.4406*(X7-0.4771)
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      IF(REWAT.GE.6.0.AND.REWAT.LT.10.0) C38=1.2788+0.7591*(X7-0.7782)
      IF(REWAT.GE.10.0.AND.REWAT.LT.20.0)C38=1.4472+0.7776*(X7-1.0000)
      IF(REWAT.GE.20.0)                  C38=1.6812+0.9744*(X7   -1.3010)
      WRITE(6,118)
118   FORMAT(' ','50 FT. RECOVERY WELLS')
      P38=2100  *MGD
74    C38=10.** (C38)
      L38=(10.**(L38))*MGD
      M38=(10.**(M38))*MGD
80    IF(MGD.LT.0.4)                     C39=1.60206
      IF(MGD.GE.0.4.AND.MGD.LT.0.8)  C39=1.6021+0.2630*(X1 +0.3979)
      IF(MGD.GE.0.8.AND.MGD.LT.2.0)  C39=1.6812+0.2968*(X1   +0.0969)
      IF(MGD.GE.2.0.AND.MGD.LT.6.0)  C39=1.7993+0.5073*(X1   -0.3010)
      IF(MGD.GE.6.0)                     C39=2.0414+0.6244*(X1   -0.7782)
      IF(MGD.LT.6.0)                     L39=4.1461-0.5721*(X1 +0.6990)
      IF(MGD.GE.6.0.AND.MGD.LT.40.0) L39=3.3010-0.5170*(X1 -0.7782)
      IF(MGD.GE.40.0)                    L39=2.8751-0.4475*(X1 -1.6021)
      IF(MGD.LT.5.0)                     M39=3.4771-0.4811*(X1 +0.3979)
      IF(MGD.GE.5.0.AND.MGD.LT.30.0) M39=2.9494-0.4464*(X1 -0.6990)
      IF(MGD.GE.30.0)                    M39=2.6021-0.2599*(X1 -1.4771)
      ACR1=ACRE + ACRE3 + ACRE2*ACRE
      IF(ACR1.LT.100.0)                       C41S=0.9731+0.6078*(X5-1.3010)
      IF(ACR1.GE.100.0)                       C41S=1.3979+0.8139*(X5-2.0000)
      IF(ACR1.LT.70.0)                        M41S=1.2553-0.3931*(X5-1.3010)
      IF(ACR1.GE.70.0.AND.ACR1.LT.200.0) M41S=1.0414-0.3033*(X5-1.8451)
      IF(ACR1.GE.200.0.AND.ACR1.LT.700.0)M41S=0.9031-0.1658*(X5-2.3010)
      IF(ACR1.GE.700.0)                       M41S=0.8129-0.0778*(X5-2.8451)
      IF(ACR1.LT.100.0)                       C41S=1.0414+0.4583*(X5-1.3010)
      WCC40=0
      L40=0
      M40=0
      IF(WELLS.EQ.0) GO TO 82
      X8=ALOG10(WD)
      WRITE(6,120) WELLS,WD
120   FORMAT(' ',F3.0,'MONITORING WELLS',F6.0,'FEET DEEP')
      IF(WD .LT.40.0)                    M40=1.1761+0.5525*(X8-1.3010)
      IF(WD .GE.40.0)                    M40=1.3424+0.6992*(X8-1.6021)
      IF(WD.LT.40.0)                         C40=2.7708+0.4393*(X8-1.3010)
      IF(WD.GE.40.0.AND.WD.LT.90.0)          C40=2.9031+0.5987*(X8-1.6021)
      IF(WD.GE.90.0)                         C40=3.1139+0.7737*(X8-1.9542)
      IF(WD.LT.40.0)                         L40=1.9031
      IF(WD.GE.40.0.AND.WD.LT.70.0)          L40=1.9031+0.3071*(X8-1.6021)
      IF(WD.GE.70.0)                         L40=1.9777+0.3999*(X8-1.8451)
      L40=(10.**(L40))*WELLS
      M40=(10.**(M40))*WELLS
      WCC40=(10.**(C40))*WELLS
82    C41F=0
      M41F=0
      IF(I6.EQ.0) GO TO 81
      WRITE(6,119)
119   FORMAT(' ','FENCING ')
      IF(ACR1.GE.100.0)                      C41F=1.3617+0.5282*(X5-2.0000)
      IF(ACR1.LT.80.0)                       M41F=0.6532-0.5498*(X5-1.3010)
      IF(ACR1.GE.80.0)                       M41F=0.3222-0.4507*(X5-1.9031)
      C41F= 10.** (C41F)
      M41F=(10.**M41F) *ACRE
81    REV=0
      $FARM=0
      IF(IPRI.EQ.6)  GO TO 99
      IF(CROP.EQ.0) GO TO 99
```
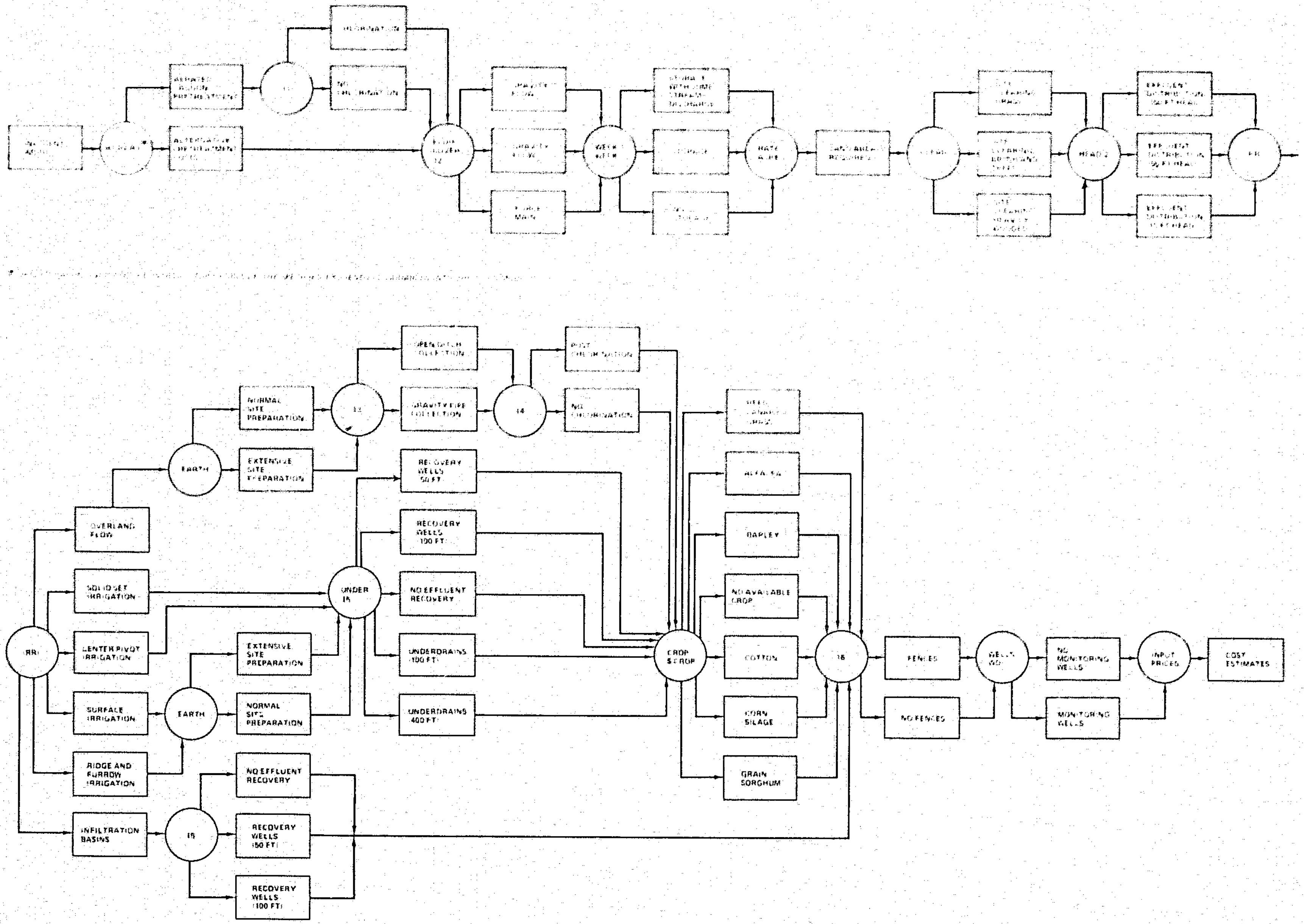

```
      IF(CROP.GT.1) GO TO 302
      REV=8*ACRE*$CROP
      $FARM=(76*WAGE/5 + 135*WPI/120) *ACRE
      WRITE(6,311) $CROP
311   FORMAT(' ','CROP=ALFALFA HAY                           PRICE OF CROP=',F8.2)
      GO TO 60
302   IF(CROP.GT.2) GO TO 303
      REV=4.5*ACRE*$CROP
      $FARM=(76*WAGE/5 + 135*WPI/120) *ACRE
      WRITE(6,312) $CROP
312   FORMAT(' ','CROP=REED CANARY GRASS                           PRICE OF CROP=',F8.2)
      GO TO 60
303   IF(CROP.GT.3) GO TO 304
      REV=50*ACRE*$CROP
      $FARM=([illegible]*WAGE/5 + 76*WPI/120) *ACRE
      WRITE(6,313) $CROP
313   FORMAT(' ','CROP=BARLEY                          PRICE OF CROP=',F8.2)
      GO TO 60
304   IF(CROP.GT.4) GO TO 305
      REV=35*ACRE*$CROP
      $FARM=(32*WAGE/5 + 112*WPI/120) *ACRE
      WRITE(6,314) $CROP
314   FORMAT(' ','CROP=CORN SILAGE                         PRICE OF CROP=',F8.2)
      GO TO 60
305   IF(CROP.GT.5) GO TO 306
      REV=[illegible]*ACRE*$CROP
      $FARM=(46*WAGE/5 + 224*WPI/120) *ACRE
      WRITE(6,315) $CROP
315   FORMAT(' ','CROP=COTTON LINT                         PRICE OF CROP=',F8.2)
      GO TO 60
306   REV=65*ACRE*$CROP
      $FARM=(26*WAGE/5 + 83*WPI/120) *ACRE
      WRITE(6,316) $CROP
316   FORMAT(' ','CROP=GRAIN SORGHUM                    PRICE OF CROP=',F8.2)
60    CAPR=(C1+10.** (C33)+C34+10.** (C39))*STPCI*1000/177.5
      CAPS=((C13        +BCW+SC  )+1000*(CP22+BC22+L122+10.**(C24)+BC+
     110.** (C41S)+C41F))*SCCI/194.2 +WCC40*SCCI/194.2
      $CAP=(CAPR + CAPS) * 1.30 * (1 - SUB)
      $LAB=(A2+L18+L22+BL+(10.** L33)*MGD+L38+(10.** L39)*MGD)*(WAGE/5)
     1+L40*WAGE/5
      $MAT=(A3+M18+M22+BM+(10.** M33)*MGD+M38+(10.** M39)*MGD+(10.** M41
     1S)*ACRE+M41F       )*(WPI /120)    +M40*WPI/120
      $POW=(P21+BP+P33+P38)*(PPOW/0.02)   +P16*(PPOW/0.02)
      $CHL=(CHL17+BCHL)*(PCHL/0.05)
      $OPER=$LAB+$MAT+$POW+$CHL
      $REV=REV-$FARM
      AVCRP=(REV-$FARM)/(365000*MGD)
      AVOP=$OPER/(365000*MGD)
      $LAND=ACRE1*PLAND*(1 - SUB)
      ANLAN=(ACRE1*R*(1-SUB)+(ACRE3+ACRE2*ACRE)*(R/(1-(1+R)**(-YR))))*
     1PLAND
      AVLAN=ANLAN/(365000*MGD)
      ANCAP= $CAP*R/(1-(1+R)**(-YR))
      AVCAP=ANCAP/(365000*MGD)
      TOTAL=$CAP+$LAND
      AN=ANLAN+ANCAP
      AV=AVCAP+AVLAN
      ANTOT=AN+$OPER-$REV
      AVTOT=AVCAP+AVLAN+AVOP -AVCRP
      WRITE(6,121)
```

```
121    FORMAT(' ',T16,100('*'))
        WRITE(6,122)
122    FORMAT(' ',T50,'SYSTEM COSTS ')
        WRITE(6,123) $CAP,$LAB
123    FORMAT(' ','INITIAL CONSTRUCTION COSTS =',F12.0,T70,'ANNUAL LABOR
      1COSTS          =',F12.0)
        WRITE(6,124) ANCAP,$MAT
124    FORMAT(' ','ANNUAL CONSTRUCTION COSTS  =',F12.0,T70,'ANNUAL MATERI
      1ALS COSTS   =',F12.0)
        WRITE(6,125) AVCAP,$POW
125    FORMAT(' ','AVERAGE CONSTRUCTION COSTS =',F12.4,T70,'ANNUAL ELECTR
      1IC COSTS    =',F12.0)
        WRITE(6,126)$LAND,$CHL
126    FORMAT(' ','INITIAL LAND COSTS         =',F12.0,T70,'ANNUAL CHLORI
      1NE COSTS    =',F12.0)
        WRITE(6,127) ANLAN,$OPER
127    FORMAT(' ','ANNUAL LAND COSTS          =',F12.0,T70,'ANNUAL OPERAT
      1ING COSTS   =',F12.0)
        WRITE(6,128) AVLAN,AVOP
128    FORMAT(' ','AVERAGE LAND COSTS         =',F12.4,T70,'AVERAGE OPERA
      1TING COSTS =',F12.4)
        WRITE(6,129) TOTAL,$FARM
129    FORMAT(' ','INITIAL CAPITAL COSTS      =',F12.0,T70,'ANNUAL FARMIN
      1G COSTS     =',F12.0)
        WRITE(6,130) AN,REV
130    FORMAT(' ','ANNUAL CAPITAL COSTS       =',F12.0,T70,'ANNUAL CROP R
      1EVENUE      =',F12.0)
        WRITE(6,131) AV,AVCRP
131    FORMAT(' ','AVERAGE CAPITAL COSTS      =',F12.4,T70,'AVERAGE NET C
      1ROP REVENUE=',F12.4)
        WRITE(6,132) ANTOT,AVTOT
132    FORMAT('0','ANNUAL TOTAL COSTS         =',F12.0,T70,'AVERAGE TOTAL
      1 COSTS       =',F12.4)
        WRITE(6,137)
137    FORMAT(' ',132('*'))
        WRITE(6,136)
136    FORMAT(' ',132('*'))
        A1=0.0
        A2=0.0
        A3=0.0
300    CONTINUE
        STOP
        END
```



Appendix Figure 1. Flow diagram of the CLAW model.

APPENDIX B

Variable Names

1. Data Cards

Card 1, col. 1-5 K = Number of subruns

Card 2, col. 1-5 MGD = Average flow of wastewater (1.0)[1]

col. 6-10 SUB = Amount of Federal subsidy available for capital expenditures (0.00)

col. 11-15 TRANS = Distance in miles that effluent is transported (2.0)

col. 16-20 SCCI = Sewer construction cost index (248.7)

col. 21-25 STPCI = Sewage treatment plant construction cost index (232.5)

col. 26-30 WPI = Wholesale price index (140)

col. 31-35 WAGE = Wage rate ($6.00/hr.)

col. 36-40 PCHL = Price of chlorine ($0.06/lb.)

col. 41-45 PPOW = Price of electricity (0.03/kwh)

col. 46-50 RATE = Application rate (2 in./wk.)

col. 51-55 ACRE 2 = Proportionate amount of land to be set aside for future expansion. (Ex ACRE 2 = .10 implies that 10% more land is obtained)

col. 56-60 R = Interest rate (0.06)

col. 61-65 PLAND = Price of land (1000)

col. 66-67 YR = Discounting period (20)

col. 68-69 WEEK 1 = Number of weeks wastes are not applied to land (12)

col. 70-71 WEEK 2 = Number of weeks wastes are discharged to streams (0)

col. 72-73 WELLS = Number of monitoring wells (3)

Card 3, col. 1 IRRI = Irrigation technique used

= 1 Solid-set irrigation

= 2 Center pivot irrigation

= 3 Surface flooding

= 4 Ridge and furrow irrigation

= 5 Overland flow

= 6 Infiltration basins

col. 2 II = 0 Chlorination of lagoon effluent (10, fig. 17) (0)

= 1 No chlorination

---

[1] The numbers in parentheses are representative values for the respective variables. Unless otherwise specified the variables are assumed to take on these values in the analysis.

col. 3 I2 = Technique for effluent transmission (1)

= 0 Gravity transmission (10, fig. 18)

= 1 Force main transmission (10, figs. 19 & 20)

col. 4 COVER = Depth of cover over gravity transmission pipes (5) (10, fig. 18)

= 5 five feet of cover (10, fig. 18)

= 9 nine feet of cover (10, fig. 18)

col. 5 CLEAR = Type of cover on original site (10, fig. 24) (1)

= 0 Grass only

= 1 Brush and trees

= 2 Heavily wooded

col. 6 I3 = Runoff collection system from overland flow (10, fig. 36)

= 0 Gravity pipes (0)

= 1 Open ditch

col. 7 I4 = Chlorination of effluent from overland flow (10, fig. 37)

= 0 Chlorination (0)

= 1 No chlorination

col. 8 I6 = No fences around site (10, fig. 41) (0)

= 1 Site is fenced

col. 9-11 ELDIF = Elevation difference for effluent transmission (30)

= 0 to 150

col. 12-14 HEAD 2 = Pumping head for effluent distribution (10, fig. 33)

= 15, 50, or 150 (50)

col. 15-17 WD = Depth of monitoring wells (30)

col. 18-20 UNDER = Underdrains in fields (10, fig. 34) (0)

= 0 No underdrains

= 100 or 400 foot spacing

col. 21-23 I5 = Depth of recovery wells (0)

= 0 No recovery wells

= 50- or 100-foot deep wells

col. 24-27 EARTH = Volume of earth moved for surface leveling (500)

= 500 Normal

= 750 Extensive

Surface irrigation (10, fig. 25)

= 1000 Normal

= 1400 Extensive

Overland flow (10, fig. 26)

Col. 25-26 CROP = Crop grown on irrigation site (1)

0 Plant operation breaks even
= 1 Alfalfa hay
= 2 Reed canary grass hay
= 3 Barley
= 4 Corn silage
= 5 Cotton lint
= 6 Grain sorghum

[illegible] = Price of agricultural crop ($49.00)

[illegible] = Capital costs if an alternative pretreatment technique is used (0)

[illegible] Labor costs if an alternative pretreatment technique is used (0)

[illegible] = Material costs if an alternative pretreatment technique is used (0)

2. Other Variables Used in the Model

[illegible] Final sum of annual labor costs
[illegible] Final sum of capital costs
[illegible] Final sum of annual material costs
[illegible] Final sum of annual power costs
[illegible] Final sum of annual chlorine costs
[illegible] Capital costs for pretreatment
[illegible] Labor costs for pretreatment
[illegible] Material costs for pretreatment
[illegible] Pipe diameter for effluent transmission
[illegible] Right of way costs for effluent transmission (35% of transmission distance at $2 per linear foot)
[illegible] Special crossings for effluent transmission
[illegible] Total daily flow of influent
S = Storage volume in million gallons
[illegible] Surface area of the aerated lagoon
[illegible] = Acres of land irrigated
[illegible] Recovered water in mgd is a function of mgd (10), figs. 35, 37, and 38)
[illegible] MGD
[illegible] = [illegible] PS
[illegible] PBW
[illegible] = [illegible] SS

X5 = log ACRE

X6 = log PAR

X7 = log REWAT

X8 = log WD

HOURO = Hours of operation labor for preliminary treatment

HOURM = Hours of maintenance labor for preliminary treatment

ACRE 3 = Acres required for pretreatment

ACR 1 = Total acreage need for wastewater treatment

BC = Sum of capital costs within IRRI

BL = Sum of labor costs within IRRI

BM = Sum of material costs within IRRI

BP = Sum of power costs within IRRI

BCHL = Sum of chlorine costs within IRRI

REV = Crop revenue

$FARM = Cost of the cropping operation

Cij = Capital costs for (10, figure ij)

Mij = Material costs for (10, figure ij)

Lij = Labor costs for (10, figure ij)

WCC40 = Well capital costs for (10, figure 40)

C41F = Fencing capital costs for (10, figure 41)

M41F = Materials costs for (10, figure 41)

C41S = Capital costs for service roads for (10, figure 41)

M41S = Materials costs for service roads for (10, figure 41)

APPENDIX C
Cost and Elasticity Estimates

Table 1--Annual total cost estimates by type of irrigation[1]

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
			Dollars			
Annual operating costs:						
0.1	19,146	21,051	24,421	24,789	18,902	16,256
0.5	42,732	45,386	52,354	55,970	40,821	35,469
1.0	65,927	70,021	81,258	86,106	61,443	53,725
5.0	219,700	233,407	269,392	292,312	192,380	168,263
10.0	396,071	417,141	494,269	523,271	338,902	296,382
50.0	1,674,681	1,722,199	2,207,303	2,146,586	1,383,090	1,213,082
100.0	3,178,767	3,235,429	4,279,896	4,012,500	2,601,178	2,288,665
Annual capital costs:						
0.1	65,323	62,478	64,309	64,101	64,106	57,576
0.5	130,959	116,951	119,548	119,678	123,483	100,283
1.0	203,008	175,464	178,407	178,660	184,990	143,450
5.0	731,290	587,210	582,957	584,274	624,822	429,965
10.0	1,369,593	1,078,000	1,056,679	1,059,391	1,150,658	762,993
50.0	6,301,506	4,807,584	4,569,125	4,583,385	5,178,915	3,208,416
100.0	12,364,260	9,349,461	8,754,446	8,783,403	10,121,940	6,109,889
Annual total costs:						
0.1	81,053	80,113	85,314	85,474	81,301	73,831
0.5	156,611	145,258	154,823	158,568	155,764	135,752
1.0	234,776	211,325	225,506	230,607	229,353	197,175
5.0	780,194	649,821	681,553	705,791	731,805	598,228
10.0	1,424,073	1,153,550	1,209,357	1,241,070	1,318,764	1,059,375
50.0	6,268,234	4,821,830	5,068,475	5,022,018	5,708,028	4,421,498
100.0	12,127,120	9,168,981	9,618,433	9,379,994	11,015,160	8,398,554

[1] Annual net crop revenue (App. table 5) must be deducted from the sum of annual operating costs and annual capital costs to obtain annual total costs.

Table 2--Average cost estimate by type of irrigation[1]

Facility size MGD	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basin
	Dollars per 1,000 gallons					
Average operating costs:						
0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.4404
0.5	[illegible]	[illegible]	[illegible]	[illegible]	0.2237	0.1944
1.0	[illegible]	[illegible]	[illegible]	0.2359	0.1685	0.1472
5.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0922
10.0	[illegible]	[illegible]	[illegible]	[illegible]	0.0928	0.0812
50.0	[illegible]	[illegible]	[illegible]	[illegible]	0.0758	0.0665
100.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0627
Average capital costs:						
0.1	[illegible]	[illegible]	[illegible]	1.7562	1.7563	[illegible]
0.5	[illegible]	[illegible]	[illegible]	0.6558	0.6766	0.5495
1.0	[illegible]	[illegible]	[illegible]	0.4893	0.5068	0.3930
5.0	[illegible]	[illegible]	[illegible]	0.3202	0.3424	0.2356
10.0	[illegible]	[illegible]	[illegible]	0.2902	[illegible]	0.2090
50.0	[illegible]	[illegible]	[illegible]	0.2511	0.2838	0.1758
100.0	[illegible]	[illegible]	[illegible]	0.2406	0.2773	0.1674
Average total costs:						
0.1	[illegible]	[illegible]	2.3374	2.3417	2.2274	2.0228
0.5	[illegible]	[illegible]	0.8483	0.8689	0.8535	0.7438
1.0	0.6432	[illegible]	0.6178	0.6318	0.6284	0.5402
5.0	0.4273	0.3564	0.3735	0.3867	0.4010	0.3278
10.0	[illegible]	0.3160	0.3313	0.3400	0.3613	0.2902
50.0	[illegible]	0.2642	0.2777	0.2752	0.3128	0.2423
100.0	0.3322	0.2512	0.2635	0.2570	0.3018	0.2301

---

[1] Average net crop revenue (App. table 5) must be deducted from the sum of average capital costs and average operating costs to obtain average total costs.

Average net crop revenue (App. table 5) must be deducted from the sum of average capital costs and average operating costs to obtain average total costs.

Table 8--Fixed cost estimates by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Graded strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
			Dollars per 1,000 gallons			
Average land costs:						
0.1	[illegible]	0.0356	0.0356	0.0356	0.0193	0.0059
0.5	[illegible]	0.0333	0.0333	0.0333	0.0176	0.0040
1.0	[illegible]	0.0328	0.0328	0.0328	0.0171	0.0035
5.0	[illegible]	0.0322	0.0322	0.0322	0.0165	0.0029
10.0	[illegible]	0.0320	0.0320	0.0320	0.0164	0.0027
50.0	[illegible]	0.0319	0.0319	0.0319	0.0162	0.0026
100.0	0.0318	0.0318	0.0318	0.0318	0.0161	0.0025
Average construction costs:						
0.1	1.7563	1.6766	1.7265	1.7208	1.7368	1.5715
0.5	[illegible]	0.6073	0.6215	0.6222	0.6589	0.5455
1.0	[illegible]	0.4476	0.4567	0.4564	0.4896	0.3895
5.0	[illegible]	0.2842	0.2870	0.2877	0.3258	0.2327
10.0	[illegible]	0.2637	0.2573	0.2580	0.2988	0.2063
50.0	[illegible]	0.2313	0.2155	0.2191	0.2675	0.1732
100.0	[illegible]	0.2241	0.2078	0.2086	0.2611	0.1649
			Dollars per year			
Total capital costs:						
0.1	[illegible]	721,850	742,860	740,472	737,913	660,733
0.5	[illegible]	1,367,624	1,397,860	1,398,884	1,429,437	1,151,976
1.0	[illegible]	2,064,937	2,098,694	2,101,603	2,148,004	1,648,849
5.0	[illegible]	6,497,174	6,948,595	6,963,593	7,297,609	4,949,105
10.0	[illegible]	12,888,430	12,643,880	12,674,990	13,459,860	8,786,359
50.0	[illegible]	57,761,920	55,026,810	55,190,360	60,711,240	36,974,760
100.0	[illegible]	112,476,200	105,631,400	105,983,500	118,716,900	70,428,920

Table 4--Components of average operating costs by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
	Dollars per 1,000 gallons					
Labor costs:						
0.1	0.3763	0.4226	0.5171	0.5178	0.3635	0.3051
0.5	0.1488	0.1610	0.1988	0.2114	0.1389	0.1171
1.0	0.1052	0.1143	0.1407	0.1511	0.0949	0.0791
5.0	0.0566	0.0622	0.0779	0.0877	0.0452	0.0354
10.0	0.0472	0.0511	0.0684	0.0735	0.0354	0.0268
50.0	0.0338	0.0346	0.0578	0.0511	0.0219	0.0151
100.0	0.0300	0.0297	0.0551	0.0443	0.0183	0.0121
Materials costs:						
0.1	0.0870	0.0878	0.0870	0.0965	0.0931	0.0790
0.5	0.0409	0.0394	0.0392	0.0464	0.0404	0.0329
1.0	0.0310	0.0295	0.0329	0.0357	0.0291	0.0237
5.0	0.0194	0.0179	0.0204	0.0232	0.0159	0.0124
10.0	0.0169	0.0153	0.0177	0.0206	0.0130	0.0100
50.0	0.0136	0.0120	0.0139	0.0172	0.0094	0.0070
100.0	0.0127	0.0111	0.0128	0.0163	0.0085	0.0062
Power costs:						
0.1	0.0588	0.0639	0.0624	0.0624	0.0588	0.0588
0.5	0.0419	0.0458	0.0465	0.0465	0.0419	0.0419
1.0	0.0419	0.0456	0.0466	0.0466	0.0419	0.0419
5.0	0.0419	0.0454	0.0468	0.0468	0.0419	0.0419
10.0	0.0419	0.0454	0.0468	0.0468	0.0419	0.0419
50.0	0.0419	0.0454	0.0468	0.0468	0.0419	0.0419
100.0	0.0419	0.0454	0.0468	0.0468	0.0419	0.0419
Chlorine costs:						
0.1	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
0.5	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
1.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
5.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
10.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
50.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
100.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025

Table 5--Crop revenue and costs

Facility size (MGD)	Irrigation	Overland flow	Infiltration basins
	Dollars per 1,000 gallons		
Average cropping costs:			
0.1	0.0869	0.0434	0
0.5	0.0869	0.0434	0
1.0	0.0869	0.0434	0
5.0	0.0869	0.0434	0
10.0	0.0869	0.0434	0
50.0	0.0869	0.0434	0
100.0	0.0869	0.0434	0
Average crop revenue:			
0.1	0.1805	0.0902	0
0.5	0.1805	0.0902	0
1.0	0.1805	0.0902	0
5.0	0.1805	0.0902	0
10.0	0.1805	0.0902	0
50.0	0.1805	0.0902	0
100.0	0.1805	0.0902	0
Average net crop revenue:			
0.1	0.0936	0.0468	0
0.5	0.0936	0.0468	0
1.0	0.0936	0.0468	0
5.0	0.0936	0.0468	0
10.0	0.0936	0.0468	0
50.0	0.0936	0.0468	0
100.0	0.0936	0.0468	0
	Dollars per year		
Annual net crop revenue:			
0.1	3,416	1,708	0
0.5	17,080	8,540	0
1.0	34,159	17,080	0
5.0	170,795	85,398	0
10.0	341,591	170,795	0
50.0	1,707,953	853,977	0
100.0	3,415,909	1,707,953	0

Table 6--Effect of subsidy for capital expenditures for solid-set irrigation

Percent subsidy	Facility size (MGD)			
	0.5	1.0	5.0	10.0
	Average capital costs Dollars per 1,000 gallons			
00	0.7176	0.5562	0.4007	0.3752
15	0.6108	0.4736	0.3413	0.3196
30	0.5041	0.3910	0.2819	0.2640
45	0.3973	0.3084	0.2225	0.2085
60	0.2906	0.2257	0.1632	0.1529
75	0.1838	0.1431	0.1038	0.0973
90	0.0771	0.0605	0.0444	0.0417
	Average total costs Dollars per 1,000 gallons			
00	0.8581	0.6432	0.4275	0.3902
15	0.7514	0.5606	0.3681	0.3346
30	0.6446	0.4780	0.3087	0.2790
45	0.5379	0.3954	0.2493	0.2234
60	0.4312	0.3128	0.1900	0.1678
75	0.3244	0.2302	0.1306	0.1122
90	0.2177	0.1476	0.0712	0.0566

Table 7.—Effect of application rate on average costs for solid set irrigation

Application rate (in./wk.)	Facility size (MGD) 0.5	1.0	5.0	10.0
	Average crop revenue Dollars per 1,000 gallons			
1.00	0.1872	0.1872	0.1872	0.1872
1.20	0.1560	0.1560	0.1560	0.1560
1.40	0.1337	0.1337	0.1337	0.1337
1.60	0.1170	0.1170	0.1170	0.1170
1.80	0.1040	0.1040	0.1040	0.1040
2.00	0.0936	0.0936	0.0936	0.0936
2.20	0.0851	0.0851	0.0851	0.0851
2.40	0.0780	0.0780	0.0780	0.0780
2.60	0.0720	0.0720	0.0720	0.0720
2.80	0.0668	0.0668	0.0668	0.0668
3.00	0.0624	0.0624	0.0624	0.0624
3.20	0.0585	0.0585	0.0585	0.0585
3.40	0.0551	0.0551	0.0551	0.0551
3.60	0.0520	0.0520	0.0520	0.0520
3.80	0.0493	0.0493	0.0493	0.0493
4.00	0.0468	0.0468	0.0468	0.0468
	Average capital costs Dollars per 1,000 gallons			
1.00	0.8935	0.7359	0.5821	0.5574
1.20	0.8359	0.6750	0.5216	0.4966
1.40	0.7942	0.6319	0.4784	0.4532
1.60	0.7621	0.5987	0.4460	0.4207
1.80	0.7373	0.5752	0.4209	0.3954
2.00	0.7176	0.5562	0.4007	0.3753
2.20	0.7017	0.5405	0.3842	0.3587
2.40	0.6884	0.5274	0.3705	0.3450
2.60	0.6775	0.5162	0.3590	0.3333
2.80	0.6682	0.5065	0.3490	0.3234
3.00	0.6600	0.4984	0.3404	0.3147
3.20	0.6527	0.4907	0.3328	0.3072
3.40	0.6463	0.4841	0.3262	0.3005
3.60	0.6405	0.4784	0.3202	0.2946
3.80	0.6353	0.4731	0.3150	0.2893
4.00	0.6306	0.4682	0.3102	0.2845

Application rate (in./wk.)	Facility size (MGD) 0.5	1.0	5.0	10.0
	Average operating costs Dollars per 1,000 gallons			
1.00	0.2698	0.2139	0.1523	0.1388
1.20	0.2581	0.2026	0.1418	0.1289
1.40	0.2496	0.1949	0.1342	0.1217
1.60	0.2436	0.1898	0.1285	0.1162
1.80	0.2387	0.1843	0.1240	0.1120
2.00	0.2341	0.1806	0.1204	0.1085
2.20	0.2309	0.1775	0.1174	0.1057
2.40	0.2281	0.1748	0.1149	0.1033
2.60	0.2256	0.1726	0.1127	0.1013
2.80	0.2235	0.1706	0.1109	0.0995
3.00	0.2217	0.1686	0.1093	0.0980
3.20	0.2200	0.1673	0.1079	0.0966
3.40	0.2185	0.1661	0.1067	0.0955
3.60	0.2172	0.1648	0.1056	0.0944
3.80	0.2160	0.1638	0.1046	0.0934
4.00	0.2149	0.1629	0.1037	0.0926
	Average total costs Dollars per 1,000 gallons			
1.00	0.9761	0.7626	0.5472	0.5090
1.20	0.9380	0.7216	0.5074	0.4695
1.40	0.9101	0.6931	0.4789	0.4412
1.60	0.8887	0.6715	0.4575	0.4199
1.80	0.8720	0.6555	0.4409	0.4034
2.00	0.8581	0.6432	0.4275	0.3902
2.20	0.8476	0.6329	0.4166	0.3793
2.40	0.8384	0.6242	0.4074	0.3703
2.60	0.8312	0.6167	0.3997	0.3626
2.80	0.8249	0.6103	0.3931	0.3560
3.00	0.8193	0.6046	0.3873	0.3503
3.20	0.8143	0.5995	0.3823	0.3453
3.40	0.8098	0.5951	0.3778	0.3409
3.60	0.8057	0.5912	0.3739	0.3370
3.80	0.8020	0.5876	0.3703	0.3335
4.00	0.7987	0.5843	0.3671	0.3303

Table 8–Effect of storage on average total cost for solid set irrigation

Weeks of stream discharge	Weeks of no land application				
	25	20	15	10	5
			0.5 MGD Dollars per 1,000 gallons		
0	1.0713	0.9842	0.9031	0.8291	0.7540
1	1.0565	0.9695	0.8887	0.8150	0.7380
2	1.0416	0.9547	0.8750	0.8006	0.7213
3	1.0266	0.9398	0.8607	0.7860	0.7045
4	1.0115	0.9249	0.8467	0.7709	0.6849
5	0.9964	0.9099	0.8325	0.7553	0.6498
6	0.9811	0.8950	0.8181	0.7391	
7	0.9658	0.8809	0.8033	0.7221	
8	0.9503	0.8666	0.7883	0.7050	
9	0.9347	0.8515	0.7729	0.6852	
10	0.9190	0.8369	0.7570	0.6498	
11	0.9036	0.8221	0.7405		
12	0.8889	0.8069	0.7230		
13	0.8741	0.7914	0.7057		
14	0.8590	0.7755			
15	0.8437	0.7592			
16	0.8275	0.7423			
17	0.8118	0.7244			
18	0.7957	0.7066			
19	0.7792				
20	0.7622				
21	0.7447				
22	0.7263				
23	0.7078				
			5 MGD Dollars per 1,000 gallons		
0	0.6264	0.5439	0.4696	0.4001	0.3343
1	0.6123	0.5303	0.4564	0.3871	0.3221
2	0.5981	0.5167	0.4432	0.3741	0.3095
3	0.5839	0.5031	0.4299	0.3611	0.2963
4	0.5697	0.4895	0.4166	0.3481	0.2828
5	0.5556	0.4759	0.4033	0.3356	0.2652
6	0.5413	0.4623	0.3900	0.3231	
7	0.5271	0.4486	0.3767	0.3103	
8	0.5129	0.4350	0.3634	0.2969	
9	0.4986	0.4213	0.3501	0.2831	
10	0.4845	0.4075	0.2373	0.2652	
11	0.4703	0.3938	0.3244		
12	0.4561	0.3801	0.3113		
13	0.4418	0.3664	0.2976		
14	0.4276	0.3526			
15	0.4133	0.3394			
16	0.3990	0.3262			
17	0.3847	0.3126			
18	0.3704	0.2985			
19	0.3561				
20	0.3423				
21	0.3285				
22	0.3144				
23	0.2997				

Weeks of stream discharge	Weeks of no land application				
	25	20	15	10	5
			1.0 MGD Dollars per 1,000 gallons		
0	0.8403	0.7595	0.6858	0.6149	0.5451
1	0.8266	0.7460	0.6725	0.6011	0.5312
2	0.8128	0.7324	0.6591	0.5872	0.5167
3	0.7990	0.7189	0.6456	0.5732	0.5011
4	0.7851	0.7054	0.6319	0.5600	0.4843
5	0.7711	0.6918	0.6180	0.5464	0.4568
6	0.7571	0.6781	0.6040	0.5323	
7	0.7430	0.6643	0.5897	0.5175	
8	0.7287	0.6503	0.5755	0.5016	
9	0.7144	0.6363	0.5619	0.4845	
10	0.7000	0.6221	0.5480	0.4569	
11	0.6857	0.6076	0.5336		
12	0.6714	0.5930	0.5185		
13	0.6569	0.5784	0.5023		
14	0.6423	0.5644			
15	0.6275	0.5501			
16	0.6127	0.5353			
17	0.5975	0.5198			
18	0.5823	0.5032			
19	0.5679				
20	0.5530				
21	0.5376				
22	0.5215				
23	0.5044				
			10 MGD Dollars per 1,000 gallons		
0	0.5874	0.5058	0.4320	0.3630	0.2971
1	0.5734	0.4923	0.4189	0.3502	0.2843
2	0.5594	0.4788	0.4057	0.3373	0.2716
3	0.5453	0.4653	0.3926	0.3243	0.2593
4	0.5313	0.4518	0.3794	0.3114	0.2465
5	0.5172	0.4383	0.3663	0.2984	0.2309
6	0.5032	0.4247	0.3531	0.2854	
7	0.4891	0.4112	0.3399	0.2724	
8	0.4750	0.3976	0.3266	0.2599	
9	0.4610	0.3841	0.3133	0.2467	
10	0.4469	0.3705	0.3000	0.2309	
11	0.4328	0.3569	0.2867		
12	0.4187	0.3433	0.2734		
13	0.4046	0.3296	0.2606		
14	0.3904	0.3159			
15	0.3763	0.3022			
16	0.3621	0.2884			
17	0.3479	0.2747			
18	0.3337	0.2614			
19	0.3194				
20	0.3051				
21	0.2908				
22	0.2765				
23	0.2627				

Table 9--Effect of transportation distance on average total cost for solid-set irrigation

Distance wastes transported	Facility size (MGD) 0.5	1	5	10
Miles	Dollars per 1,000 gallons			
1	0.7925	0.6057	0.4146	0.3821
2	0.8531	0.6401	0.4263	0.3892
3	0.9092	0.6725	0.4386	0.3975
4	0.9738	0.7129	0.4521	0.4059
5	1.0253	0.7375	0.4667	0.4149
6	1.0768	0.7787	0.4790	0.4245
7	1.1282	0.8089	0.4955	0.4348
8	1.1797	0.8391	0.5000	0.4458
9	1.2311	0.8694	0.5147	0.4545
10	1.3287	0.8996	0.5245	0.4606

Table 10 Average cost estimates for sprinkler irrigation as dummy variables

Variable	Facility size	Average operating costs	Average capital costs	Average total cost
	MGD	Dollars per 1,000 gallons		
Base estimates[1]	0.5	0.2341	0.7176	0.8581
	1.0	0.1806	0.5561	0.6432
	5.0	0.1204	0.4007	0.4275
	10.0	0.1085	0.3752	0.3902
No chlorination of lagoon effluent	0.5	0.2398	0.6964	0.8226
	1.0	0.1689	0.5425	0.6191
	5.0	0.1144	0.3949	0.4152
	10.0	0.1032	0.2710	0.3806
Gravity transmission of effluent 35 ft rise	0.5	0.2179	0.6291	0.7534
	1.0	0.1657	0.4984	0.5706
	5.0	0.1080	0.3755	0.3925
	10.0	0.0969	0.3587	0.3620
Gravity transmission of effluent 10 ft rise	0.5	0.2129	0.6419	0.7663
	1.0	0.1655	0.5056	0.5776
	5.0	0.1080	0.3804	0.3949
	10.0	0.0969	0.3599	0.3672
Original site 2 [illegible] with [illegible]	0.5	0.2341	0.6858	0.8264
	1.0	0.1806	0.5266	0.6132
	5.0	0.2104	0.3757	0.4025
	10.0	0.1085	0.3519	0.3662
Original site heavily wooded	0.5	0.2541	0.7855	0.9261
	1.0	0.1806	0.6264	0.7134
	5.0	0.1204	0.4766	0.5023
	10.0	0.1085	0.4518	0.4667
Site fenced	0.5	0.2352	0.7184	0.8600
	1.0	0.1814	0.5682	0.6561
	5.0	0.1208	0.4063	0.4336
	10.0	0.1088	0.3793	0.3946
Pump head for effluent distribution at 150 ft	0.5	0.2510	0.7246	0.8820
	1.0	0.1975	0.5622	0.6661
	5.0	0.1372	0.4036	0.4473
	10.0	0.1254	0.3780	0.4098
50 ft deep monitoring wells	0.5	0.2344	0.7181	0.8589
	1.0	0.1807	0.5564	0.6436
	5.0	0.1204	0.4008	0.4276
	10.0	0.1085	0.3753	0.3902
5 monitoring wells	0.5	0.2354	0.7187	0.8606
	1.0	0.1813	0.5567	0.6444
	5.0	0.1205	0.4008	0.4277
	10.0	0.1086	0.3753	0.3903

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[1] Variable values used to generate these estimates are presented in Appendix B

Table 11--Effluent recovery costs

Type	Facility size	Average operating costs	Average capital costs	Average total costs
	MGD	------ Dollars per 1,000 gallons ------		
Solid-set irrigation:				
Underdrains (100 ft spacing)	0.5	0.2704	0.7851	0.9619
	1.0	0.2110	0.6230	0.7404
	5.0	0.1420	0.4675	0.5160
	10.0	0.1273	0.4420	0.4758
Underdrains (400 ft spacing)	0.5	0.2529	0.7460	0.9053
	1.0	0.1949	0.5777	0.6790
	5.0	0.1284	0.4195	0.4544
	10.0	0.1148	0.3935	0.4148
Recovery wells (50 ft deep)	0.5	0.2557	0.7239	0.8860
	1.0	0.1990	0.5599	0.6653
	5.0	0.1342	0.4018	0.4424
	10.0	0.1211	0.3759	0.4035
Recovery wells (100 ft deep)	0.5	0.2639	0.7284	0.8987
	1.0	0.2072	0.5624	0.6760
	5.0	0.1424	0.4024	0.4512
	10.0	0.1293	0.3764	0.4121
Overland flow:				
Open ditch collection (no chlorination)	0.5	0.2200	0.6298	0.8031
	1.0	0.1660	0.4673	0.5865
	5.0	0.1053	0.3127	0.3713
	10.0	0.0936	0.2881	0.3349
Open ditch collection (chlorination)	0.5	0.2340	0.6544	0.8416
	1.0	0.1756	0.4841	0.6129
	5.0	0.1097	0.3197	0.3826
	10.0	0.0968	0.2930	0.3430
Gravity pipe collection (no chlorination)	0.5	0.2097	0.6520	0.8150
	1.0	0.1587	0.4901	0.6020
	5.0	0.1010	0.3354	0.3897
	10.0	0.0896	0.3103	0.3532
Gravity pipe collection (chlorination)	0.5	0.2237	0.6766	0.8535
	1.0	0.1683	0.5068	0.6284
	5.0	0.1054	0.3424	0.4010
	10.0	0.0928	0.3152	0.3613

Table 12--Land leveling costs

Type	Facility size	Average operating costs	Average capital costs	Average total costs
	MGD	Dollars per 1,000 gallons		
Normal excavation for overland flow (1,000 cubic yards per acre)	0.5	0.2237	0.6766	0.8535
	1.0	0.1683	0.5068	0.6284
	5.0	0.1054	0.3424	0.4010
	10.0	0.0928	0.3152	0.3613
Extensive excavation for overland flow (1,400 cubic yards per acre)	0.5	0.2237	0.6842	0.8610
	1.0	0.1683	0.5137	0.6352
	5.0	0.1054	0.3488	0.4074
	10.0	0.0928	0.3215	0.3676
Normal excavation for border strip irrigation (500 cubic yards per acre)	0.5	0.2869	0.6551	0.8483
	1.0	0.2226	0.4888	0.6178
	5.0	0.1476	0.3194	0.3735
	10.0	0.1354	0.2895	0.3313
Extensive excavation for border strip irrigation (750 cubic yards per acre)	0.5	0.2869	0.6642	0.8575
	1.0	0.2226	0.4976	0.6266
	5.0	0.1476	0.3274	0.3814
	10.0	0.1354	0.2972	0.3390

Table 13--Design flow: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	-0.7886	-0.7986	-0.7338	-0.7304	-0.7962	-0.8406
0.5	-0.3849	-0.3951	-0.4322	-0.3716	-0.4049	-0.4040
1.0	-0.3166	-0.3190	-0.3188	-0.3310	-0.3620	-0.3427
5.0	-0.1644	-0.1746	-0.1725	-0.1687	-0.1982	-0.2002
10.0	-0.1209	-0.1341	-0.0872	-0.1350	-0.1473	-0.1475
50.0	-0.0764	-0.0906	-0.0467	-0.0971	-0.0907	-0.0866
100.0	-0.0658	-0.0795	-0.0375	-0.0868	-0.0762	-0.0716
Average construction costs:						
0.1	-0.5671	-0.5900	-0.5951	-0.5937	-0.5721	-0.6057
0.5	-0.4779	-0.5482	-0.5403	-0.5397	-0.5528	-0.5902
1.0	-0.3545	-0.4048	-0.4162	-0.4157	-0.3828	-0.4563
5.0	-0.1594	-0.2074	-0.2264	-0.2257	-0.1885	-0.2589
10.0	-0.0959	-0.1298	-0.1490	-0.1485	-0.1158	-0.1667
50.0	-0.0545	-0.0784	-0.1032	-0.1027	-0.0643	-0.1125
100.0	-0.0386	-0.0571	-0.0833	-0.0829	-0.0438	-0.0885
Average capital costs:						
0.1	-0.5487	-0.5700	-0.5755	-0.5741	-0.5625	-0.6043
0.5	-0.4405	-0.5002	-0.4940	-0.4935	-0.5292	-0.5872
1.0	-0.3192	-0.3584	-0.3693	-0.3688	-0.3614	-0.4536
5.0	-0.1379	-0.1730	-0.1885	-0.1880	-0.1733	-0.2568
10.0	-0.0822	-0.1066	-0.1219	-0.1215	-0.1058	-0.1655
50.0	-0.0461	-0.0627	-0.0816	-0.0813	-0.0581	-0.1112
100.0	-0.0325	-0.0454	-0.0652	-0.0649	-0.0394	-0.0874
Average total costs:						
0.1	-0.6276	-0.6534	-0.6431	-0.6417	-0.6283	-0.6564
0.5	-0.4724	-0.5234	-0.5266	-0.5033	-0.5257	-0.5394
1.0	-0.3632	-0.4014	-0.4055	-0.4077	-0.3879	-0.4234
5.0	-0.1734	-0.2159	-0.2267	-0.2232	-0.1992	-0.2409
10.0	-0.1108	-0.1449	-0.1406	-0.1578	-0.1293	-0.1604
50.0	-0.0652	-0.0920	-0.0928	-0.1127	-0.0740	-0.1045
100.0	-0.0491	-0.0716	-0.0750	-0.0948	-0.0536	-0.0831

Table 14--Application rate: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	-0.0875	-0.0817	-0.1409	-0.1450	-0.0519	-0.0358
0.5	-0.1401	-0.1435	-0.1434	-0.2182	-0.0655	-0.0463
1.0	-0.1728	-0.1962	-0.2250	-0.2349	-0.0862	-0.0581
5.0	-0.2484	-0.2688	-0.2976	-0.3365	-0.1217	-0.0667
10.0	-0.2619	-0.2768	-0.3607	-0.3425	-0.1289	-0.0658
50.0	-0.2754	-0.2777	-0.3983	-0.3385	-0.1324	-0.0583
100.0	-0.2760	-0.2733	-0.4085	-0.3319	-0.1306	-0.0550
Average construction costs:						
0.1	-0.0859	-0.0504	-0.0483	-0.0487	-0.0635	-0.0157
0.5	-0.1901	-0.0896	-0.0926	-0.0957	-0.1306	-0.0241
1.0	-0.2448	-0.1414	-0.1311	-0.1323	-0.1750	-0.0346
5.0	-0.3690	-0.2174	-0.1901	-0.1920	-0.2804	-0.0483
10.0	-0.3976	-0.2380	-0.2013	-0.2035	-0.3087	-0.0524
50.0	-0.4427	-0.2735	-0.2121	-0.2147	-0.3584	-0.0535
100.0	-0.4568	-0.2861	-0.2130	-0.2158	-0.3760	-0.0526
Average capital costs:						
0.1	-0.1002	-0.0662	-0.0637	-0.0641	-0.0709	-0.0169
0.5	-0.2213	-0.1298	-0.1318	-0.1346	-0.1485	-0.0275
1.0	-0.2819	-0.1915	-0.1811	-0.1821	-0.1974	-0.0393
5.0	-0.4109	-0.2849	-0.2608	-0.2624	-0.3088	-0.0558
10.0	-0.4401	-0.3093	-0.2783	-0.2800	-0.3382	-0.0609
50.0	-0.4849	-0.3493	-0.2998	-0.3017	-0.3885	-0.0636
100.0	-0.4984	-0.3626	-0.3045	-0.3065	-0.4058	-0.0633
Average total costs:						
0.1	-0.0631	-0.0343	-0.0519	-0.0538	-0.0489	-0.0210
0.5	-0.1242	-0.0424	-0.0500	-0.0807	-0.0850	-0.0324
1.0	-0.1600	-0.0771	-0.0867	-0.0941	-0.1146	-0.0445
5.0	-0.2561	-0.1151	-0.1129	-0.1366	-0.1896	-0.0589
10.0	-0.2780	-0.1200	-0.1338	-0.1332	-0.2105	-0.0623
50.0	-0.3133	-0.1255	-0.1374	-0.1109	-0.2486	-0.0622
100.0	-0.3244	-0.1274	-0.1360	-0.0979	-0.2628	-0.0610

Table 15-- Weeks of storage: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	0.0360	0.0331	0.0479	0.0489	0.0264	0.0239
0.5	0.0551	0.0548	0.0525	0.0750	0.0376	0.0323
1.0	0.0670	0.0723	0.0777	0.0795	0.0446	0.0383
5.0	0.0884	0.0928	0.0985	0.1082	0.0557	0.0430
10.0	0.0915	0.0946	0.1161	0.1094	0.0571	0.0424
50.0	0.0930	0.0931	0.1242	0.1070	0.0561	0.0382
100.0	0.0921	0.0909	0.1260	0.1045	0.0545	0.0356
Average construction costs:						
0.1	0.1091	0.1031	0.1000	0.1004	0.1038	0.0995
0.5	0.2174	0.2097	0.2075	0.2075	0.2045	0.2096
1.0	0.2786	0.2849	0.2776	0.2776	0.2750	0.2915
5.0	0.3914	0.4270	0.4220	0.4216	0.4039	0.4682
10.0	0.4189	0.4670	0.4655	0.4649	0.4392	0.5246
50.0	0.4578	0.5278	0.5372	0.5362	0.4910	0.6167
100.0	0.4702	0.5479	0.5636	0.5624	0.5072	0.6497
Average capital costs:						
0.1	0.1136	0.1081	0.1050	0.1054	0.1062	0.0994
0.5	0.2200	0.2133	0.2112	0.2113	0.2063	0.2090
1.0	0.2759	0.2811	0.2747	0.2746	0.2734	0.2903
5.0	0.3726	0.3979	0.3936	0.3933	0.3913	0.4648
10.0	0.3950	0.4284	0.4264	0.4261	0.4225	0.5204
50.0	0.4260	0.4729	0.4777	0.4771	0.4675	0.6108
100.0	0.4359	0.4875	0.4960	0.4953	0.4817	0.6431
Average total costs:						
0.1	0.0896	0.0824	0.0828	0.0832	0.0846	0.0828
0.5	0.1725	0.1605	0.1543	0.1599	0.1601	0.1628
1.0	0.2222	0.2187	0.2092	0.2073	0.2146	0.2216
5.0	0.3211	0.3304	0.3167	0.3137	0.3211	0.3461
10.0	0.3471	0.3639	0.3534	0.3455	0.3526	0.3866
50.0	0.3863	0.4192	0.4051	0.4012	0.4021	0.4537
100.0	0.3992	0.4387	0.4237	0.4226	0.4184	0.4775

Table 16--Transportation distance: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	0.0129	0.0117	0.0101	0.0099	0.0130	0.0152
0.5	0.0089	0.0084	0.0072	0.0068	0.0093	0.0107
1.0	0.0065	0.0062	0.0053	0.0050	0.0070	0.0080
5.0	0.0031	0.0029	0.0025	0.0023	0.0035	0.0040
10.0	0.0029	0.0028	0.0023	0.0022	0.0034	0.0039
50.0	0.0010	0.0009	0.0007	0.0008	0.0012	0.0013
100.0	0.0006	0.0006	0.0004	0.0005	0.0007	0.0008
Average construction costs:						
0.1	0.1889	0.1976	0.1919	0.1925	0.1908	0.2108
0.5	0.1469	0.1654	0.1616	0.1614	0.1525	0.1843
1.0	0.1122	0.1311	0.1288	0.1286	0.1199	0.1507
5.0	0.0533	0.0679	0.0684	0.0682	0.0603	0.0844
10.0	0.0557	0.0726	0.0742	0.0740	0.0639	0.0926
50.0	0.0193	0.0261	0.0277	0.0276	0.0226	0.0349
100.0	0.0123	0.0168	0.0181	0.0180	0.0144	0.0228
Average capital costs:						
0.1	0.1851	0.1936	0.1881	0.1887	0.1886	0.2100
0.5	0.1401	0.1569	0.1534	0.1533	0.1485	0.1829
1.0	0.1055	0.1221	0.1201	0.1199	0.1158	0.1494
5.0	0.0490	0.0610	0.0615	0.0613	0.0573	0.0833
10.0	0.0509	0.0647	0.0660	0.0658	0.0606	0.0914
50.0	0.0175	0.0230	0.0242	0.0241	0.0213	0.0344
100.0	0.0111	0.0147	0.0157	0.0156	0.0136	0.0225
Average total costs:						
0.1	0.1522	0.1540	0.1446	0.1444	0.1518	0.1671
0.5	0.1195	0.1289	0.1209	0.1181	0.1202	0.1379
1.0	0.0931	0.1034	0.0969	0.0948	0.0953	0.1108
5.0	0.0468	0.0562	0.0536	0.0517	0.0499	0.0610
10.0	0.0498	0.0614	0.0586	0.0571	0.0537	0.0669
50.0	0.0179	0.0232	0.0221	0.0223	0.0196	0.0253
100.0	0.0115	0.0152	0.0145	0.0148	0.0126	0.0166

Table 17--Reserve land: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average capital costs:						
0.1	0.0022	0.0023	0.0023	0.0023	0.0011	0.0002
0.5	0.0056	0.0063	0.0061	0.0061	0.0030	0.0005
1.0	0.0072	0.0083	0.0082	0.0082	0.0040	0.0007
5.0	0.0100	0.0125	0.0126	0.0125	0.0059	0.0011
10.0	0.0107	0.0136	0.0139	0.0138	0.0064	0.0013
50.0	0.0116	0.0152	0.0160	0.0160	0.0071	0.0015
100.0	0.0118	0.0157	0.0167	0.0167	0.0072	0.0016
Average total costs:						
0.1	0.0018	0.0018	0.0017	0.0017	0.0009	0.0001
0.5	0.0047	0.0050	0.0047	0.0046	0.0024	0.0004
1.0	0.0062	0.0069	0.0065	0.0064	0.0032	0.0005
5.0	0.0094	0.0113	0.0107	0.0104	0.0050	0.0008
10.0	0.0103	0.0127	0.0121	0.0118	0.0056	0.0009
50.0	0.0117	0.0152	0.0145	0.0146	0.0064	0.0011
100.0	0.0121	0.0160	0.0152	0.0156	0.0067	0.0012

Table 18--Acreage requirements and land costs for various barrier distances[1]

Treatment scale	Barrier distance in feet			
	0	100	300	500
1,000 gal./day				
	Land requirement in acres[2]			
50	9	16	34	60
100	18	26	50	81
500	89	108	152	203
1,000	175	201	260	325
10,000	1750	1831	1999	2174
	cents/1,000 gallons[3]			
50	3.86	6.89	15.19	26.71
100	3.86	5.83	11.04	17.86
500	3.86	4.78	6.71	8.96
1,000	3.86	4.44	5.73	7.18
10,000	3.86	4.04	4.41	4.80

[1] Carlson [1974].

[2] Based on 1.5 acre inches per week and a square application site.

[3] Based on land costs of $1,000/acre, 30-year life of land facility with no salvage value, and 7% discount rate.

Table 19--Land price: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average capital costs:						
0.1	0.0198	0.0207	0.0201	0.0202	0.0111	0.0037
0.5	0.0468	0.0524	0.0512	0.0512	0.0262	0.0073
1.0	0.0595	0.0688	0.0677	0.0676	0.0341	0.0090
5.0	0.0809	0.1007	0.1014	0.1012	0.0485	0.0122
10.0	0.0859	0.1092	0.1114	0.1111	0.0521	0.0130
50.0	0.0929	0.1218	0.1282	0.1278	0.0573	0.0146
100.0	0.0946	0.1252	0.1337	0.1332	0.0586	0.0152
Average total costs:						
0.1	0.0159	0.0161	0.0151	0.0151	0.0088	0.0029
0.5	0.0391	0.0422	0.0396	0.0386	0.0208	0.0054
1.0	0.0514	0.0571	0.0535	0.0523	0.0275	0.0066
5.0	0.0758	0.0910	0.0868	0.0838	0.0414	0.0088
10.0	0.0826	0.1020	0.0973	0.0948	0.0455	0.0094
50.0	0.0934	0.1215	0.1155	0.1166	0.0520	0.0106
100.0	0.0965	0.1276	0.1217	0.1248	0.0538	0.0110

Table 20--Sewer construction cost index: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average construction costs:						
0.1	0.6833	0.6686	0.6782	0.6771	0.6801	0.6464
0.5	0.7589	0.7283	0.7346	0.7349	0.7495	0.6972
1.0	0.7925	0.7574	0.7617	0.7620	0.7783	0.7209
5.0	0.8607	0.8223	0.8209	0.8213	0.8423	0.7788
10.0	0.8816	0.8452	0.8417	0.8422	0.8639	0.8023
50.0	0.9206	0.8921	0.8855	0.8860	0.9068	0.8555
100.0	0.9341	0.9093	0.9021	0.9025	0.9223	0.8763
Average capital costs:						
0.1	0.6698	0.6547	0.6646	0.6635	0.6725	0.6440
0.5	0.7233	0.6900	0.6968	0.6971	0.7299	0.6921
1.0	0.7454	0.7052	0.7101	0.7105	0.7517	0.7144
5.0	0.7911	0.7395	0.7376	0.7382	0.8015	0.7692
10.0	0.8058	0.7530	0.7480	0.7486	0.8189	0.7919
50.0	0.8350	0.7834	0.7720	0.7728	0.8548	0.8430
100.0	0.8457	0.7955	0.7815	0.7823	0.8683	0.8630
Average total costs:						
0.1	0.5398	0.5106	0.5010	0.4976	0.5303	0.5022
0.5	0.6048	0.5556	0.5380	0.5261	0.5786	0.5113
1.0	0.6445	0.5856	0.5618	0.5505	0.6063	0.5198
5.0	0.7415	0.6682	0.6309	0.6111	0.6843	0.5529
10.0	0.7750	0.7037	0.6535	0.6390	0.7145	0.5703
50.0	0.8395	0.7811	0.6960	0.7053	0.7756	0.6117
100.0	0.8622	0.8112	0.7113	0.7325	0.7979	0.6279

Table 21--Sewage treatment plant cost index: Cost elasticities by type irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average construction costs:						
0.1	0.3168	0.3315	0.3219	0.3230	0.3200	0.3536
0.5	0.2415	0.2720	0.2657	0.2654	0.2508	0.3030
1.0	0.2080	0.2430	0.2387	0.2384	0.2221	0.2793
5.0	0.1401	0.1783	0.1798	0.1793	0.1584	0.2217
10.0	0.1192	0.1554	0.1590	0.1585	0.1368	0.1982
50.0	0.0803	0.1088	0.1153	0.1149	0.0941	0.1452
100.0	0.0669	0.0916	0.0988	0.0984	0.0786	0.1245
Average capital costs:						
0.1	0.3105	0.3247	0.3154	0.3165	0.3164	0.3523
0.5	0.2303	0.2579	0.2523	0.2520	0.2442	0.3008
1.0	0.1956	0.2263	0.2226	0.2223	0.2147	0.2768
5.0	0.1288	0.1603	0.1615	0.1612	0.1507	0.2190
10.0	0.1090	0.1385	0.1413	0.1409	0.1297	0.1956
50.0	0.0729	0.0955	0.1005	0.1002	0.0887	0.1431
100.0	0.0606	0.0801	0.0856	0.0853	0.0740	0.1226
Average total costs:						
0.1	0.2503	0.2532	0.2378	0.2373	0.2495	0.2748
0.5	0.1926	0.2076	0.1948	0.1902	0.1936	0.2222
1.0	0.1691	0.1879	0.1761	0.1722	0.1731	0.2014
5.0	0.1207	0.1449	0.1381	0.1334	0.1287	0.1574
10.0	0.1048	0.1294	0.1234	0.1203	0.1132	0.1409
50.0	0.0733	0.0952	0.0906	0.0914	0.0804	0.1039
100.0	0.0618	0.0817	0.0779	0.0798	0.0680	0.0892

Table 22--Discount rate: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average construction costs:						
0.1	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
0.5	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
1.0	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
5.0	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
10.0	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
50.0	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
100.0	0.4925	0.4925	0.4925	0.4925	0.4925	0.4925
Average capital costs:						
0.1	0.5003	0.5007	0.5004	0.5005	0.4965	0.4931
0.5	0.5120	0.5144	0.5139	0.5138	0.5028	0.4942
1.0	0.5177	0.5216	0.5212	0.5211	0.5063	0.4948
5.0	0.5275	0.5360	0.5364	0.5363	0.5129	0.4964
10.0	0.5298	0.5399	0.5409	0.5408	0.5147	0.4969
50.0	0.5331	0.5457	0.5485	0.5483	0.5172	0.4978
100.0	0.5339	0.5472	0.5509	0.5507	0.5177	0.4981
Average total costs:						
0.1	0.4032	0.3905	0.3772	0.3753	0.3915	0.3845
0.5	0.4281	0.4141	0.3968	0.3878	0.3986	0.3651
1.0	0.4476	0.4331	0.4123	0.4037	0.4084	0.3600
5.0	0.4944	0.4844	0.4588	0.4439	0.4380	0.3568
10.0	0.5096	0.5046	0.4726	0.4616	0.4491	0.3579
50.0	0.5359	0.5441	0.4944	0.5004	0.4692	0.3612
100.0	0.5443	0.5580	0.5014	0.5157	0.4758	0.3623

Table 23--Discount period: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average construction costs:						
0.1	-0.3594	-0.3541	-0.3576	-0.3572	-0.3583	-0.3503
0.5	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
1.0	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
5.0	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
10.0	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
50.0	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
100.0	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747	-0.4747
Average capital costs:						
0.1	-0.3544	-0.3489	-0.3525	-0.3521	-0.3558	-0.3459
0.5	-0.4565	-0.4543	-0.4547	-0.4547	-0.4651	-0.4731
1.0	-0.4512	-0.4475	-0.4479	-0.4480	-0.4618	-0.4725
5.0	-0.4420	-0.4340	-0.4337	-0.4338	-0.4556	-0.4710
10.0	-0.4398	-0.4303	-0.4294	-0.4296	-0.4539	-0.4706
50.0	-0.4368	-0.4250	-0.4224	-0.4225	-0.4516	-0.4698
100.0	-0.4360	-0.4235	-0.4201	-0.4202	-0.4511	-0.4695
Average total costs:						
0.1	-0.3567	-0.3440	-0.3332	-0.3315	-0.3514	-0.3478
0.5	-0.3817	-0.3658	-0.3511	-0.3432	-0.3687	-0.3495
1.0	-0.3901	-0.3715	-0.3544	-0.3470	-0.3725	-0.3438
5.0	-0.4143	-0.3922	-0.3710	-0.3591	-0.3890	-0.3385
10.0	-0.4230	-0.4022	-0.3752	-0.3667	-0.3961	-0.3389
50.0	-0.4391	-0.4237	-0.3808	-0.3856	-0.4098	-0.3409
100.0	-0.4446	-0.4319	-0.3823	-0.3935	-0.4145	-0.3416
Average operating costs:						
0.1	-0.3009	-0.2737	-0.2359	-0.2324	-0.3048	-0.3544

Table 24--Wage rate: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	0.9112	0.9090	0.9249	0.9121	0.8983	0.6851
0.5	0.7769	0.7804	0.8082	0.7971	0.7694	0.6025
1.0	0.6959	0.7025	0.7238	0.7273	0.6847	0.5377
5.0	0.5356	0.5480	0.5809	0.5966	0.5036	0.3836
10.0	0.4951	0.5041	0.5533	0.5576	0.4516	0.3301
50.0	0.4194	0.4159	0.5162	0.4741	0.3513	0.2274
100.0	0.3913	0.3814	0.5047	0.4397	0.3142	0.1927
Average total costs:						
0.1	0.2217	0.2454	0.2709	0.2706	0.2121	0.1509
0.5	0.2287	0.2619	0.2902	0.2979	0.2099	0.1574
1.0	0.2176	0.2574	0.2839	0.2942	0.1948	0.1465
5.0	0.1844	0.2372	0.2681	0.2842	0.1502	0.1079
10.0	0.1745	0.2277	0.2695	0.2773	0.1359	0.0924
50.0	0.1539	0.2029	0.2765	0.2548	0.1081	0.0624
100.0	0.1458	0.1918	0.2791	0.2440	0.0980	0.0525
Average total costs: (holding farming wages constant):						
0.1	0.1637	0.1868	0.2161	0.2159	0.1574	0.1509
0.5	0.1686	0.1972	0.2298	0.2389	0.1578	0.1574
1.0	0.1595	0.1931	0.2238	0.2354	0.1468	0.1465
5.0	0.1299	0.1719	0.2060	0.2242	0.1100	0.1079
10.0	0.1189	0.1592	0.2042	0.2137	0.0956	0.0924
50.0	0.0966	0.1285	0.2060	0.1835	0.0681	0.0624
100.0	0.0887	0.1162	0.2073	0.1703	0.0588	0.0525

Table 25--Wholesale price index: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	0.1658	0.1522	0.1301	0.1421	0.1798	0.1774
0.5	0.1748	0.1583	0.1366	0.1512	0.1799	0.1691
1.0	0.1712	0.1533	0.1472	0.1510	0.1728	0.1608
5.0	0.1612	0.1396	0.1384	0.1448	0.1498	0.1350
10.0	0.1557	0.1340	0.1304	0.1437	0.1401	0.1233
50.0	0.1479	0.1267	0.1147	0.1464	0.1247	0.1049
100.0	0.1457	0.1248	0.1094	0.1487	0.1199	0.0994
Average total costs:						
0.1	0.0718	0.0730	0.0683	0.0722	0.0581	0.0391
0.5	0.1322	0.1405	0.1316	0.1368	0.0898	0.0442
1.0	0.1609	0.1762	0.1705	0.1713	0.1040	0.0438
5.0	0.2150	0.2538	0.2488	0.2474	0.1300	0.0380
10.0	0.2291	0.2779	0.2721	0.2738	0.1364	0.0345
50.0	0.2506	0.3197	0.3110	0.3261	0.1461	0.0288
100.0	0.2564	0.3326	0.3238	0.3457	0.1484	0.0271
Average total costs: (holding farm materials constant):						
0.1	0.0394	0.0403	0.0375	0.0415	0.0421	0.0391
0.5	0.0480	0.0498	0.0465	0.0537	0.0476	0.0442
1.0	0.0485	0.0512	0.0534	0.0568	0.0465	0.0438
5.0	0.0455	0.0503	0.0549	0.0601	0.0397	0.0380
10.0	0.0434	0.0486	0.0534	0.0608	0.0361	0.0345
50.0	0.0396	0.0454	0.0501	0.0627	0.0303	0.0288
100.0	0.0383	0.0441	0.0488	0.0638	0.0284	0.0271

Table 26--Electric rate: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	-0.2210	-0.1921	-0.1678	-0.1653	-0.2238	-0.2603
0.5	0.1790	0.1844	0.1619	0.1515	0.1875	0.2157
1.0	0.2322	0.2377	0.2096	0.1978	0.2490	0.2848
5.0	0.3482	0.3548	0.3174	0.2925	0.3980	0.4546
10.0	0.3863	0.3970	0.3460	0.3268	0.4515	0.5162
50.0	0.4568	0.4808	0.3873	0.3983	0.5531	0.6306
100.0	0.4813	0.5118	0.3995	0.4262	0.5882	0.6685
Average total costs:						
0.1	0.0434	0.0463	0.0428	0.0428	0.0433	0.0477
0.5	0.0488	0.0576	0.0548	0.0535	0.0491	0.0564
1.0	0.0652	0.0787	0.0755	0.0738	0.0667	0.0776
5.0	0.0981	0.1274	0.1254	0.1211	0.1045	0.1279
10.0	0.1074	0.1436	0.1414	0.1378	0.1160	0.1444
50.0	0.1220	0.1717	0.1687	0.1702	0.1340	0.1730
100.0	0.1262	0.1806	0.1778	0.1823	0.1389	0.1822
Average construction costs:						
0.1	0.1211	0.1267	0.1230	0.1234	0.1223	0.1351
Average capital costs:						
0.1	0.1170	0.1223	0.1188	0.1192	0.1201	0.1346

Table 27--Chlorine price: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average operating costs:						
0.1	0.0047	0.0043	0.0037	0.0036	0.0048	0.0055
0.5	0.0105	0.0099	0.0086	0.0080	0.0111	0.0127
1.0	0.0137	0.0129	0.0111	0.0105	0.0147	0.0168
5.0	0.0205	0.0193	0.0167	0.0154	0.0235	0.0267
10.0	0.0227	0.0216	0.0182	0.0172	0.0267	0.0304
50.0	0.0269	0.0261	0.0204	0.0210	0.0327	0.0371
100.0	0.0283	0.0278	0.0210	0.0224	0.0347	0.0393
Average total costs:						
0.1	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012
0.5	0.0029	0.0031	0.0029	0.0028	0.0029	0.0033
1.0	0.0038	0.0043	0.0040	0.0039	0.0039	0.0046
5.0	0.0058	0.0069	0.0066	0.0064	0.0062	0.0075
10.0	0.0063	0.0078	0.0074	0.0073	0.0069	0.0085
50.0	0.0072	0.0093	0.0089	0.0090	0.0079	0.0102
100.0	0.0074	0.0098	0.0094	0.0096	0.0082	0.0107

Table 28--Alfalfa price: Cost elasticities by type of irrigation

Facility size (MGD)	Solid-set irrigation	Center pivot irrigation	Border strip irrigation	Ridge and furrow irrigation	Overland flow	Infiltration basins
Average total costs:						
0.1	-0.0804	-0.0813	-0.0764	-0.0762	-0.0403	0
0.5	-0.2041	-0.2195	-0.2064	-0.2016	-0.1042	0
1.0	-0.2697	-0.2984	-0.2804	-0.2744	-0.1407	0
5.0	-0.3978	-0.4721	-0.4516	-0.4371	-0.2180	0
10.0	-0.4334	-0.5273	-0.5047	-0.4928	-0.2411	0
50.0	-0.4881	-0.6213	-0.5937	-0.5987	-0.2769	0
100.0	-0.5034	-0.6504	-0.6228	-0.6371	-0.2866	0

END