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ABSTRACT

OPTIMAL RESERVOIR DESIGN CRITERIA IN CONJUNCTIVE USE OF SURFACE WATER AND GROUND WATER FOR SOYBEAN IRRIGATION IN EASTERN ARKANSAS

A computer simulation model, named Arkansas Offstream Reservoir Analysis (ARORA) was developed to simulate present worth of net income from soybean production systems for conditions varying with respect to ground water availability, offstream reservoir capacity, and many other variables. Additional algorithms were incorporated into the model to enable it to optimize reservoir dimensions given realistic constraints and to identify the reservoir capacity corresponding to maximum present worth of simulated net income. The model was written in FORTRAN programming language and requires significant input data in order to provide significant flexibility with respect to the situations which may be accomodated.

The model was demonstrated using 210 hypothetical situations which varied in terms of ground water availability, initial saturated depth of the aquifer, rate of decline of potentiometric surface, interest/discount rates, soil, and soybean price. The results were very reasonable and clearly point out that all of these variables impact optimal reservoir capacity, although no single variable is the sole determining factor in the decision of whether or not to construct a reservoir. The results further indicate that depending on model accuracy, there are many scenarios in which construction of a reservoir would be to the best interests of a soybean producer - especially those in regions with no ground water available or with a saturated aquifer depth of 25 ft or less.

D.R. Edwards and J.A. Ferguson

Completion Report to the U.S. Department of the Interior, Geological Survey, Reston, VA, June 1989.

Keywords - Conjunctive Use/Irrigation Management/Water Resources Development

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INTRODUCTION

Soybeans, rice, and cotton are, from an economic perspective, Arkansas' most important crops. 1989 cash receipts from these three crops were approximately 1.16 billion dollars (Arkansas Agricultural Statistics Service, 1990), a significant proportion of the state's total agricultural income. These crops require appreciable water inputs over the growing season in order to produce maximum obtainable yields. Although Arkansas' total annual precipitation is adequate for production of these crops, the timing of the precipitation events is such that droughts frequently occur during the crops' growing seasons (roughly May through September). As a result, farmers often find it necessary to irrigate in order to ensure acceptable yields. In eastern Arkansas, where the majority of rice, soybeans, and cotton is produced, approximately five million acre-feet of water was used in 1986 for irrigation purposes; 86% of this amount was supplied from regional aquifers (Soil Conservation Service, 1987). Peralta, et al. (1985), among others, has pointed out that in some areas, withdrawal exceeds recharge to the aquifers. This has resulted in a net decrease in ground water available for irrigation and other purposes. Since it is projected that the demand for irrigation water will increase (Soil Conservation Service, 1987), it is expected that ground water availability will continue to decrease if current irrigation practices continue. Further declines in ground water levels may lead to increased pumping costs and threaten current production levels of irrigated cash crops.

Ranjha, et al. (1985) have studied the potential benefits associated with diverting excess stream and river flow for irrigation purposes. In connection with this research, a plan was developed whereby both surface and ground water may be used conjunctively for irrigation and other purposes. Such a plan has appreciable merit in that if implemented, it would both conserve ground water resources and make more effective use of surface water resources. This conjunctive water resources use plan was developed for a regional scale; the smallest area considered individually was nine square miles. Due to the scale of the study, the plan is relatively insensitive to economic dynamics at the farm level. In order for this (or any other) type of conjunctive water use plan to gain widespread support, acceptance, it must ultimately be proven economically beneficial to those directly influenced by its implementation; namely, the individual crop producer.

Costs associated with storing and distributing excess surface water are a significant aspect of the economics associated with conjunctive use of water resources. Storage costs are primarily influenced by the size of the reservoir which is constructed as a holding facility for excess surface water. Reservoir size is in turn (or should be) governed by the crops to be irrigated, climatic variables (rainfall, temperature, evaporation, etc.), soils, topography, ground water availability and pumping costs, and reservoir reliability (the degree to which the reservoir may be counted on to provide irrigation water).

The costs of constructing, operating, and maintaining a reservoir for storage of supplemental irrigation water represent a substantial investment on the part of the individual producer. However, relatively few published research accounts have addressed the question of how to determine capacity of reservoirs used to store supplemental irrigation water. This is particularly true in situations in which surface-stored water is to be used in conjunction with ground water to meet irrigation needs.

Sharma and Helweg (1982) applied systems analysis to determine economically optimal reservoir capacity, dimensions, and location for two hypothetical irrigation reservoirs in India. This methodology did not incorporate rigorous treatment of climatic or economic uncertainty and did not consider physiological characteristics of the crops in the optimization procedure.

Palmer, et al. (1982a, 1982b) presented a method for selecting capacity of reservoirs to supply irrigation water to corn grown in Kentucky. This procedure assumed that the reservoir was to be filled using only excess rainfall occurring in the vicinity of the reservoir and further assumed that no ground water was available for conjunctive use in supplying irrigation needs. A model to simulate excess rainfall, crop growth, and crop yield was developed to obtain relationships between reservoir capacity and corn yield. The optimal capacity was defined as that which resulted in maximum net benefits as determined by a present worth analysis.

The objectives of this research were to (1) develop a framework for optimal design of offstream reservoirs used to store water for conjunctive use with ground water in supplying irrigation for soybeans in eastern Arkansas, and (2) demonstrate the design framework using selected hypothetical farming operations.

In response to the first objective, a computer simulation model, named the Arkansas Offstream Reservoir Analysis (ARORA) model, was developed to simulate overall reservoir performance. ARORA is a field-scale model, written in FORTRAN programming language, which simulates reservoir and soil water balances, soybean yield, ground water hydraulics and numerous other processes; extensive economic accounting is also performed. ARORA is capable of (1) analyzing economic performance of a given reservoir/field/economic/weather scenario and (2) varying reservoir characteristics to identify those resulting in best economic performance. ARORA is a reasonably comprehensive model in terms of the number of phenomena which are quantitatively described. It is also extremely flexible in that it can be readily applied to individual situations. ARORA is also well-suited as a tool in answering "what if" questions; e.g. ARORA can be used to investigate the impact of differing soybean prices, ground water levels, soils, and a multitude of other factors. A more detailed description of the model, in terms of algorithms, assumptions, and input requirements, is provided in following sections. Although ARORA has not been validated, per se, the mathematical relationships used in the model are well established. In addition, it would be quite impractical to attempt validation in view of the scope of the model.

The capabilities of ARORA are demonstrated by results of 210 runs of the model. These runs corresponded to hypothetical situations differing with respect to soil, availability of ground water, rate of decline of ground water potentiometric surface, interest rate, discount rate, and soybean price. Results from the runs illustrate the type of information provided to the user, the sensitivity of reservoir performance to the previously listed variables, and the feasibility as assessed by the model of constructing offstream reservoirs under the hypothetical circumstances.

MODEL DESCRIPTION

In broad terms, ARORA uses weather data, data on the soybean field of interest, economic data related to soybean production, and other data to simulate 30 years' income and expenses associated with offstream reservoirs of various capacities. ARORA contains an additional algorithm to identify the reservoir capacity corresponding to the maximum present worth of simulated net income. This capacity is taken as optimal; i.e., the optimization criterion is maximized present worth of the simulated 30-year series of net incomes. After optimal capacity has been identified, the model prints a summary of simulation information and stops execution.

General Model Execution

The following paragraphs provide a qualitative description of the operation of ARORA.

1. Weather data are read into memory and appropriate unit conversions are carried out.

2. Other input data are read into memory and converted into appropriate units.

3. If ground water is available, then depreciation, interest, and repair costs associated with the well pumping plant are computed.

4. Reservoir and pumping plant ownership costs are computed. If reservoir capacity is zero or less, then reservoir and pumping plant ownership costs are zero. If reservoir capacity is greater

than zero, then dimensions are determined. Excavation and seeding costs are computed based on reservoir dimensions and reservoir input data. Depreciation, interest, maintenance, and tax costs are computed based on reservoir input data and general economic input data.

5. Remaining irrigated area is determined. If reservoir capacity is greater than zero, then the field area input by the user is decreased by the area occupied by the reservoir and a 10 foot border around the reservoir. Otherwise, the original field area is unchanged.

6. Depreciation and interest costs associated with the irrigation system are calculated. If reservoir capacity is less than or equal to zero and no ground water is available, then these costs are set to zero. Otherwise, irrigation system input data and general economic input data are used to compute the costs.

7. Ownership and operating costs which are not associated with irrigation or dependent on yield magnitude are computed. Ownership cost data, operating cost data, and general economic data are used in the computations.

8. Reservoir fill is allowed to proceed if the following conditions are met: (a) the reservoir is not currently full, (b) the reservoir has not been filled in the current year, (c) reservoir capacity is greater than zero, (d) the current day of year is greater than or equal to the earliest allowed fill date. If all these conditions exist, then fill commences/continues in

accordance with the capacity of the relift pump. The reservoir level is updated and fill costs computed.

9. Recharge of the aquifer is allowed if the following conditions hold: (a) ground water is available, (b) ground water has been used during the current year, (c) ground water is not currently being used to provide irrigation. If recharge is allowed, then a new potentiometric surface elevation is computed.

10. Irrigation is allowed if (a) surface water or ground water is available, (b) no rain occurred on the current day, (c) the computed soil moisture deficit is greater than the triggering soil moisture deficit, and (d) the current day of year is within the growing season of the crop as defined in the input data. If irrigation occurs, it will be supplied from reservoir storage, if available. Otherwise, the irrigation will be supplied from ground water, if available. The gross amount of irrigation supplied on that day is computed based on appropriate irrigation pump capacity and irrigation system efficiency but is constrained to a maximum as that which negates the computed soil moisture deficit.

11. If irrigation occurred and any was supplied by ground water, a new potentiometric surface depth is computed. If the new depth is outside the parameters specified in the input data (i.e. the aquifer is drawn down to zero or less saturated depth), then the amount of irrigation supplied by ground water is decreased and ground water is placed off limits as an irrigation source until one day of recharge has occurred.

12. If irrigation occurred, associated costs are computed based on the source(s), the gross amount of irrigation, ground water parameters (if applicable), and all appropriate economic inputs.

13. Evapotranspiration is computed based on crop age, weather variables, current soil moisture deficit, and parameters input among crop and field data.

14. Reservoir evaporation is computed based on weather data and albedo of water. If reservoir capacity or available reservoir storage is less than or equal to zero, then reservoir evaporation is equal to zero.

15. Soil moisture deficit is updated based on rainfall, irrigation, and evapotranspiration.

16. If reservoir capacity is greater than zero, then lateral and vertical seepage is computed based on reservoir dimensions, water level within the reservoir, and saturated hydraulic conductivity of the soil. If the water level is zero, then both lateral and vertical seepage are taken as zero.

17. If reservoir capacity is greater than zero, then reservoir level is updated based on previous reservoir level, lateral and vertical seepage, rainfall, evaporation, and irrigation supplied. (Steps 8 through 17 are repeated for each day of the year)

18. Crop yield and value of production are computed based on plant transpiration over the growing season and the price of

soybeans. Net income is also computed. (This step is repeated for each year of the simulation)

19. Net incomes for all years of the simulation are converted to present worth.

20. If ARORA is being executed in the optimizing mode and neither of the stopping criteria are met, then the optimization algorithm is called. A new value of reservoir capacity is returned from the optimization algorithm, and execution is passed to Step 4. Otherwise, execution stops and summary information on the simulation involving the current value of reservoir capacity is written to an external file for later viewing.

Specific Major Model Algorithms

Economic Computations. Depreciation is computed by the straight-line method; i.e., for a quantity with cost COST and expected useful lifetime LIFE, the depreciation DEP is given by

$$DEP = COST/LIFE \tag{1}$$

For given COST and interest rate INTRATE, the interest INT is computed as

$$INT = (COST/2)*INTRATE \tag{2}$$

This method of approximation is widely employed (e.g. Clark, et al., 1989).

In order to find the present worth PW of future cash flows CASH occurring N years from the present, these flows are discounted by the discount rate DISRATE as

$$PW = CASH*(1+DISRATE)**(-N) \tag{3}$$

Computation of Runoff. Runoff is computed using the Soil Conservation Service (1972) curve number method. In this method, a curve number for average moisture conditions is selected and specified by the user as part of the required input data. In general, the curve number will vary with soil, hydrologic condition, and land usage; appropriate curve numbers may be selected from information provided by the Soil Conservation Service (1972, 1986). The curve number will also vary with antecedent rainfall; high antecedent rainfall will increase the curve number, while low antecedent rainfall will decrease the curve number. Only the curve number for average moisture conditions is required to be input; ARORA adjusts the curve number as a function of antecedent moisture. Given the curve number for appropriate antecedent moisture conditions, a parameter S is computed from

$$S = (1000/CN) - 10 \tag{4}$$

where S is referred to as the maximum potential abstraction from soil moisture (in) and CN is curve number. Runoff is then computed from

$$\begin{aligned} RUNOFF &= ((RAIN-0.2*S)**2)/(RAIN+0.8*S), & RAIN>0.2*S \\ &= 0, & RAIN<=0.2*S \end{aligned} \tag{5}$$

Runoff is assumed ineffective in adding to the water content of the soil.

Computation of Reservoir Dimensions. ARORA assumes that the reservoir to be constructed is to be square. For a square reservoir with inside levee slope of XN2, depth of excavation below ground surface H1, and base length of L, the excavated volume EXVOL is

$$EXVOL = (H1*(L**2))+(2*L*XN2*(H1**2))+((4/3)*(H1**3)* \\ *(XN2**2)) \tag{6}$$

The cost of reservoir excavation EXCOST is proportional to EXVOL; i.e.,

$$EXCOST = EXVOL*EXCST \tag{7}$$

where EXCST is the excavation cost, in $/cubic yd and EXVOL is expressed in cubic yd. It is desirable to minimize the cost of construction. This is accomplished when the volume excavated is equal to the volume of fill used to construct the levees. The volume comprised by the levees is equal to

$$LVOL = 4(L+(H1*XN2)+T+N1(H2+F))*(0.5(N1+XN2)(H2+F)**2 + \\ + T(H2+F)) \tag{8}$$

where XN2 is the outside levee slope, T is the top width of the levee, and F is the freeboard.

It is additionally necessary to have an expression for the total reservoir storage volume VTOT. VTOT is given by

$$VTOT = (1/3)(H1+H2)(L**2 + L(L+2*XN2*(H1+H2))+ \\ + (L+2*XN2(H1+H2))**2) \tag{9}$$

It is now necessary to specify the required storage volume, RVOL, as well as the excavated depth H1. This leaves L and H2 to be determined. Optimal values of L and H2 are found by minimizing EXVOL subject to

$$\text{EXVOL = LVOL} \tag{10}$$

and

$$\text{VTOT = VREQ} \tag{11}$$

This optimization may be accomplished by the method of Lagrange multipliers. The procedure is to define the Lagrangian l of the variables to be optimized (L and H2) and arbitrary factors LAM1 and LAM2. The resulting Lagrangian is

$$\begin{aligned}&\text{l(L,H2,LAM1,LAM2) = EXVOL + LAM1(EXVOL-LVOL) +}\\ &\qquad\qquad\text{+ LAM2(VTOT-VREQ)}\end{aligned} \tag{12}$$

Partial derivatives with respect to LAM1 and LAM2 are determined and set to zero. The resulting two simultaneous equations are solved with respect to L and H2 (LAM1 and LAM2 vanish). The resulting simultaneous equations are

$$\begin{aligned}&\text{(H1+H2)*L**2 + 2*L*XN2*(H1+H2)**2 +}\\ &\text{+ (4/3)*XN2**2*(H1+H2)**3 - VREQ = 0}\end{aligned} \tag{13}$$

$$\begin{aligned}&\text{4(L+XN2*(H1+H2+F)+T+N1*(H2+F)) * (0.5((N1+XN2)*(F+H2)**2)+}\\ &\text{+T(H2+F)) - ((VREQ*L**2)+(2*L*XN2*H1**2)+((4/3)*XN2**2*}\\ &\text{*(H1+H2)**3)-VREQ) = 0}\end{aligned} \tag{14}$$

Equations (13) and (14) may be solved given VREQ and H1. For purposes of this study, H1 was chosen such that (H1+H2)<= 6 ft. Procedures presented by Gerald and Wheatley (1984) for solution of nonlinear simultaneous equations are used in ARORA to compute optimal reservoir dimensions given the constraints developed earlier.

Seepage Through Reservoir Base and Levees. Seepage losses through the base of the reservoir are computed using Darcy's Law under the assumption of unit hydraulic gradient. Under this assumption, seepage velocity VSEEP is equal to the saturated hydraulic conductivity SEEP of the reservoir material; i.e.,

$$VSEEP = SEEP \tag{15}$$

The maximum area through which this seepage occurs is the original ground level cross sectional area of the storage volume. Below this elevation, seepage area is computed based on the elevation of water in the reservoir.

Lateral levee seepage is computed only when the elevation of water in the reservoir is above original ground level. In this case, seepage velocity is computed as (Schwab, et al., 1981)

$$LATSEEP = QU * SEEPLENGTH \tag{16}$$

where SEEPLENGTH is the perimeter of the reservoir corresponding to the current storage elevation (ft) and

$$QU = (4*SEEP*H2**2)/(9*LSEEP) \tag{17}$$

where LSEEP is the length of the seepage line (ft). LSEEP is determined by assuming that the seepage exits the levee at a point $(H2)/3$ above original ground level and that the seepage line extends from the exit point to a point located a distance $0.3*H2*N1$ inside the levee along the water surface.

Ground Water Hydraulics. ARORA currently treats the aquifer (if ground water is assumed available) as unconfined. Drawdown is computed from the Theis (1935) equation as

$$\mathrm{DDN} = (\mathrm{WELLFLOW}*\mathrm{W(U)})/(12.57*\mathrm{TRANS}) \tag{18}$$

where DDN is drawdown (ft), WELLFLOW is well flow rate (cubic ft/day), W(U) is referred to as "well function of U", and TRANS is the transmissivity of the aquifer. W(U) is computed as

$$\mathrm{W(U)} = -0.5772 - \ln(\mathrm{U}) + \mathrm{U} - (\mathrm{U}**2)/4 + (\mathrm{U}**3)/18 \tag{19}$$

where

$$\mathrm{U} = ((\mathrm{WELLDIAM}**2)*\mathrm{STORCON})/(4*\mathrm{TRANS}*\mathrm{TIME}) \tag{20}$$

where WELLDIAM is well diameter (ft), STORCON is the storage coefficient of the aquifer, and TIME is the time since pumping began (days). TRANS is calculated from

$$\mathrm{TRANS} = \mathrm{KSAT}*\mathrm{SATDEPTH} \tag{21}$$

where KSAT is the saturated hydraulic conductivity of the aquifer (ft/day) and SATDEPTH is the saturated depth of the aquifer (ft).

Residual drawdown existing after periods of recharge is computed from

$$\mathrm{DDN} = (\mathrm{WELLFLOW}*(\mathrm{W(U)}-\mathrm{W(U')}))/(12.57*\mathrm{TRANS}) \tag{22}$$

where U' is computed substituting TIME' for TIME and TIME' is the time since pumping stopped.

It is common for pumping to commence when residual drawdown is present. In this case, TIME is not defined as the elapsed time of new pumping; rather, it is defined as the sum of elapsed time of new pumping and the elapsed pumping time required to produce the residual drawdown. The pumping time required to produce the residual drawdown is identified by use of an iterative procedure.

<u>Evapotranspiration</u>. Potential evapotranspiration is computed using general methods discussed by Ritchie (1972, 1975) and Ritchie, et al. (1976), in which evaporation from the soil surface and crop transpiration are computed separately.

Daily potential evaporation above the crop surface is computed using the modified Penman (1963) equation as

$$\text{POTEVAP} = (\text{DEL}/\text{GAM})*\text{RNET} + 0.262*(1+0.0061*\text{WIND})* *(\text{EO}-\text{EA})*(\text{GAM}/(\text{DEL}+\text{GAM})) \quad (23)$$

where POTEVAP is potential evaporation (cal/sq. cm) above the soil surface, DEL is the slope of the vapor pressure-temperature curve (mb/deg C), GAM is the psychrometric constant (mb/deg C), RNET is net radiation above the crop surface (cal/sq. cm), WIND is wind run at 2 m height (km), and (EO-EA) is the mean vapor pressure deficit (mb). POTEVAP is converted to a potential depth of water evaporated by dividing POTEVAP by 59 cal/sq. cm/in water evaporated. Soil heat is neglected in this estimation of POTEVAP.

Methods discussed by Bosen (1960) are used to compute DEL as

$$\text{DEL} = 2*((0.00738*\text{TMEAN}+0.8072)**7) - 0.00116 \quad (24)$$

where TMEAN is mean daily temperature (deg C). TMEAN is in turn computed from

$$\text{TMEAN} = (\text{TMAX}+\text{TMIN})/2 \quad (25)$$

where the values of TMAX and TMIN are supplied from the WGEN model. The value of GAM is computed by an equation given by Brunt (1952) as

$$\text{GAM} = (0.386*\text{PRES})/\text{LAT} \quad (26)$$

where PRES is average station barometric pressure (mb) and LAT is the latent heat of vaporization (cal/g). The value of PRES is calculated from (Burman, et al., 1983)

$$PRES = 1013 - 0.1055*ELEV \tag{27}$$

where ELEV is elevation relative to mean sea level (m). LAT is calculated from (Brunt, 1952)

$$LAT = 595 - 0.51*TMEAN \tag{28}$$

where TMEAN is as previously defined.

Net radiation is computed from (Burman, et al., 1983)

$$RNET = ((1 - ALBEDO)*RS) - RB \tag{29}$$

where ALBEDO is the composite albedo of the soil and crop and RB is outgoing long wave radiation. ALBEDO is estimated as

$$ALBEDO = ALBEDOSOIL + 0.25*(0.23-ALBEDOSOIL)*LAI \tag{30}$$

where ALBEDOSOIL is the albedo of the bare soil and LAI is the crop leaf area index. LAI is constrained to a maximum value of 4 for the purposes of Eqn. 30. LAI as a function of days past emergence is taken from Shaw and Laing (1966).

RB is computed from (Burman, et al., 1983)

$$RB = ((A1*RS/RSO) + A2) * RBO \tag{31}$$

where RSO is clear-day solar radiation (cal/sq. cm) and RBO is net outgoing long wave radiation on a clear day (cal/sq. cm). The values of the coefficients A1 and A2 were taken as 1.35 and -0.35, respectively, and correspond to those reported by Jensen (1974) as applicable to Davis, CA. RSO is estimated from an equation of the form

$$RSO = WAVEMEAN + AMP*SIN((2*PI*DAY/365) - PSHIFT) \tag{32}$$

The parameters MEAN, AMP, and PSHIFT were fitted to maximum daily values of solar radiation as determined from 100 year WGEN (Richardson and Wright, 1984) simulations for various stations. Table C1 summarizes the values of MEAN, AMP, and PSHIFT by station.

RBO is computed from (Burman, et al., 1983)

$$RBO = (B1+B2*EO**0.5)*(11.71*10**-8)*(TK**4) \tag{33}$$

where TK is the average daily air temperature in Kelvin units and EO is as previously defined. The values used for B1 and B2 were 0.35 and -0.046, respectively, as reported by Jensen (1974), again for Davis, CA.

The mean daily vapor pressure deficit, (EO-EA) was obtained by first defining EO as the saturation vapor pressure at TMEAN and EA as the saturation vapor pressure at the daily dew point. It was also necessary to assume that the daily dew point temperature is well-approximated by TMIN. The approximation of Bosen (1960) was then used to compute these saturation vapor pressures from

$$\begin{aligned} ES = {} & 33.8639((0.00738*T+0.8072)**8 - \\ & - 0.000019|1.8*T+48|+0.001316) \end{aligned} \tag{34}$$

where ES is saturation vapor pressure (mb) at temperature T (deg C).

Potential evapotranspiration at the soil surface below the crop canopy (POTEVAPSOIL) is computed from

$$\mathrm{POTEVAPSOIL} = (\mathrm{DEL}/\mathrm{GAM}){*}\mathrm{RNETSOIL} + 0.262{*}(1+0.0061{*}\mathrm{WIND}){*}\\ {*}(\mathrm{EO}-\mathrm{EA}){*}(\mathrm{GAM}/(\mathrm{DEL}+\mathrm{GAM})) \tag{35}$$

where RNETSOIL is the net radiation at the soil surface, computed from

$$\mathrm{RNETSOIL} = \mathrm{RNET} * \mathrm{EXP}(-0.398{*}\mathrm{LAI}) \tag{36}$$

Actual soil evaporation is assumed to proceed at the potential rate until cumulative soil evaporation exceeds first stage soil evaporation. After that point, actual soil evaporation is taken as proportional to the square root of time since second stage evaporation began.

Transpiration from the plant is estimated from

$$\mathrm{EVAPPLANT} = \mathrm{POTEVAP}{*}(-0.21+0.70{*}(\mathrm{LAI}{*}{*}0.5)) \tag{37}$$

with the constraint that the maximum value of LAI is 2.7 insofar as LAI applies to Eqn. 37. EVAPPLANT is also constrained such that the sum of EVAPSOIL and EVAPPLANT must be less than or equal to POTEVAP.

If the water content in the root zone falls to below 75% of maximum available water content, then EVAPPLANT is estimated from

$$\mathrm{EVAPPLANT} = 4{*}(-0.21+0.70{*}(\mathrm{LAI}{*}{*}0.5)){*}\mathrm{POTEVAP}{*}(\mathrm{SW}/\mathrm{SWT}) \tag{38}$$

for $\mathrm{LAI} < 2.7$ where SW is the water content of the root zone (cm) and SWT is the maximum available water in the root zone (cm). If $\mathrm{LAI} >= 2.7$, then EVAPPLANT is computed from

$$\mathrm{EVAPPLANT} = 4{*}\mathrm{POTEVAP}{*}(\mathrm{SW}/\mathrm{SWT}) \tag{39}$$

Soil Water Balance. A one-dimensional water balance is used to model soil water status as

$$SMD(I) = SMD(I-1) - RAINEFF(I) + EVAPTRAN(I) - IRR(I) \qquad (40)$$

where SMD is the soil moisture deficit, RAINEFF is effective rainfall, EVAPTRAN is the sum of evaporation from the soil and transpiration from the crop, IRR is net irrigation. All variables have units of length. If rainfall or irrigation are sufficient to result in a negative deficit, then the excess water is assumed to percolate and be lost from the root zone.

Reservoir Evaporation. The same methods as described for estimation of potential evaporation from the soil surface are used to estimate potential evaporation from the reservoir surface. The major exception is that ALBSOIL is replaced by ALBEDOWAT, the average albedo of the water surface. A value of 0.36 for ALBEDOWAT was found to yield average annual evaporation values similar to those reported for Arkansas by Kohler, et al. (1959). Water in the reservoir is assumed to evaporate at the potential rate except when the reservoir is empty, in which case evaporation is taken as zero.

Reservoir Water Balance. Another one-dimensional water balance was used to estimate the elevation of water in the reservoir. The equation used is

$$\begin{aligned} ELEV(I) = {} & ELEV(I-1) + RAIN(I) + FILL(I) - \\ & - EVAP(I) - SEEP(I) - IRR(I) \qquad (41) \end{aligned}$$

where ELEV is reservoir elevation, RAIN is daily rainfall (RAIN is taken as all rainfall falling on or within the inside levee slopes), FILL is the amount of water added to the reservoir by the relift pump, EVAP is evaporation from the reservoir, SEEP is vertical and lateral seepage losses from the reservoir, and IRR is gross daily irrigation. All variables are converted to units of length. The subscript denotes the day on which the computation is made.

Crop Yield Estimation. Soybean yields are estimated from

$$Y/YP = ANNTRANS/POTANNTRANS \tag{42}$$

where Y is yield (bu/ac), YP is potential yield (bu/ac), ANNTRANS is crop transpiration over the growing season (cm), and POTANNTRANS is potential crop transpiration over the growing season (cm). The value of YP is input from the user and should reflect the maximum expected yield for the particular soybean variety planted. Values such as those reported by Walker (1988) may be used as YP. Values of ANNTRANS and POTANNTRANS are computed by summing daily values of plant transpiration and actual plant transpiration, respectively.

It is recognized that using the simplified relationship of Eqn. (42) neglects numerous significant aspects of soybean growth (insects, fertility, etc.) and treats water stresses as having the same relative impact on yield regardless of time of occurrence. However, a more detailed treatment of plant growth would have required extensive additional input parameters from the user. Given the large number of varieties planted in Arkansas (and the ongoing development of new varieties) and the lack of reported research to calibrate physiological models to the many varieties, it appeared unrealistic to attempt to incorporate the existent rigorous physiological relationships for soybean into ARORA.

Optimization Algorithm. The direct search algorithm described by Monro (1971) was used to identify the reservoir capacity corresponding to the maximum value of the optimization criterion. Since this is a direct search algorithm, the ability of the algorithm to correctly identify the maximum is dependent on the starting value of reservoir capacity, the behavior of the capacity vs. 30-year net benefits curve, the stopping criterion, and the initial increment on reservoir capacity to be used in the search. The model user may control the initial value of reservoir capacity, upper and lower limits on capacity, and the optimization search increment.

Model Input Data

Input Weather Data. ARORA requires 30 years' daily weather data on precipitation (RAIN), maximum air temperature (TMAX), minimum air temperature (TMIN), solar radiation (RS), and wind run (WIND). The Weather Generator Model (WGEN) (Richardson and Wright, 1984) was modified for the inclusion of wind run and used to generate the required weather data. The model uses statistics from a historical weather data base to produce arbitrarily long sequences of values of the required weather variables. In general, the generated values will have statistical properties which are similar to those of the observed data. In addition, the correlation between the variables is preserved by use of multivariate data generation techniques.

WGEN inputs supplied by Richardson and Wright (1984) were used in generating values of RS. Statistics necessary for generation of TMAX, TMIN, and RAIN values were obtained primarily from an analysis of 20 years' temperature and rainfall data for thirteen weather stations distributed across the state and to a lesser degree from Richardson and Wright (1984). Those stations used in the statistical analysis were: Camden, Clarksville, Eudora, Fayetteville, Gilbert, Hope, Hot Springs, Keiser, Marianna, Mena, Morrilton, Rowher, and Stuttgart. The statistics necessary for the generation of WIND values were obtained from analyses of wind run data for the following stations: Blakely Mountain Dam, Blue Mountain Dam, Hope, Russellville, and Stuttgart. Observed wind run values were assumed as occurring at a height of two feet above ground level; these values were adjusted to two-meter wind runs by assuming a logarithmic wind velocity profile. Matching the wind statistics with the nearest temperature and rainfall data stations enables generation of weather variables for a wide variety of locations within Arkansas. This modified version of WGEN with inputs as described above has been evaluated in terms of representativeness of outputs (Edwards and Mayfield, 1990) and judged satisfactory for most applications.

WGEN must currently be executed independently of ARORA in order to create the weather data file required by ARORA.

Other Input Data. A significant quantity of user-supplied input data are required by ARORA. The data may be classified as general simulation data, crop and field data, general economic data, operating cost data, ownership cost data, ground water data, irrigation system data, reservoir data, reservoir pumping plant data, and optimization data.

The general simulation data include the number of years to simulate and a code signifying whether ARORA is to be executed in the optimizing or non-optimizing mode. One should be cognizant of the fact that different values of the number of years simulated will impact the optimization criterion and optimal reservoir capacity. In all demonstration runs described in following sections, the number of years simulated was set to 30 (equivalent to the expected life of the reservoir). Executing ARORA in the optimizing mode will result in identification of the optimal reservoir capacity. Execution in the non-optimizing mode will allow the user to view intermediate output on soil moisture and reservoir level status and will compute and output general simulation results for only one specified reservoir capacity. Table B1 describes the required general simulation input variables.

The crop and field data include pre-reservoir production area, Soil Conservation Service curve number for average moisture conditions, elevation above mean sea level, clear-day solar radiation parameters, soil moisture evaporation parameters, depth of root zone, available water in the root zone, albedo of the soil, planting date, days from planting until maturity, and maximum expected soybean yield under non-water-limited conditions. Table B2 describes the crop and field input variables. The appropriate curve number may be obtained from tables published by SCS (1972, 1986). Field elevations may be determined from topographic maps. Clear-day solar radiation parameters may be obtained from Table C1. Table C2 contains suggested values (Ritchie, 1972) of the evaporation parameters. Rooting zone depth and available water may be determined on the basis of existing soils from soil surveys. Table C3 contains representative values of soil albedo (Rosenberg, et al., 1983). The value of the planting date should reflect the average day of year on which the crop is planted. Days from planting until maturity will be a function largely of the maturity group of the soybean variety. Maximum expected yields may be estimated from data such as that presented by Walker (1988).

General economic parameters include the interest rate, the discount rate, and rates for insurance and taxes. The selling price of soybeans is also required. These variables are described in Table B3. Inputted values should reflect current conditions unless one specifically wishes to quantify effects of different values of these variables.

Operating and ownership cost data are described in Tables B4 and B5. This data set includes essentially the same variables used by the Arkansas Cooperative Extension Service in preparing production budgets. Values for these variables may be specified based on experience or estimated using figures such as those published by Clark, et al. (1989).

Aquifer data such as initial depth to the potentiometric surface, rate of annual decline, storage constant, and saturated hydraulic conductivity are among the ground water data required. Pumping rates, pumping plant efficiency, initial costs, expected lives, and repair costs of the well, pump, and power unit are also required as are fuel and lubricant costs. These data are described in Table B6. Data on depth to potentiometric surface and annual rate of decline may be determined from individual experience or estimated from data such as those published by Freiwald and Plafcan (1987). The storage constant, saturated depth, and hydraulic conductivity should be determined by subsurface investigation or estimated from published reports such as Peralta and Killian (1985). Pumping rate and pumping plant efficiency should be determined based on pumping analyses, if possible; Table C4 contains representative values of pumping plant efficiencies (Soil Conservation Service, 1987). Required cost and expected life data may be determined on the basis of experience or by contacting an Arkansas Cooperative Extension Service Specialist; these data are not routinely published as numbered publications.

The irrigation system data includes application efficiency, operating pressure, and the soil moisture deficit at which irrigation is to be initiated. Data on the irrigation system cost, expected life, and repair cost are needed together with the associated rates of required manual labor. These required inputs are described in Table B7. Table C5 contains representative values of irrigation system application efficiencies (SCS, 1987). The appropriate value of operating pressure should be system specific. Table C6 contains suggested values of the soil moisture deficit at which irrigation should begin (Ferguson, et al., 1988). Other values may be input based on experience or estimated based on information obtained from Arkansas Cooperative Extension Service Specialists.

Reservoir data include topwidth, slopes of inside and outside levees, saturated hydraulic conductivity of the soil used to construct the reservoir, the albedo of the water, and the starting day of year on which reservoir fill will begin. Other data on excavation cost, seeding cost, maintenance cost, and expected useful life are also required. These input data are described in Table B8. Reservoir topwidths are commonly in the order of roughly 12 feet, and slopes are commonly 3:1 (horizontal: vertical), both inside and outside, although 2:1 inside slopes are also used. Saturated hydraulic conductivity of the reservoir base may be estimated from area soil surveys. A value of 0.36 for average water albedo was used to obtain agreement between modeled reservoir evaporation and published values of evaporation (Kohler, et al., 1959). Excavation and seeding costs estimates may be obtained from local contractors, although considerable variation may be observed. The simulation described in later sections used \$0.65/cubic yd for excavation cost and \$1000/ac for seeding cost. Data regarding expected reservoir life and reservoir maintenance costs were obtained from Palmer, et al. (1982b). Table C7, Appendix C, shows proportion of annual flow occurring during each month; this information may be used as a guide in specifying the beginning fill date.

The required reservoir pumping plant data consist of initial costs, maintenance costs, lubrication costs, and expected useful lifetimes of the relift and irrigation pump. Information on discharges, efficiencies, and total dynamic heads are also necessary. Required reservoir pumping plant data are described in Table B9. These data may be obtained from vendor estimates, estimates of Palmer, et al. (1982b), and analysis of the existing field situation.

The optimization data are comprised of the starting value of reservoir capacity, the search increment, and upper and lower constraints on reservoir capacity. A starting value of capacity equal to 1.5 times total field area is suggested. The lower limit should be some negative number; the upper limit may be arbitrarily large. Table B10 describes required optimization input data.

Operating Rules and Assumptions

Reservoir Fill. Fill will begin on the date specified by the user and continue until the reservoir has been filled to its maximum capacity; after that point, no further fill (other than by rainfall) is allowed until the following year. It is recognized that additional surface water may be available during the course of the year; however, ARORA assumes that the occurrence of appreciable flows during the growing season is not highly reliable.

Aquifer Recharge. Aquifer recharge is allowed after cessation of pumping from the well (if present). If drawdown exceeds the saturated thickness, then the aquifer is allowed one day for recharge before pumping is allowed to proceed.

Aquifer Depletion. Depending on initial values of aquifer saturated depth and annual rate of decline, the aquifer may be depleted during the simulation period. Should this occur, then ground water is taken as unavailable. Well and pumping plant operating costs are subsequently set to zero for the remainder of the simulation; however, depreciation and interest costs for the well and pumping plant are unaffected. The same rule applies to the irrigation system.

Irrigation. The value of the soil moisture deficit during the growing season is considered the determining factor in decisions to irrigate. Each time during the growing season that the computed soil moisture deficit exceeds a threshold value, it is assumed that the field will be irrigated and that the net depth of irrigation will be equal to the current value of the soil moisture deficit. The only exception to this rule is that no irrigation is applied on days receiving rainfall. If irrigation is in progress and rainfall occurs prior to completing irrigation, no irrigation is applied on the day receiving rainfall. Irrigation may commence on the following day depending on the value of the soil moisture deficit.

Irrigation Source. If a reservoir is present and has any stored water, the reservoir will be the first source of irrigation. After the reservoir is depleted, irrigation will be supplied from ground water, if available. Otherwise, no irrigation will be supplied until the reservoir again has stored water (from rainfall additions or next year's fill). If irrigation is being supplied from ground water and the drawdown exceeds the saturated depth of the aquifer, then irrigation must cease for one day to allow recharge, as described previously.

Foregone Production. Area of foregone production is taken as the area occupied by the reservoir and a 10 ft buffer area around the perimeter of the reservoir.

DEMONSTRATION OF MODEL

For demonstration purposes, ARORA was structured to simulate the present worth of 30 years' net incomes for reservoir capacities ranging from 0 to 500 ac-ft. This version of the model was then executed for a hypothetical soybean farming operation near Stuttgart. A total of 210 runs were executed for varying availability of ground water, aquifer saturated depth, rate of decline of potentiometric surface, interest rate, discount rate, soil, and soybean price. With regard to ground water availability, ground water was assumed either available or unavailable. If ground water was available, then the depth to the potentiometric surface was taken as 120 ft. Saturated depth values were 25 and 50 ft (not applicable if ground water was taken as unavailable). Rate of decline was assigned values of 0.5, 0, and 1.0 ft/yr. Interest/discount rate combinations used were 10%/8%, 12%/8%, 6%/2%, 6%/4%, and 8%/4%. The soils used were loam and clay. Soybean prices were assigned values of $6.50, $5.50, and $7.50 per bushel. Table 1 summarizes variable values by run. Depth to potentiometric surface and saturated depth of aquifer values were based on information reported by Peralta, et al. (1985) as representative of the Quaternary aquifer in the Grand Prairie region of Arkansas; the saturated depth value of 25 ft corresponds to a situation categorized by Peralta, et al. (1985) as "critical". The 0.5 ft/yr rate of decline was presented by Peralta, et al. (1985) as the average rate for the Quaternary

Table 1

Variable Values for Demonstration Runs

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
1	120	50.0	0.5	10	8	Loam	6.50
2	120	50.0	0.0	10	8	Loam	6.50
3	120	50.0	1.0	10	8	Loam	6.50
4	120	50.0	0.5	10	8	Loam	5.50
5	120	50.0	0.0	10	8	Loam	5.50
6	120	50.0	1.0	10	8	Loam	5.50
7	120	50.0	0.5	10	8	Loam	7.50
8	120	50.0	0.0	10	8	Loam	7.50
9	120	50.0	1.0	10	8	Loam	7.50
10	120	50.0	0.5	12	8	Loam	6.50
11	120	50.0	0.0	12	8	Loam	6.50
12	120	50.0	1.0	12	8	Loam	6.50
13	120	50.0	0.5	12	8	Loam	5.50
14	120	50.0	0.0	12	8	Loam	5.50
15	120	50.0	1.0	12	8	Loam	5.50
16	120	50.0	0.5	12	8	Loam	7.50
17	120	50.0	0.0	12	8	Loam	7.50
18	120	50.0	1.0	12	8	Loam	7.50
19	120	50.0	0.5	6	2	Loam	6.50
20	120	50.0	0.0	6	2	Loam	6.50
21	120	50.0	1.0	6	2	Loam	6.50
22	120	50.0	0.5	6	2	Loam	5.50
23	120	50.0	0.0	6	2	Loam	5.50
24	120	50.0	1.0	6	2	Loam	5.50
25	120	50.0	0.5	6	2	Loam	7.50
26	120	50.0	0.0	6	2	Loam	7.50
27	120	50.0	1.0	6	2	Loam	7.50
28	120	50.0	0.5	6	4	Loam	6.50
29	120	50.0	0.0	6	4	Loam	6.50
30	120	50.0	1.0	6	4	Loam	6.50
31	120	50.0	0.5	6	4	Loam	5.50
32	120	50.0	0.0	6	4	Loam	5.50
33	120	50.0	1.0	6	4	Loam	5.50
34	120	50.0	0.5	6	4	Loam	7.50
35	120	50.0	0.0	6	4	Loam	7.50
36	120	50.0	1.0	6	4	Loam	7.50

Table 1, cont.

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
37	120	50.0	0.5	8	4	Loam	6.50
38	120	50.0	0.0	8	4	Loam	6.50
39	120	50.0	1.0	8	4	Loam	6.50
40	120	50.0	0.5	8	4	Loam	5.50
41	120	50.0	0.0	8	4	Loam	5.50
42	120	50.0	1.0	8	4	Loam	5.50
43	120	50.0	0.5	8	4	Loam	7.50
44	120	50.0	0.0	8	4	Loam	7.50
45	120	50.0	1.0	8	4	Loam	7.50
46	120	25.0	0.5	10	8	Loam	6.50
47	120	25.0	0.0	10	8	Loam	6.50
48	120	25.0	1.0	10	8	Loam	6.50
49	120	25.0	0.5	10	8	Loam	5.50
50	120	25.0	0.0	10	8	Loam	5.50
51	120	25.0	1.0	10	8	Loam	5.50
52	120	25.0	0.5	10	8	Loam	7.50
53	120	25.0	0.0	10	8	Loam	7.50
54	120	25.0	1.0	10	8	Loam	7.50
55	120	25.0	0.5	12	8	Loam	6.50
56	120	25.0	0.0	12	8	Loam	6.50
57	120	25.0	1.0	12	8	Loam	6.50
58	120	25.0	0.5	12	8	Loam	5.50
59	120	25.0	0.0	12	8	Loam	5.50
60	120	25.0	1.0	12	8	Loam	5.50
61	120	25.0	0.5	12	8	Loam	7.50
62	120	25.0	0.0	12	8	Loam	7.50
63	120	25.0	1.0	12	8	Loam	7.50
64	120	25.0	0.5	6	2	Loam	6.50
65	120	25.0	0.0	6	2	Loam	6.50
66	120	25.0	1.0	6	2	Loam	6.50
67	120	25.0	0.5	6	2	Loam	5.50
68	120	25.0	0.0	6	2	Loam	5.50
69	120	25.0	1.0	6	2	Loam	5.50
70	120	25.0	0.5	6	2	Loam	7.50
71	120	25.0	0.0	6	2	Loam	7.50
72	120	25.0	1.0	6	2	Loam	7.50
73	120	25.0	0.5	6	4	Loam	6.50
74	120	25.0	0.0	6	4	Loam	6.50

Table 1, cont.

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
75	120	25.0	1.0	6	4	Loam	6.50
76	120	25.0	0.5	6	4	Loam	5.50
77	120	25.0	0.0	6	4	Loam	5.50
78	120	25.0	1.0	6	4	Loam	5.50
79	120	25.0	0.5	6	4	Loam	7.50
80	120	25.0	0.0	6	4	Loam	7.50
81	120	25.0	1.0	6	4	Loam	7.50
82	120	25.0	0.5	8	4	Loam	6.50
83	120	25.0	0.0	8	4	Loam	6.50
84	120	25.0	1.0	8	4	Loam	6.50
85	120	25.0	0.5	8	4	Loam	5.50
86	120	25.0	0.0	8	4	Loam	5.50
87	120	25.0	1.0	8	4	Loam	5.50
88	120	25.0	0.5	8	4	Loam	7.50
89	120	25.0	0.0	8	4	Loam	7.50
90	120	25.0	1.0	8	4	Loam	7.50
91	120	50.0	0.5	10	8	Clay	6.50
92	120	50.0	0.0	10	8	Clay	6.50
93	120	50.0	1.0	10	8	Clay	6.50
94	120	50.0	0.5	10	8	Clay	5.50
95	120	50.0	0.0	10	8	Clay	5.50
96	120	50.0	1.0	10	8	Clay	5.50
97	120	50.0	0.5	10	8	Clay	7.50
98	120	50.0	0.0	10	8	Clay	7.50
99	120	50.0	1.0	10	8	Clay	7.50
100	120	50.0	0.5	12	8	Clay	6.50
101	120	50.0	0.0	12	8	Clay	6.50
102	120	50.0	1.0	12	8	Clay	6.50
103	120	50.0	0.5	12	8	Clay	5.50
104	120	50.0	0.0	12	8	Clay	5.50
105	120	50.0	1.0	12	8	Clay	5.50
106	120	50.0	0.5	12	8	Clay	7.50
107	120	50.0	0.0	12	8	Clay	7.50
108	120	50.0	1.0	12	8	Clay	7.50
109	120	50.0	0.5	6	2	Clay	6.50
110	120	50.0	0.0	6	2	Clay	6.50
111	120	50.0	1.0	6	2	Clay	6.50
112	120	50.0	0.5	6	2	Clay	5.50

Table 1, cont.

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
113	120	50.0	0.0	6	2	Clay	5.50
114	120	50.0	1.0	6	2	Clay	5.50
115	120	50.0	0.5	6	2	Clay	7.50
116	120	50.0	0.0	6	2	Clay	7.50
117	120	50.0	1.0	6	2	Clay	7.50
118	120	50.0	0.5	6	4	Clay	6.50
119	120	50.0	0.0	6	4	Clay	6.50
120	120	50.0	1.0	6	4	Clay	6.50
121	120	50.0	0.5	6	4	Clay	5.50
122	120	50.0	0.0	6	4	Clay	5.50
123	120	50.0	1.0	6	4	Clay	5.50
124	120	50.0	0.5	6	4	Clay	7.50
125	120	50.0	0.0	6	4	Clay	7.50
126	120	50.0	1.0	6	4	Clay	7.50
127	120	50.0	0.5	8	4	Clay	6.50
128	120	50.0	0.0	8	4	Clay	6.50
129	120	50.0	1.0	8	4	Clay	6.50
130	120	50.0	0.5	8	4	Clay	5.50
131	120	50.0	0.0	8	4	Clay	5.50
132	120	50.0	1.0	8	4	Clay	5.50
133	120	50.0	0.5	8	4	Clay	7.50
134	120	50.0	0.0	8	4	Clay	7.50
135	120	50.0	1.0	8	4	Clay	7.50
136	120	25.0	0.5	10	8	Clay	6.50
137	120	25.0	0.0	10	8	Clay	6.50
138	120	25.0	1.0	10	8	Clay	6.50
139	120	25.0	0.5	10	8	Clay	5.50
140	120	25.0	0.0	10	8	Clay	5.50
141	120	25.0	1.0	10	8	Clay	5.50
142	120	25.0	0.5	10	8	Clay	7.50
143	120	25.0	0.0	10	8	Clay	7.50
144	120	25.0	1.0	10	8	Clay	7.50
145	120	25.0	0.5	12	8	Clay	6.50
146	120	25.0	0.0	12	8	Clay	6.50
147	120	25.0	1.0	12	8	Clay	6.50
148	120	25.0	0.5	12	8	Clay	5.50
149	120	25.0	0.0	12	8	Clay	5.50
150	120	25.0	1.0	12	8	Clay	5.50

Table 1, cont.

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
151	120	25.0	0.5	12	8	Clay	7.50
152	120	25.0	0.0	12	8	Clay	7.50
153	120	25.0	1.0	12	8	Clay	7.50
154	120	25.0	0.5	6	2	Clay	6.50
155	120	25.0	0.0	6	2	Clay	6.50
156	120	25.0	1.0	6	2	Clay	6.50
157	120	25.0	0.5	6	2	Clay	5.50
158	120	25.0	0.0	6	2	Clay	5.50
159	120	25.0	1.0	6	2	Clay	5.50
160	120	25.0	0.5	6	2	Clay	7.50
161	120	25.0	0.0	6	2	Clay	7.50
162	120	25.0	1.0	6	2	Clay	7.50
163	120	25.0	0.5	6	4	Clay	6.50
164	120	25.0	0.0	6	4	Clay	6.50
165	120	25.0	1.0	6	4	Clay	6.50
166	120	25.0	0.5	6	4	Clay	5.50
167	120	25.0	0.0	6	4	Clay	5.50
168	120	25.0	1.0	6	4	Clay	5.50
169	120	25.0	0.5	6	4	Clay	7.50
170	120	25.0	0.0	6	4	Clay	7.50
171	120	25.0	1.0	6	4	Clay	7.50
172	120	25.0	0.5	8	4	Clay	6.50
173	120	25.0	0.0	8	4	Clay	6.50
174	120	25.0	1.0	8	4	Clay	6.50
175	120	25.0	0.5	8	4	Clay	5.50
176	120	25.0	0.0	8	4	Clay	5.50
177	120	25.0	1.0	8	4	Clay	5.50
178	120	25.0	0.5	8	4	Clay	7.50
179	120	25.0	0.0	8	4	Clay	7.50
180	120	25.0	1.0	8	4	Clay	7.50
181	NA	NA	NA	10	8	Loam	6.50
182	NA	NA	NA	10	8	Loam	5.50
183	NA	NA	NA	10	8	Loam	7.50
184	NA	NA	NA	12	8	Loam	6.50
185	NA	NA	NA	12	8	Loam	5.50
186	NA	NA	NA	12	8	Loam	7.50
187	NA	NA	NA	6	2	Loam	6.50
188	NA	NA	NA	6	2	Loam	5.50

Table 1, cont.

Run	Depth to* Ground Water (ft)	Saturated Depth (ft)	Rate of Decline (ft/yr)	Interest Rate (%)	Discount Rate (%)	Soil	Soybean Price ($/bu)
189	NA	NA	NA	6	2	Loam	7.50
190	NA	NA	NA	6	4	Loam	6.50
191	NA	NA	NA	6	4	Loam	5.50
192	NA	NA	NA	6	4	Loam	7.50
193	NA	NA	NA	8	4	Loam	6.50
194	NA	NA	NA	8	4	Loam	5.50
195	NA	NA	NA	8	4	Loam	7.50
196	NA	NA	NA	10	8	Clay	6.50
197	NA	NA	NA	10	8	Clay	5.50
198	NA	NA	NA	10	8	Clay	7.50
199	NA	NA	NA	12	8	Clay	6.50
200	NA	NA	NA	12	8	Clay	5.50
201	NA	NA	NA	12	8	Clay	7.50
202	NA	NA	NA	6	2	Clay	6.50
203	NA	NA	NA	6	2	Clay	5.50
204	NA	NA	NA	6	2	Clay	7.50
205	NA	NA	NA	6	4	Clay	6.50
206	NA	NA	NA	6	4	Clay	5.50
207	NA	NA	NA	6	4	Clay	7.50
208	NA	NA	NA	8	4	Clay	6.50
209	NA	NA	NA	8	4	Clay	5.50
210	NA	NA	NA	8	4	Clay	7.50

* Depth below ground surface at which potentiometric surface of aquifer is located. "NA" designates nonavailability of ground water.

aquifer; the other values were specified to represent either worsening or improving mining conditions with regard to the aquifer. Interest/discount rate combinations and soybean prices to be used in the simulations were based on information provided by Fryar (1990).

By varying the soils used in the runs, it was necessary to vary values of those variables related to the soils; these variables included ALPHASOIL, USOIL, ROOTZONE (depth of the root zone), and CRITSMD (the soil moisture deficit at which irrigation is initiated). The values of these variables appear in Table 2.

Other input variables required by ARORA are listed in Appendix D. These variable values were selected to be representative of conditions near the Stuttgart region and were obtained from previously described sources as well as contractors in the region. In general, the input variables were structured to reflect a 160 ac field planted to continuous soybeans (Forrest variety) with furrow irrigation (when water, either surface or ground, is available for irrigation). Values of daily weather variables required by the model were obtained from the modified WGEN model described previously.

Table 2. Soil-Dependent Variable Values

Variable	Value for	
	Loam	Clay
ALPHASOIL	4.04	3.50
USOIL	9.00	12.00
ROOTZONE	18.00	30.00
CRITSMD	50.80	44.50

RESULTS AND DISCUSSION

Each run resulted in 50 values of reservoir capacity vs. present worth of 30 years' simulated net incomes. Table 3 was constructed from this data and lists the maximum present worth values and corresponding reservoir capacities for each run.

An inspection of Table 3 reveals that optimal reservoir capacity is affected, during one or another set of runs, by each of the inputs that were varied during the runs. Also, it will be noted that there are a large number of runs which had an optimal capacity of zero; this indicates that according to the model results, it would be best, from the standpoint of the optimization criterion, not to construct a reservoir of any capacity under the conditions applicable to those runs.

Effect of Ground Water Availability on Optimal Capacity

It may be noted from Table 1 that runs 1-45 differ from runs 46-90 only with regard to aquifer depth, and runs 181-195 are identical to either set except that no ground water is assumed available. The soil for runs 1-90 and 181-195 was loam. While optimal capacities in runs 1-90 were generally either zero or in the order of 190 ac-ft, depending on saturated depth, interest/discount rate, and soybean price, optimal capacity for runs 181-195 was 160 ac-ft in each case. This suggests that based on the general situation of these runs, the results of the model, the range of other variables, and the optimization criterion used in the study, it is in the best interests of the producer to

Table 3

Demonstration Run Results

Run	Optimal Capacity (ac-ft)	Present Worth ($)	Run	Optimal Capacity (ac-ft)	Present Worth ($)
1	0	207,025	37	0	304,730
2	0	207,979	38	0	307,042
3	0	205,420	39	0	300,514
4	0	119,911	40	0	171,313
5	0	120,765	41	0	173,626
6	0	118,315	42	0	167,437
7	0	294,239	43	0	454,335
8	0	295,193	44	0	456,167
9	0	292,524	45	0	450,205
10	0	201,494	46	0	135,561
11	0	202,456	47	0	206,660
12	0	199,879	48	0	98,196
13	0	114,280	49	0	62,114
14	0	115,242	50	0	119,447
15	0	112,775	51	0	32,096
16	0	288,707	52	0	209,008
17	0	289,670	53	0	293,874
18	0	286,984	54	0	164,296
19	0	423,853	55	0	130,200
20	0	426,477	56	0	201,125
21	0	417,761	57	0	92,935
22	0	251,720	58	0	56,753
23	0	254,344	59	0	113,911
24	0	246,235	60	0	26,835
25	0	595,985	61	0	203,647
26	0	598,610	62	0	288,339
27	0	589,287	63	0	159,035
28	0	313,402	64	0	216,732
29	0	315,692	65	0	423,871
30	0	309,206	66	210	206,277
31	0	179,985	67	0	84,705
32	0	182,276	68	0	251,738
33	0	176,129	69	210	66,786
34	0	446,819	70	180	358,851
35	0	449,109	71	0	596,003
36	0	442,283	72	190	345,829

Table 3, cont.

Run	Optimal Capacity (ac-ft)	Present Worth ($)	Run	Optimal Capacity (ac-ft)	Present Worth ($)
73	0	186,744	109	0	508,520
74	0	329,420	110	0	511,028
75	190	160,874	111	0	502,982
76	0	81,098	112	0	323,663
77	0	196,192	113	0	326,172
78	190	52,232	114	0	318,664
79	0	292,390	115	0	693,376
80	0	462,647	116	0	695,885
81	190	269,515	117	0	687,299
82	0	178,595	118	0	393,343
83	0	320,915	119	0	395,077
84	190	143,224	120	0	389,897
85	0	72,948	121	0	250,556
86	0	187,688	122	0	252,290
87	190	34,582	123	0	247,411
88	0	284,241	124	0	536,130
89	0	454,142	125	0	537,864
90	190	251,865	126	0	532,383
91	0	246,020	127	0	384,856
92	0	246,931	128	0	386,606
93	0	244,540	129	0	381,395
94	0	152,987	130	0	242,069
95	0	153,898	131	0	243,819
96	0	151,604	132	0	238,909
97	0	339,053	133	0	527,643
98	0	339,963	134	0	529,393
99	0	337,476	135	0	523,881
100	0	240,500	136	0	192,181
101	0	241,419	137	0	245,673
102	0	239,011	138	0	160,926
103	0	147,467	139	0	110,002
104	0	148,386	140	0	152,641
105	0	146,075	141	0	85,144
106	0	333,532	142	0	274,359
107	0	334,452	143	0	338,706
108	0	331,947	144	0	236,708

Table 3, cont.

Run	Optimal Capacity (ac-ft)	Present Worth ($)	Run	Optimal Capacity (ac-ft)	Present Worth ($)
145	0	186,819	178	0	397,832
146	0	240,149	179	0	527,460
147	0	155,663	180	0	346,028
148	0	104,461	181	160	129,864
149	0	147,117	182	160	56,035
150	0	79,881	183	160	203,692
151	0	268,998	184	160	120,694
152	0	333,182	185	160	46,866
153	0	231,445	186	160	194,523
154	0	351,344	187	160	281,920
155	0	508,539	188	160	137,213
156	0	300,992	189	160	426,627
157	0	198,350	190	160	221,191
158	0	323,682	191	160	108,872
159	0	158,834	192	160	333,510
160	0	504,338	193	160	207,094
161	0	693,396	194	160	94,775
162	0	443,151	195	160	319,413
163	0	285,073	196	0	177,343
164	0	393,162	197	0	109,418
165	0	242,152	198	0	245,268
166	0	164,156	199	0	175,610
167	0	250,375	200	0	107,685
168	110	116,592	201	0	243,535
169	0	405,990	202	110	351,444
170	0	535,949	203	0	211,176
171	0	354,033	204	110	507,114
172	0	276,915	205	110	273,138
173	0	384,673	206	0	166,083
174	0	234,148	207	110	393,619
175	0	155,988	208	0	266,388
176	0	241,886	209	0	163,422
177	0	122,267	210	110	380,578

construct a reservoir if ground water is unavailable. This was not the case for clay soils. Runs 1-90 were identical to runs 91-180 except that the soil was clay for the second set of runs; similarly, runs 181 through 195 were identical to runs 196-210 except for soil. The results of runs 196-210 indicate that optimal reservoir capacity depends on factors other than the availability of ground water in clay soil situations; specifically, optimal capacity in the absence of ground water and with clay soils depends on soybean price and interest/discount rates.

Figure 1 demonstrates the relationship between present worth of 30-year simulated net income vs. reservoir capacity for runs 1 and 181 which, again, vary only with regard to availability of ground water. The figure implies several interesting points. First, if no ground water is available, then it would be better to build no reservoir than to build one smaller than approximately 100 ac-ft in capacity; similarly, it would be better to build no reservoir than to build one larger than approximately 300 ac-ft. It is suggested that for capacities outside the range of 100-300 ac-ft, increased yields do not offset the costs of foregone production and reservoir construction, operation, and maintenance. This is especially likely on the high end of capacities, where the reservoir will be large enough to supply virtually all crop needs and thus will not result in added income. The second point is that for reservoir capacities greater than approximately 140

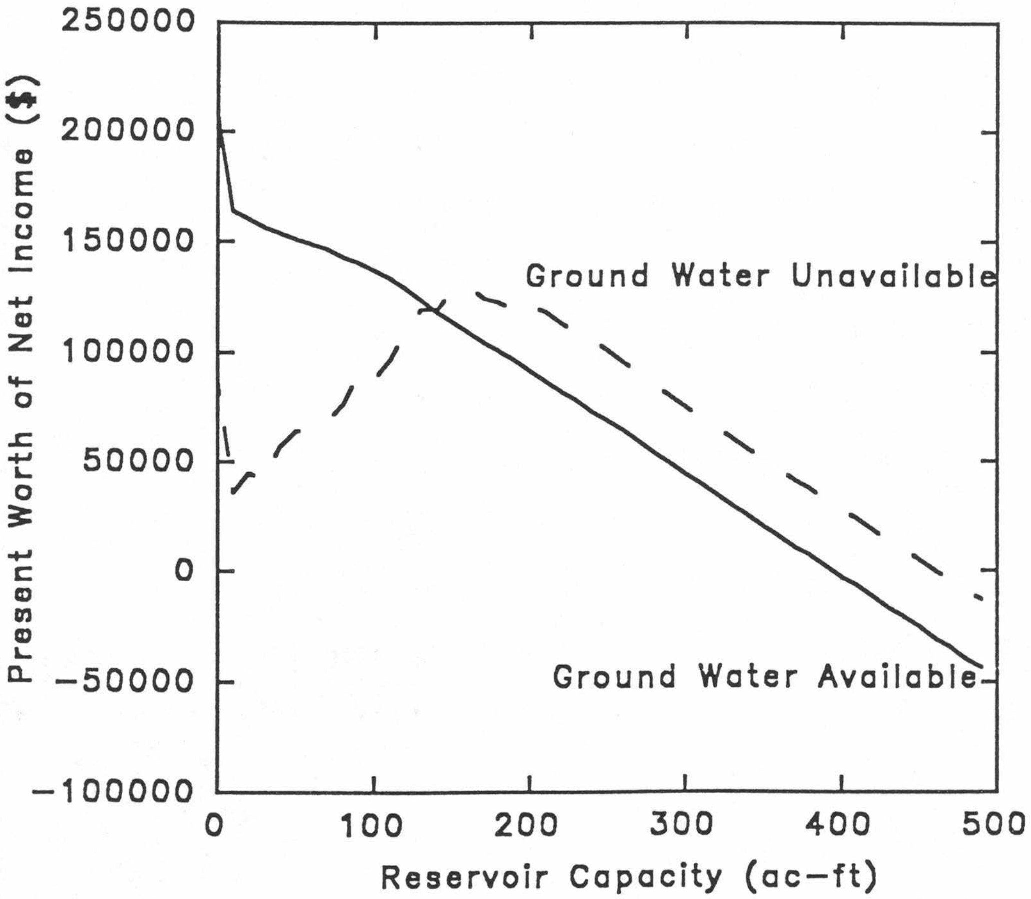

Fig. 1. Present worth of simulated net income vs. reservoir capacity for varying ground water availability.

ac-ft, the optimization criterion for situations with ground water is less than that for situations without ground water. This disparity can most likely be explained by the higher ownership and operating costs associated with the well and pumping plant for the situation with ground water available.

Effect of Saturated Depth on Optimal Capacity

As pointed out previously, runs 1-45 are identical to runs 46-90 except with respect to saturated depth. The same statement holds for runs 91-135 and 136-180. The effect of saturated depth on optimal capacity is especially apparent on comparing results from runs 1-45 to those from runs 46-90. For runs 1-46, optimal capacity was in each case zero. In contrast, when saturated depth was set to 25 ft, as in runs 46-90, optimal capacity was in several cases greater than zero. The values of optimal capacity clearly indicate that the optimums are dependent on other variables; namely, rate of aquifer decline and interest/discount rate combinations. However, initial saturated depth may be seen to clearly influence the issue of whether or not to construct a reservoir. With clay soils, as were specified for runs 91-180, the effect of saturated depth is seen to play a less prominent role and to influence reservoir capacity only in conjunction with all other variables.

Figure 2 illustrates the impact of initial aquifer saturated depth on present worth of the simulated net incomes. The curves are derived from runs 21 and 66 which vary only in terms of

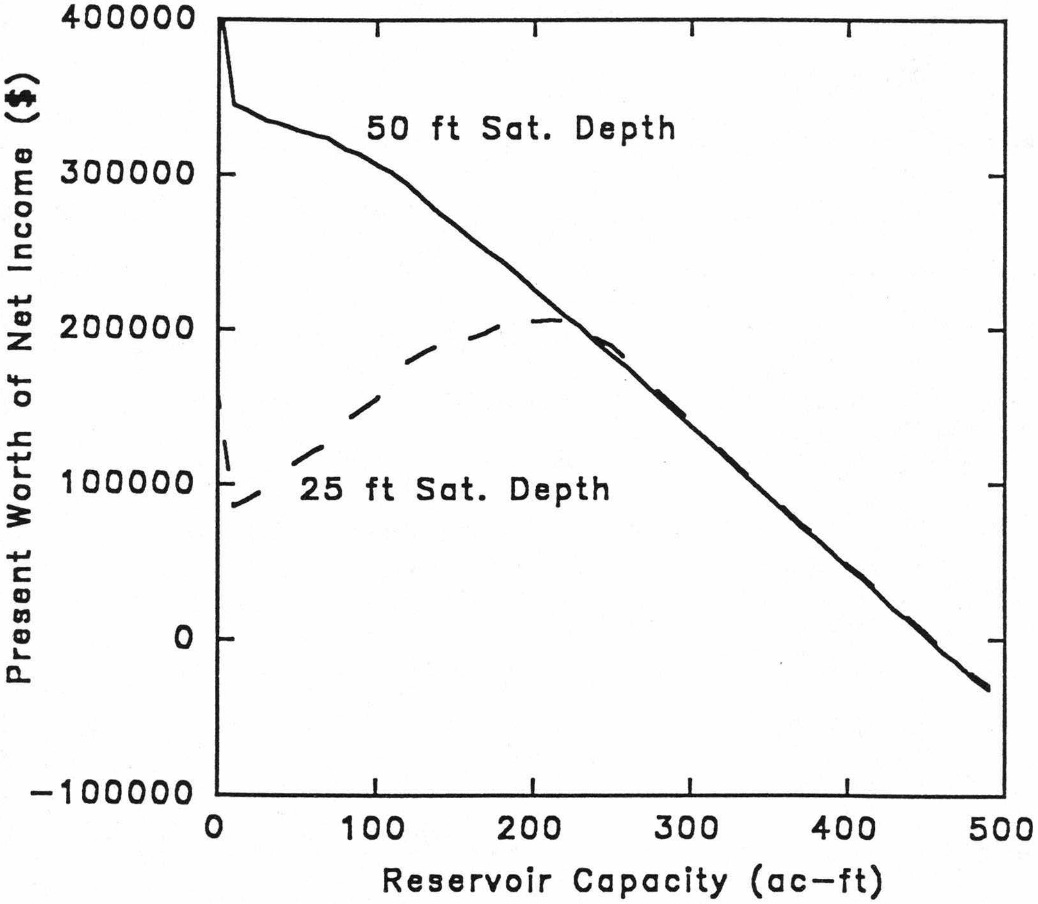

Fig. 2. Present worth of simulated net income vs. reservoir capacity for varying aquifer saturated depths.

initial saturated depth. It may be noted that for an initial saturated depth of 50 ft, the greatest value of present worth corresponds to zero capacity, indicating that it is best to build no reservoir. For the curve corresponding to a 25 ft saturated depth, however, it may be seen that the greatest value of present worth is associated with a capacity of 210 ac-ft, suggesting that it is best to build a reservoir and the best capacity is 210 ac-ft. It may also be noted that there is a wide range of capacities which may be constructed and which lead to greater present worth than zero capacity. It is also evident that for capacities greater than approximately 300 ac-ft, the two curves essentially coincide; this suggests that for capacities greater than 300 ac-ft, virtually all crop needs may be supplied from the reservoir. Since the operating rules mandate that water will be first taken from the reservoir, the influence of initial saturated depth will be nullified for capacities greater than 300 ac-ft.

Effect of Rate of Decline on Optimal Capacity

As Table 1 is constructed, each set of three runs differs only with respect to rate of decline of aquifer potentiometric surface. Table 1 indicates that rate of decline does influence optimal reservoir capacity, but generally only in conjunction with other situations; namely, 25 ft saturated depth of aquifer, loam soils and interest/discount rates either 6%/2%, 6%/4%, or 8%/4%. This is quite apparent on inspecting the results of runs 1-45 and 46-90.

Figure 3 illustrates the relation between present worth of 30 years' simulated net incomes vs. reservoir capacity for runs 82-84, which differ only with regard to rate of aquifer decline. It is apparent that for these three runs, optimal reservoir capacity is greater than zero only when rate of decline is one ft/yr (in which case the aquifer is depleted 25 years into the simulation), and the optimal capacity in this case is 190 ac-ft. It may also be noted that for capacities beyond the range of approximately 222 ac-ft, the dependent variable is a function only of reservoir capacity and not rate of decline. This again suggests that reservoirs larger than this capacity are capable of meeting practically all crop water requirements without need of ground water which, in effect, negates the impact of variable levels of decline.

Effect of Interest/Discount Rate Combinations on Optimal Capacity

On correlating the results from Table 3 to the inputs as shown in Table 1, it is apparent that interest/discount rates also influence optimal reservoir capacity. This is particularly obvious for runs 46-90, in which optimal capacity was zero except for cases involving interest/discount rate combinations of 6%/2%, 6%/4%, and 8%/4%. The interest/discount rate combination, however, was not the sole determining factor, and optimal capacity was also strongly influenced by rate of decline of potentiometric surface. Interest/discount rate combinations may also be seen to

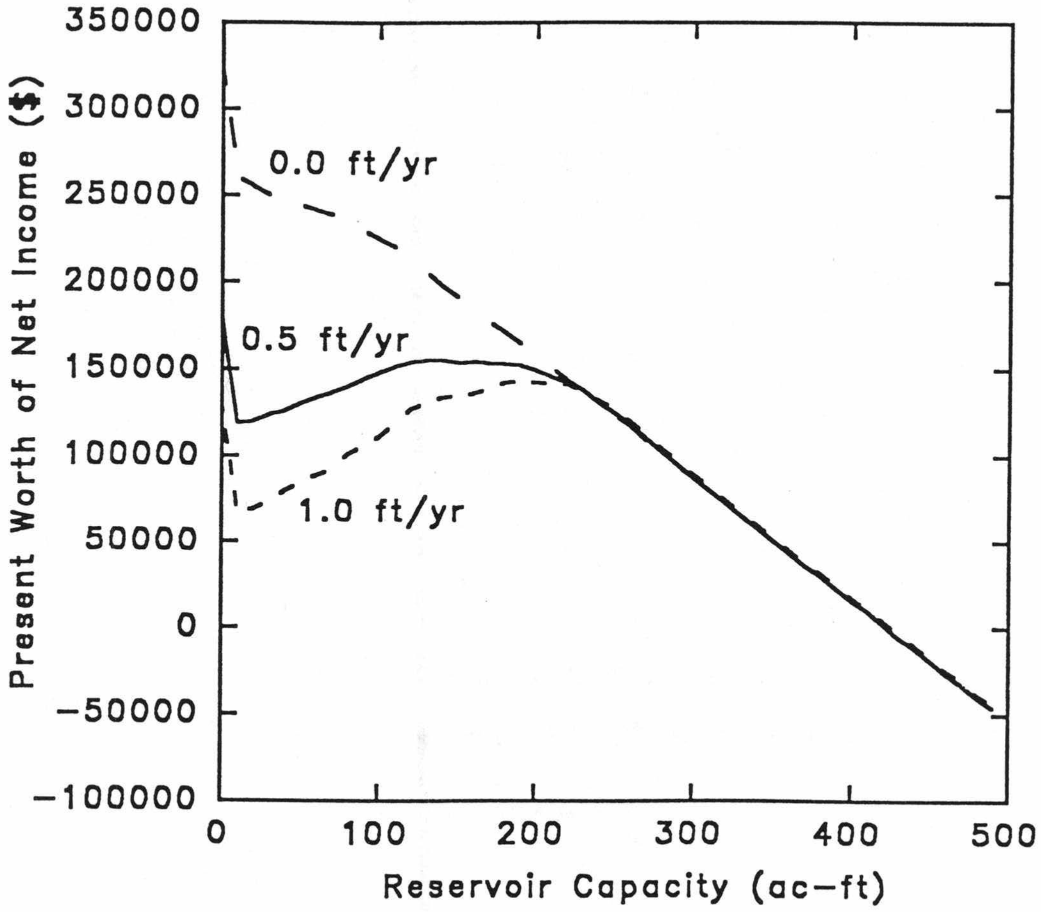

Fig. 3. Present worth of simulated net income vs. reservoir capacity for varying rates of decline of aquifer potentiometric surface.

have influenced optimal capacities of other runs; most notably, runs 196-210.

Figure 4 shows present worth vs. reservoir capacity for runs 48, 57, 66, 75, and 84, which differ only with respect to interest/discount rate combination. The curves of Fig. 4 demonstrate that the optimal capacity is zero for combinations of 10%/8% and 12%/8%. For other combinations, optimal capacity was either 190 or 210 ac-ft. Interestingly, the five curves take on much the same shape; it appears that the interest/discount rate combination impacts more on the judgement as to whether to construct the reservoir rather than which is the best capacity to construct.

Effect of Soil on Optimal Capacity

Runs 1-90 and 181-195 are identical to runs 91-180 and 196-210, respectively, except for the soils specified for the runs. The results of Table 3 suggest an impact of the soils, as accounted for in the runs, on optimal capacity. In general, the optimal capacity is zero in more cases for clay soils than for loam soils. Also, it may be noted that non-zero optimal capacities for clay soils are significantly smaller than those for clay soils. This is illustrated in Figure 5, which shows plots of present worth vs. reservoir capacity for runs 66 and 156. It is possible that the response of optimal capacity to soil may be more a function of the root zone depths used in the simulation than of

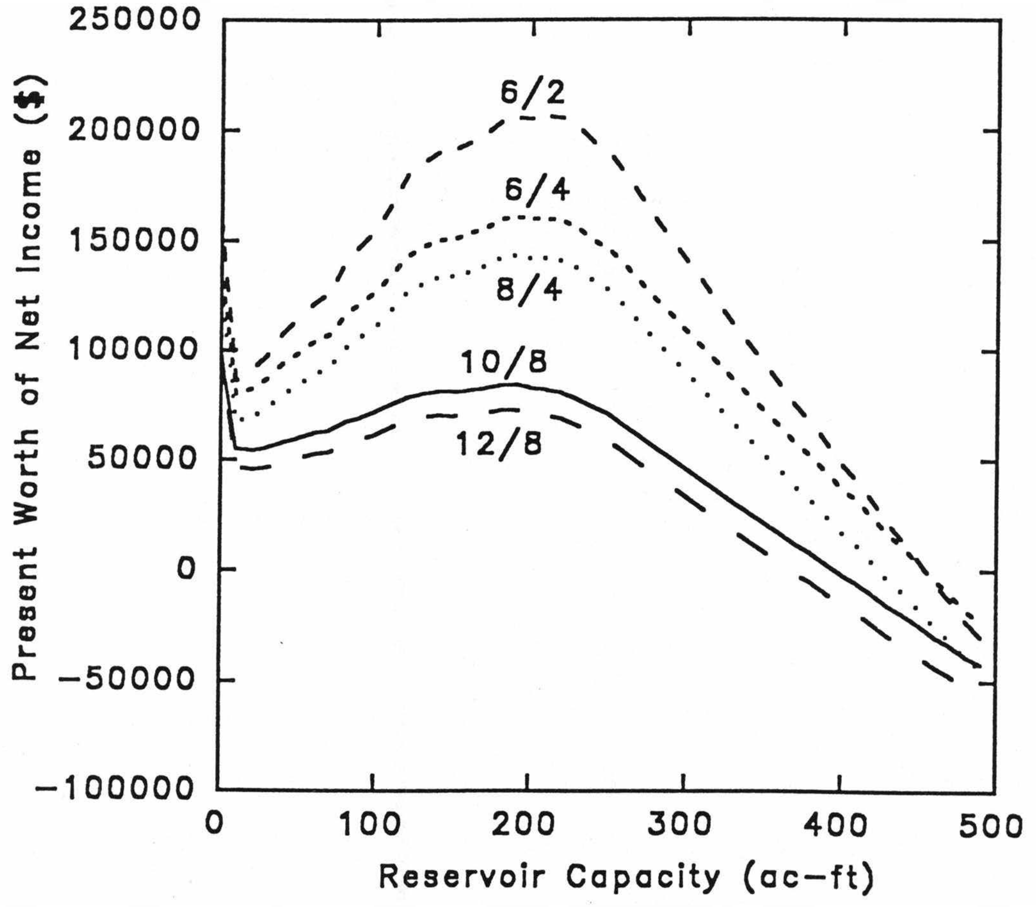

Fig. 4. Present worth of simulated net income vs. reservoir capacity for varying interest/discount rate combinations.

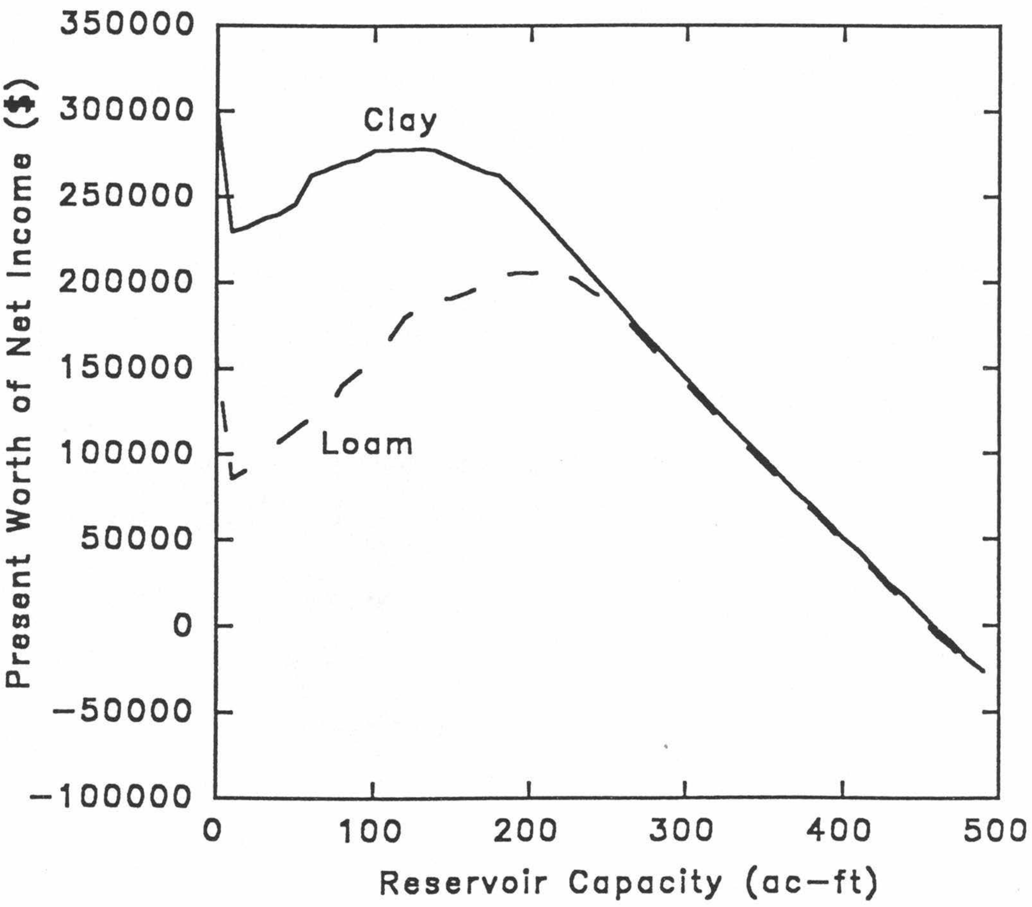

Fig. 5. Present worth of simulated net income vs. reservoir capacity for varying soils.

the characteristics of the soils with respect to evapotranspiration.

Effect of Soybean Price on Optimal Capacity

Soybean prices may be observed to have a small impact on optimal reservoir capacity relative to the other variables addressed. Instead, soybean price acted in conjunction with interest/discount rate combinations to influence present worths fairly uniformly, as may be expected. On inspecting the results of Table 3 for runs 196-210, soybean price may be seen to influence optimal capacity, but only in conjunction with interest/discount rate combinations. Figure 6 demonstrates the impact of soybean price on present worth vs. reservoir capacity for runs 202, 203, and 204. Soybean prices are seen to influence the relationships in much the same manner as interest/discount rates. Soybean prices seem not to affect the best capacity to construct so much as whether one should construct any reservoir. For example, the upper two curves indicate that for soybean prices of \$7.50 and \$6.50/bu, the producer's interests are best served by constructing a reservoir, and the best capacity is 110 ac-ft. The lower curve suggests that for soybean prices of \$5.50/bu, the producer would be better served not to construct a reservoir; if the producer insists, however, then the best capacity would again be 110 ac-ft.

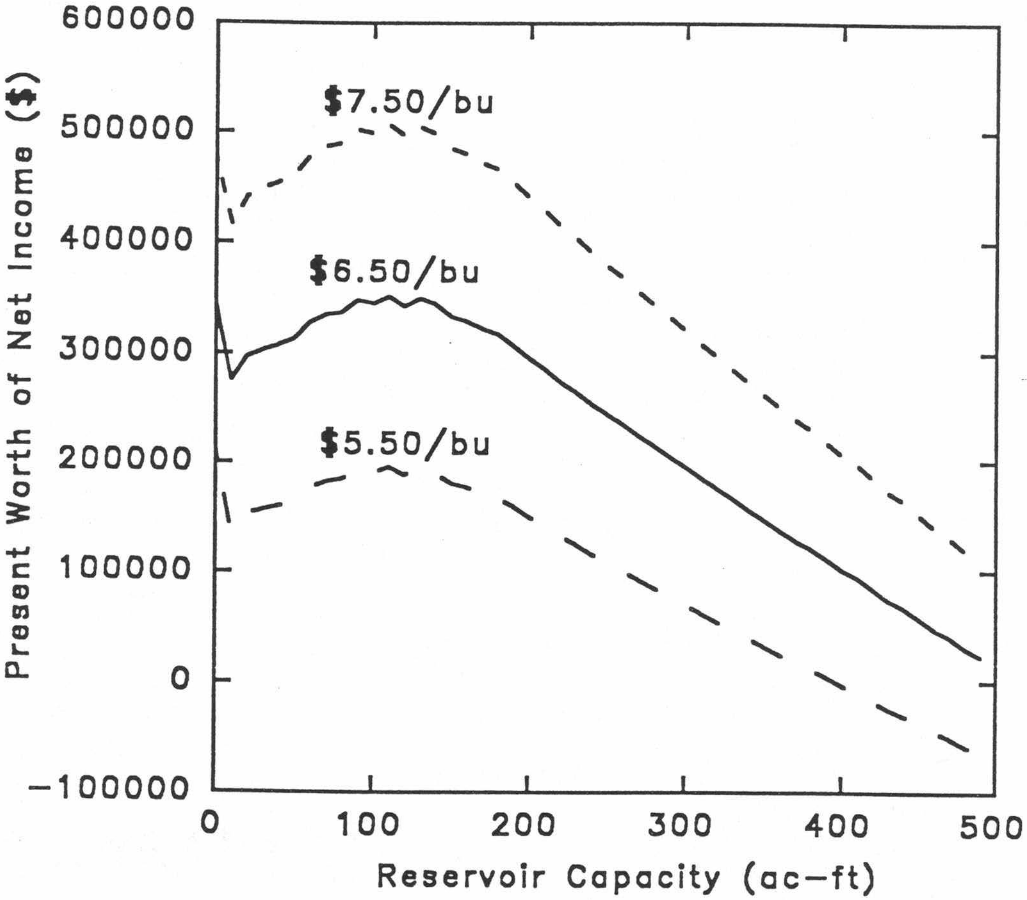

Fig. 6. Present worth of simulated net income vs. reservoir capacity for varying soybean prices.

SUMMARY AND CONCLUSIONS

A computer simulation model was developed to simulate present worth of net income from soybean production systems for conditions varying with respect to ground water availability, offstream reservoir capacity, and many other variables. Additional algorithms were incorporated into the model to enable it to optimize reservoir dimensions given realistic constraints and to identify the reservoir capacity corresponding to maximum present worth of simulated net income. The model was written in FORTRAN programming language and requires significant input data in order to provide significant flexibility with respect to the situations which may be accomodated.

The model was demonstrated using 210 hypothetical situations which varied in terms of ground water availability, initial saturated depth of the aquifer, rate of decline of potentiometric surface, interest/discount rates, soil, and soybean price. The results were very reasonable and clearly point out that all of these variables impact optimal reservoir capacity, although no single variable is the sole determining factor in the decision of whether or not to construct a reservoir. The results further indicate that depending on model accuracy, there are many scenarios in which construction of a reservoir would be to the best interests of a soybean producer - especially those in regions with no ground water available or designated as "critical" with regard to saturated aquifer depth.

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APPENDIX A

ARORA SOURCE CODE

```
$NOTRUNCATE
C     ******************************************************************
C     ******************************************************************
C     PROGRAM ARORA 1 NOVEMBER 1990
C
C     PROGRAM TO MODEL RESERVOIR PERFORMANCE AND TO
C     OPTIMIZE RESERVOIR CHARACTERISTICS
C     ******************************************************************
C     ******************************************************************
C
C     ------------------------------------------------------------------
C     INITIALIZE ARRAYS
C     ------------------------------------------------------------------
      REAL INTRATE,IRRIVOL,IREQ,IRRIGATION,ISYSLAB,LIFTFLOW
      REAL ISYSLCOST,LATSEEP,LTOT,LSEEP,IRRIG(30),OWNEXPENSE(30)
      REAL OPEXPENSE(30),NETINC(30),IRLBS(30),IRLBG(30)
      REAL OPTIM,LAT,LAI,INSRATE,LUBIRRP,ISYSINT,LIFTTDH
      REAL LIMECOST,INSECOST,MFOLCOST,MREPCOST,MISCCOST,OTHRCOST
      REAL MQPDEP,MQPINT,OHLACOST,OTOHCOST,LAPRCOST,MANACOST
      REAL IGWDEPTH,LUBCOST,ISYSCST,ISYSLIFE,ISYSREP,LIFTEFF
      REAL ISYSPRES,LIFTPCST,LIFTLIFE,LIFTREP,LUBLIFTP,IRRTDH
      REAL MAXDEPTH,LIFTPCOST,ISYSCOST,ISYSDEP,ISRPCST
      REAL OPCOST,OPINT,LAIA,IRRFLOW,IRREFF,IRRPCST,IRRPCOST
      REAL IRRLIFE,IRRREP
      DIMENSION XRAIN(30,365),XTMAX(30,365),XTMIN(30,365),XRS(30,365)
      DIMENSION XWIND(30,365),CN(3),PREVP(5),POTTRANSP(30)
      DIMENSION DELTA(5),BA(5), B(5)
      DIMENSION NSIGN(5),LES(5),ICLOSL(5),ICLOSH(5),YINCOME(30)
      DIMENSION RFOLCOST(30),ETS(30),ETW(30),GETS(30),TRAIN(30)
      DIMENSION PGETS(30),GTRAIN(30),PETS(30),PETW(30)
      DIMENSION FVOL(30),TIFOLCOST(30),PWNETINC(30)
      DIMENSION X(2),F(2),A(10,11),XSAVE(10),FSAVE(10),AB(10,11)
      DIMENSION GIVOL(30),SIVOL(30),GPSVOL(30),GIFOLCOST(30)
      DIMENSION SIFOLCOST(30),SPVOL(30),EVPVOL(30),RNVOL(30)
      DIMENSION TRANSP(30),YIELD(30),SUM(20)
      CHARACTER RSTATUS*15,SIMNAME*20,SSTATUS*10,ISTATUS*10,RREM*10
      COMMON AA(18),DDELTA(18),CHECKL(18),CHECKH(18)
      COMMON OPTIM,NUMA,NSTART,NPER,KC,MAXN,ISTOP
      COMMON TMEAN,ELEV,LAI,ALBSOIL,ALBEDOWAT,USOIL,RAINEFF,ALPHASOIL
      COMMON SDEF,RMWTR,EVAPTOT,EVAPPLANT,EVAPSOIL,PVAPS
      ISTOP=0
      NUMA=1
      NPER=0
      MAXN=3000
      KC=5
      NSTART=0
C     ------------------------------------------------------------------
C     READ INITIALIZATION DATA FROM INPUT FILE
C     ------------------------------------------------------------------
      OPEN(2,FILE='INIT2.DAT')
C
C     GENERAL SIMULATION PARAMETERS
C
      READ(2,*) NYEARS
```

```
      READ(2,*) OPTIND
C
C     CROP AND FIELD PARAMETERS
C
      READ(2,*) TFARAC
      READ(2,*) CN2
      READ(2,*) ELEV
      READ(2,*) WAVEMEAN
      READ(2,*) AMPLITUDE
      READ(2,*) PSHIFT
      READ(2,*) ALPHASOIL
      READ(2,*) USOIL
      READ(2,*) ROOTZONE
      READ(2,*) AVAILWAT
      READ(2,*) ALBSOIL
      READ(2,*) IPLANTDATE
      READ(2,*) IMATDATE
      READ(2,*) YIELDMAX
C
C     ECONOMIC PARAMETERS
C
      READ(2,*) INTRATE
      READ(2,*) DISRATE
      READ(2,*) INSRATE
      READ(2,*) TAXRATE
      READ(2,*) SBPRICE
C
C     OPERATING COST PARAMETERS
C
      READ(2,*) SSEEDCOST
      READ(2,*) FERTCOST
      READ(2,*) LIMECOST
      READ(2,*) HERBCOST
      READ(2,*) FUNGCOST
      READ(2,*) INSECOST
      READ(2,*) DEFOCOST
      READ(2,*) AEAPCOST
      READ(2,*) MFOLCOST
      READ(2,*) MREPCOST
      READ(2,*) CLABCOST
      READ(2,*) SPRDCOST
      READ(2,*) HAULCOST
      READ(2,*) DRYGCOST
      READ(2,*) MISCCOST
      READ(2,*) CRINCOST
      READ(2,*) OTHRCOST
C
C     OWNERSHIP COST PARAMETERS
C
      READ(2,*) TRACDEP
      READ(2,*) TRACINT
      READ(2,*) EQUIPDEP
      READ(2,*) EQUIPINT
      READ(2,*) SEQUIPDEP
```

```
      READ(2,*) SEQUIPINT
      READ(2,*) MQPDEP
      READ(2,*) MQPINT
      READ(2,*) TAXINS
      READ(2,*) COMINT
      READ(2,*) OHLACOST
      READ(2,*) OTOHCOST
      READ(2,*) LAPRCOST
      READ(2,*) MANACOST
C
C     GROUND WATER PARAMETERS
C
      READ(2,*) IGWDEPTH
      READ(2,*) GWDECLINE
      READ(2,*) STORCON
      READ(2,*) GWKSAT
      READ(2,*) SATDEPTH
      READ(2,*) WELLDIAM
      READ(2,*) WELLCOST
      READ(2,*) WELLLIFE
      READ(2,*) WELLREP
      READ(2,*) WELLFLW
      READ(2,*) WELLEFF
      READ(2,*) PUMPCOST
      READ(2,*) PUMPLIFE
      READ(2,*) PUMPREP
      READ(2,*) DISDIAM
      READ(2,*) POWCOST
      READ(2,*) POWLIFE
      READ(2,*) POWREP
      READ(2,*) FUELCOST
      READ(2,*) LUBCOST
C
C     IRRIGATION SYSTEM PARAMETERS
C
      READ(2,*) APPEFF
      READ(2,*) ISYSCST
      READ(2,*) ISYSLIFE
      READ(2,*) ISYSREP
      READ(2,*) ISYSLAB
      READ(2,*) ISYSLCOST
      READ(2,*) ISYSPRES
      READ(2,*) CRITSMD
C
C     RESERVOIR PARAMETERS
C
      READ(2,*) FBD
      READ(2,*) TWD
      READ(2,*) XN1
      READ(2,*) XN2
      READ(2,*) EXCST
      READ(2,*) SEEDCST
      READ(2,*) RESLIFE
      READ(2,*) RESMAINT
```

```
      READ(2,*) SEEP
      READ(2,*) ALBEDOWAT
      READ(2,*) IBEGFILL
C
C     RELIFT AND IRRIGATION PUMP PARAMETERS
C
      READ(2,*) LIFTTDH
      READ(2,*) LIFTFLOW
      READ(2,*) LIFTEFF
      READ(2,*) LIFTPCST
      READ(2,*) LIFTLIFE
      READ(2,*) LIFTREP
      READ(2,*) LUBLIFTP
      READ(2,*) IRRTDH
      READ(2,*) IRRFLOW
      READ(2,*) IRREFF
      READ(2,*) IRRPCST
      READ(2,*) IRRLIFE
      READ(2,*) IRRREP
      READ(2,*) LUBIRRP
C
C     OPTIMIZATION PARAMETERS
C
      READ(2,*) AA(1)
      READ(2,*) DDELTA(1)
      READ(2,*) CHECKL(1)
      READ(2,*) CHECKH(1)
      CLOSE (2,STATUS='KEEP')
C
C     READ WEATHER DATA
C
      OPEN(2,FILE='WEATHER.DAT')
      DO 87 IIYEAR=1,NYEARS
         DO 88 IIDAY=1,365
888         READ(2,*) LA,LB,LC,LD,XRAIN(IIYEAR,IIDAY),
     &      XTMAX(IIYEAR,IIDAY),XTMIN(IIYEAR,IIDAY),XRS(IIYEAR,IIDAY),
     &      XWIND(IIYEAR,IIDAY)
            IF((LA.EQ.2).AND.(LB.EQ.29)) GO TO 888
88       CONTINUE
87    CONTINUE
      CLOSE(2,STATUS='KEEP')
C     -----------------------------------------------------------------
C     MAKE CONVERSIONS
C     -----------------------------------------------------------------
      SEEDCST=SEEDCST/43560.0
      TFAREA=TFARAC*43560.0
      ELEV=ELEV*.3048
      AA(1)=AA(1)*43560.0
      DDELTA(1)=DDELTA(1)*43560.0
      CHECKL(1)=CHECKL(1)*43560.0
      CHECKH(1)=CHECKH(1)*43560.0
      TRANS=GWKSAT*SATDEPTH
      IRRFLOW=IRRFLOW*60.0*24.0*0.1337
      WELLFLW=WELLFLW*60.0*24.0*0.1337
```

```
      LIFTFLOW=LIFTFLOW*60.0*24.0*0.1337
      RMWTR=ROOTZONE*AVAILWAT*25.4
      CN(2)=CN2
      CN(1)=(4.2*CN(2))/(10.0-(0.058*CN(2)))
      CN(3)=(23.0*CN(2))/(10.0+(0.13*CN(2)))
C     ------------------------------------------------------------------
C     COMPUTE DEPRECIATION AND INTEREST COSTS ASSOCIATED WITH WELL
C     ------------------------------------------------------------------
      IF (WELLFLW.LE.0.) THEN
         WELLCOST=0.0
         POWCOST=0.0
         PUMPCOST=0.0
      ENDIF
      WDEP=WELLCOST/WELLLIFE
      WINT=(WELLCOST/2.0)*INTRATE
      POWDEP=POWCOST/POWLIFE
      POWINT=(POWCOST/2.0)*INTRATE
      PUMPDEP=PUMPCOST/PUMPLIFE
      PUMPINT=(PUMPCOST/2.0)*INTRATE
C     ------------------------------------------------------------------
C     COMPUTE REPAIR COSTS ASSOCIATED WITH WELL
C     ------------------------------------------------------------------
      WREPCOST=WELLCOST*WELLREP
      POWREPCOST=POWCOST*POWREP
      PUMPREPCOST=PUMPCOST*PUMPREP
      GWREPCOST=WREPCOST+POWREPCOST+PUMPREPCOST
C     ------------------------------------------------------------------
C     IF NO RESERVOIR, THEN ZERO THE COSTS ASSOCIATED WITH THE RESERVOIR
C     ------------------------------------------------------------------
1960  EXDEPTH=3.0
      IF(AA(1).GT.0.) GO TO 2030
      CONCOST=0.
      SDCOST=0.
      EXCOST=0.
      SEEDCOST=0.
      FAREA=TFAREA
      RESDEP=0.
      LFTPDEP=0.
      SIRPDEP=0.
      RESINT=0.
      LFTPINT=0.
      SIRPINT=0.
      RESTX=0.
      RESTXI=0.
      FAREAC=TFARAC
      LIFTPCOST=0.
      IRRPCOST=0.
      GO TO 2320
C     ------------------------------------------------------------------
C     CALL SUBROUTINE TO DETERMINE RESERVOIR DIMENSIONS GIVEN CAPACITY
C     ------------------------------------------------------------------
2030  X(1)=900.0
      X(2)=10.0
      CALL NONLIN(X,XN1,XN2,FBD,TWD,EXDEPTH)
```

```
      MAXDEPTH=EXDEPTH+X(2)
      IF(MAXDEPTH.LT.5.0) THEN
        EXDEPTH=EXDEPTH+0.01
        GO TO 2030
      ENDIF
      IF(MAXDEPTH.GT.6.0) THEN
         EXDEPTH=EXDEPTH-0.01
         GO TO 2030
      ENDIF
C     -----------------------------------------------------------------
C     COMPUTE ANNUAL RESERVOIR OWNERSHIP COSTS BASED ON DIMENSIONS
C     AND CAPACITY
C     -----------------------------------------------------------------
      EXCOST=EXCST
      SEEDCOST=SEEDCST
      MAXDEPTH = EXDEPTH+X(2)
      RT4=.5*(XN1+XN2)*(FBD+X(2))**2.0+TWD*(X(2)+FBD)
      RT5= X(1) + XN2*(EXDEPTH+X(2)+FBD) + TWD + XN1*(X(2)+FBD)
      XA=4.0*RT4*RT5/27.0
      CONCOST=XA*EXCOST
      ASD1=4.0*(((EXDEPTH+X(2)+FBD)**2.0+(XN2*(EXDEPTH+X(2)+FBD))**
     & 2.0)**0.5)
     &*(X(1)+(EXDEPTH+X(2)+FBD)*XN2)
      ASD2=4.0*TWD*(X(1)+XN2*(EXDEPTH+X(2)+FBD)+TWD)
      ASD3=4.0*(((X(2)+FBD)**2.0+(XN1*(X(2)+FBD))**2.0)**0.5)*(X(1)+
     &(EXDEPTH+X(2)+FBD)*XN2+TWD+XN1*(X(2)+FBD))
      SDCOST=SEEDCOST*(ASD1+ASD2+ASD3)
      XA=10.0+X(1)+(EXDEPTH+X(2)+FBD)*XN2+TWD+(X(2)+FBD)*XN1
      AFGP=XA**2.0
      FAREA=TFAREA-AFGP
      FAREAC=FAREA/43560.0
      LIFTPCOST=LIFTPCST
      IRRPCOST=IRRPCST
      RESDEP=(CONCOST+SDCOST)/RESLIFE
      LFTPDEP=LIFTPCOST/LIFTLIFE
      SIRPDEP=IRRPCOST/IRRLIFE
      RESINT=((CONCOST+SDCOST)/2.0)*INTRATE
      LFTPINT=(LIFTPCOST/2.0)*INTRATE
      SIRPINT=(IRRPCOST/2.0)*INTRATE
      RESTX=(CONCOST+SDCOST+LIFTPCOST+IRRPCOST)*(TAXRATE+INSRATE)
      RESTXI=RESTX+(INTRATE*RESTX)
      RESOWNCOST=RESDEP+LFTPDEP+SIRPDEP+RESINT+LFTPINT+SIRPINT+RESTXI
      RESMAINTCOST=RESMAINT*(CONCOST+SDCOST)
      SURFREPCOST=LIFTREP*LIFTPCOST+IRRREP*IRRPCOST
C     -----------------------------------------------------------------
C     COMPUTE IRRIGATION SYSTEM DEPRECIATION AND INTEREST COSTS
C     -----------------------------------------------------------------
2320  IF((AA(1).LE.0.).AND.(WELLFLW.LE.0.)) ISYSCOST=0.
      IF((AA(1).GT.0.).OR.(WELLFLW.GT.0.)) ISYSCOST=ISYSCST
      ISYSDEP=ISYSCOST/ISYSLIFE
      ISYSINT=(ISYSCOST/2.0)*INTRATE
      ISRPCST=ISYSCOST*ISYSREP
C     -----------------------------------------------------------------
C     COMPUTE OWNERSHIP AND OPERATING COSTS EXCLUSIVE OF RESERVOIR AND
```

```
C     IRRIGATION
C     ------------------------------------------------------------------
      TOTALDEP=FAREAC*(TRACDEP+EQUIPDEP+SEQUIPDEP+MQPDEP)+ISYSDEP+
     &WDEP+POWDEP+PUMPDEP
      TOTALINT=FAREAC*(TRACINT+EQUIPINT+SEQUIPINT+MQPINT)+ISYSINT+
     &WINT+POWINT+PUMPINT
      TOTALTXI=(TAXINS*FAREAC)+((WELLCOST+POWCOST+PUMPCOST+ISYSCOST)*
     &(INSRATE+TAXRATE))
      TOTALINT2=TOTALINT+(COMINT*FAREAC)+(TOTALTXI-(TAXINS*FAREAC))*
     &INTRATE
      TOWNCOST=TOTALDEP+TOTALTXI+TOTALINT2+FAREAC*(OHLACOST+OTOHCOST+
     &MANACOST)+(LAPRCOST*TFARAC)
      OPCOST=FAREAC*(SSEEDCOST+FERTCOST+LIMECOST+HERBCOST+FUNGCOST+
     &INSECOST+DEFOCOST)
      OPCOST=OPCOST+FAREAC*(AEAPCOST+MFOLCOST+MREPCOST+CLABCOST+
     &SPRDCOST+MISCCOST+CRINCOST)
      OPCOST=OPCOST+(FAREAC*OTHRCOST)+GWREPCOST+ISRPCST
      OPINT=(OPCOST/2.0)*INTRATE
      TOPCOST=OPCOST+OPINT
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
C     BEGIN MAIN PROGRAM
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
      SDEF=0.0
      RELEV=0.0
      CAVAIL=0.0
      ANTMOIST=0.0
C     ------------------------------------------------------------------
C     INITIALIZATIONS FOR ANNUAL LOOPS
C     ------------------------------------------------------------------
      DO 2400 IYEAR=1,NYEARS
      IRFIL=0
      IIND=0
      GPIND=0.
      IAGIND=0
      TPUMP=0.
      TREC=0.
      TPPUMP=0.
      DDN=0.
      IARIND=0
      GTDH=IGWDEPTH+FLOAT(IYEAR-1)*GWDECLINE
      DSAT=SATDEPTH-(FLOAT(IYEAR-1)*GWDECLINE)
      IF(DSAT.LE.0.) THEN
         WELLFLOW=0.
         OPCOST=FAREAC*(SSEEDCOST+FERTCOST+LIMECOST+HERBCOST+FUNGCOST+
     &   INSECOST+DEFOCOST)
         OPCOST=OPCOST+FAREAC*(AEAPCOST+MFOLCOST+MREPCOST+CLABCOST+
     &   SPRDCOST+MISCCOST+CRINCOST)
         IF(AA(1).GT.0.) THEN
            OPCOST=OPCOST+(FAREAC*OTHRCOST)+ISRPCST
         ELSE
            OPCOST=OPCOST+(FAREAC*OTHRCOST)
         ENDIF
```

```
         OPINT=(OPCOST/2.0)*INTRATE
         TOPCOST=OPCOST+OPINT
      ELSE
         WELLFLOW=WELLFLW
      ENDIF
      IF(DSAT.GT.0.) ISWELL=0
      IF(DSAT.LE.0.) ISWELL=1
      TRANS=GWKSAT*DSAT
      GWLEV=GTDH
C     ----------------------------------------------------------------
C     INITIALIZATIONS FOR DAILY LOOPS
C     ----------------------------------------------------------------
      DO 2490 IDAY=1,365
      IRRIGATION = 0.0
      IDAP = IDAY-IPLANTDATE
      IF(IDAP.LE.0) IDAP=0
      IDPP=INT((FLOAT(IDAP)/FLOAT(IMATDATE))*125.0)
      CALL XLEAREA(IDPP,LAI)
C     ----------------------------------------------------------------
C     SUBTRACT RUNOFF
C     ----------------------------------------------------------------
      RAIN=XRAIN(IYEAR,IDAY)
      ANTMOIST=PREVP(5)+PREVP(4)+PREVP(3)+PREVP(2)+PREVP(1)
      PREVP(5)=PREVP(4)
      PREVP(4)=PREVP(3)
      PREVP(3)=PREVP(2)
      PREVP(2)=PREVP(1)
      PREVP(1)=RAIN
      IF((IDAY.LT.80).OR.(IDAY.GT.262)) ISEASON=1
      IF((IDAY.GE.80).AND.(IDAY.LE.263)) ISEASON=2
      IF((ANTMOIST.LT.0.5).AND.(ISEASON.EQ.1)) IAMC=1
      IF((ANTMOIST.GE.0.5).AND.(ANTMOIST.LE.1.1).AND.(ISEASON.EQ.1))
     +IAMC=2
      IF((ANTMOIST.GE.1.1).AND.(ISEASON.EQ.1)) IAMC=3
      IF((ANTMOIST.LT.1.4).AND.(ISEASON.EQ.2)) IAMC=1
      IF((ANTMOIST.GE.1.4).AND.(ANTMOIST.LE.2.1).AND.(ISEASON.EQ.2))
     +IAMC=2
      IF((ANTMOIST.GE.2.1).AND.(ISEASON.EQ.2)) IAMC=3
      CVN=CN(IAMC)
      SCN=(1000.0/CVN)-10.0
      STEST=0.2*SCN
      IF(RAIN.LE.STEST) GO TO 2321
      RNOFF=((RAIN-0.2*SCN)**2.0)/(RAIN+0.8*SCN)
      RAIN=RAIN-RNOFF
C     ----------------------------------------------------------------
C     MAKE METRIC AND OTHER CONVERSIONS OF WEATHER DATA
C     ----------------------------------------------------------------
2321  TMAX=XTMAX(IYEAR,IDAY)
      TMIN=XTMIN(IYEAR,IDAY)
      RS=XRS(IYEAR,IDAY)
      WIND=XWIND(IYEAR,IDAY)
      TMAX=(5.0/9.0)*(TMAX-32.0)
      TMIN=(5.0/9.0)*(TMIN-32.0)
      TMEAN=(TMAX+TMIN)/2.0
```

```
      WIND=WIND*1.609*1.27
      RS=RS/59.0
      RAIN=RAIN*25.4
C     ------------------------------------------------------------------
C     CHECK WHETHER TO ALLOW RESERVOIR FILL
C     ------------------------------------------------------------------
      IF((AA(1).LE.0.).OR.(IDAY.LE.IBEGFILL)
     &.OR.(CAVAIL.GT.AA(1)).OR.(IRFIL.EQ.1)) THEN
         RSVRVOL=0.
         RSTATUS='               '
         GO TO 2780
      ENDIF
C     ------------------------------------------------------------------
C     ALLOW FILL, COMPUTE COSTS
C     ------------------------------------------------------------------
      RSTATUS='*** FILLING ***'
      RSVRVOL=LIFTFLOW
      IF(RSVRVOL.GT.(AA(1)-CAVAIL)) THEN
         RSVRVOL=(AA(1)-CAVAIL)
         IRFIL=1
      ENDIF
      RENERGY=(RSVRVOL*62.4*LIFTTDH/LIFTEFF)*((.0003766)/1000.0)
      CFIL=RENERGY*FUELCOST
      FVOL(IYEAR)=FVOL(IYEAR)+RSVRVOL
      RFOLCOST(IYEAR) = RFOLCOST(IYEAR)+(1.0+LUBLIFTP)*CFIL
C     ------------------------------------------------------------------
C     DETERMINE WHETHER TO ALLOW RECHARGE OF AQUIFER
C     ------------------------------------------------------------------
2780  IF(WELLFLOW.EQ.0.) GO TO 3050
      IF(ISWELL.EQ.1) GO TO 2920
      IF((IAGIND.EQ.1).AND.(IIND.EQ.1).AND.(RAIN.GT.0.)) GO TO 2920
      IF((IAGIND.EQ.1).AND.(IIND.EQ.1).AND.(IDAY.GT.(IPLANTDATE+
     &IMATDATE)))GO TO 2920
      IF((IAGIND.EQ.1).AND.(IIND.EQ.0).AND.(SDEF.LT.CRITSMD)) GO TO 2920
      IF((IAGIND.EQ.1).AND.(IIND.EQ.1).AND.(SSTATUS.EQ.'SU')) GO TO 2880
      GO TO 3050
2880  IF((SDEF.GT.CRITSMD).AND.(IIND.EQ.0)) GO TO 3050
C     ------------------------------------------------------------------
C     ALLOW RECHARGE OF AQUIFER
C     ------------------------------------------------------------------
2920  IARIND = 1
      TREC=TREC+1.0
      TPPUMP=TPPUMP+1.0
      UG1=(((WELLDIAM/2.0)**2.0)*STORCON)/(4.0*TRANS*TPPUMP)
      UG2=(((WELLDIAM/2.0)**2.0)*STORCON)/(4.0*TRANS*TREC)
      WU1 = -.5772-(ALOG(UG1))+UG1-((UG1**2.0)/4.0)+((UG1**3.0)/18.0)
      WU2 = -.5772-(ALOG(UG2))+UG2-((UG2**2.0)/4.0)+((UG2**3.0)/18.0)
      DDN = (WELLFLOW*(WU1-WU2))/(12.57*TRANS)
      TPUMP = 0.0
C     ------------------------------------------------------------------
C     DETERMINE WHETHER TO IRRIGATE
C     ------------------------------------------------------------------
3050  IF((AA(1).LE.0.).AND.(WELLFLOW.LE.0.)) GO TO 4230
      IF((RAIN.GT.0.).OR.(IDAY.LT.IPLANTDATE).OR.(IDAY.GT.(IPLANTDATE+
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     &IMATDATE))) THEN
         IRRIVOL=0.
         ISTATUS= '  '
         SSTATUS= '  '
         SSUP=0.
         GSUP=0.
         GO TO 4230
      ENDIF
      IF((SDEF.LT.CRITSMD).AND.(IIND.EQ.0)) THEN
         SSUP=0.
         GSUP=0.
         IRRIVOL=0.
         SSTATUS= '  '
         GO TO 4230
      ENDIF
C     -----------------------------------------------------------------
C     IRRIGATE
C     -----------------------------------------------------------------
      IIND=1
C     -----------------------------------------------------------------
C     COMPUTE REQUIRED IRRIGATION VOLUME, DETERMINE WHETHER RESERVOIR
C     CAPACITY IS SUFFICIENT TO MEET IRRIGATION REQUIREMENT
C     -----------------------------------------------------------------
      IREQ=(SDEF*FAREA)/(25.4*12.0*APPEFF)
      IF(IRRFLOW.LT.CAVAIL) GO TO 3230
      IF((IRRFLOW.GE.CAVAIL).AND.(CAVAIL.GE.IREQ)) GO TO 3230
      GO TO 3310
C     -----------------------------------------------------------------
C     USE SURFACE WATER TO IRRIGATE
C     -----------------------------------------------------------------
3230  SSUP = IRRFLOW
      SSTATUS= 'SU'
      IF(IRRFLOW.GT.IREQ) THEN
         SSUP=IREQ
         IIND=0
      ENDIF
      GSUP = 0.0
      GO TO 4060
C     -----------------------------------------------------------------
C     USE AT LEAST SOME GROUND WATER TO IRRIGATE
C     -----------------------------------------------------------------
3310  IF(WELLFLOW.EQ.0.) GO TO 4060
      IAGIND = 1
C     -----------------------------------------------------------------
C     DETERMINE WHETHER WELL PUMPED DRY PREVIOUS DAY.  IF SO, NO
C     GROUND WATER FOR IRRIGATION
C     -----------------------------------------------------------------
      IF(ISWELL.EQ.1) THEN
         SSUP=CAVAIL
         GSUP=0.
         ISWELL=0
         SSTATUS= '  '
         T1=0.0
         GO TO 4060
```

```
      ENDIF
C     -----------------------------------------------------------------
C     DETERMINE WHETHER A NEW EQUIVALENT PUMPING TIME SHOULD BE COMPUTED
C     -----------------------------------------------------------------
      IF(DDN.EQ.0.) THEN
         TPUMP=0.
         GO TO 3610
      ENDIF
      IF(IARIND.EQ.0) GO TO 3610
      IF((IIND.EQ.1).AND.(SSTATUS.EQ.'GW')) GO TO 3610
C     -----------------------------------------------------------------
C     DETERMINE NEW EQUIVALENT PUMPING TIME
C     -----------------------------------------------------------------
      GPT1=0.0
      FU=0.0
3540  GPT1=GPT1+1.0
      AWELLFLOW=WELLFLOW/1440.0
      ATRANS=TRANS/1440.0
      GALPH=AWELLFLOW/(12.57*ATRANS)
      GU=(((WELLDIAM/2.0)**2.0)*STORCON)/(4.0*ATRANS*GPT1)
      FU=GALPH*(-.5772-(ALOG(GU))+GU-((GU**2.0)/4.0)+((GU**3.0)/18.0))
      IF(FU.LT.DDN) GO TO 3540
      IF(GPT1.EQ.1.0) THEN
         GPT1=0.0
         GO TO 3570
      ENDIF
      GPT1=(2.0*GPT1-1.0)/2.0
3570  TPUMP=GPT1/1440.0
C     -----------------------------------------------------------------
C     SEE IF FULL DAY'S PUMPING IS TOO MUCH TO MEET NEED
C     -----------------------------------------------------------------
3610  SSTATUS = 'GW'
      SSUP=CAVAIL
      GSUP=WELLFLOW
      TREC=0.0
      IF((SSUP+GSUP).LE.IREQ) GO TO 3710
      GSUP=IREQ-SSUP
      T1 = TPUMP
      T2=TPUMP+(GSUP/WELLFLOW)
      TPUMP=T2
      IIND=0
      GO TO 3730
3710  T1 = TPUMP
      T2=TPUMP+1.0
      TPUMP=T2
3730  TPPUMP = TPUMP
C     -----------------------------------------------------------------
C     COMPUTE DRAWDOWN IN WELL
C     -----------------------------------------------------------------
      UG=((WELLDIAM/2.0)**2.0*STORCON)/(4.0*TRANS*TPUMP)
      WU=-.5772-(ALOG(UG))+UG-((UG**2.0)/4.0)+((UG**3.0)/18.0)
      ZDN=(WELLFLOW*WU)/(12.57*TRANS)
      AVHD=(DDN+ZDN)/2.0
      DDN=ZDN
```

```
C     ------------------------------------------------------------------
C     CHECK TO SEE WHETHER DRAWDOWN EXCEEDS SATURATED THICKNESS OF
C     AQUIFER.  IF SO, ADJUST DRAWDOWN AND SET WELL INDICATOR TO
C     DRY STATUS
C     ------------------------------------------------------------------
      IF(DDN.LT. DSAT) GO TO 4060
      RREM = 'DRY WELL'
      AWELLFLOW=WELLFLOW/1440.0
      ATRANS = TRANS/1440.0
      FU=0.0
      DDN=DSAT
      ISWELL=1
      GPT1 = T1 * 1440.0
3970  GPT1 = GPT1 + 1.0
      GALPH = AWELLFLOW / (12.57 * ATRANS)
      GU = ((WELLDIAM/2.0)**2.0*STORCON)/(4.0*ATRANS*GPT1)
      FU=GALPH*(-.5772-(ALOG(GU))+GU-((GU**2.0)/4.0)+((GU**3.0)/18.0))
      IF(FU.LT.DDN) GO TO 3970
      IF(GPT1.EQ.1.) THEN
         GPT1=T1*1440.0
         GO TO 4000
      ENDIF
      GPT1=(2.0*GPT1-1.0)/2.0
4000  GSUP=AWELLFLOW*(GPT1-(T1*1440.0))
      TPUMP=GPT1/1440.0
      TPPUMP=TPUMP
C     ------------------------------------------------------------------
C     COMPUTE ENERGY AND COSTS ASSOCIATED WITH PROVIDING IRRIGATION
C     ------------------------------------------------------------------
4060  IRRIVOL=SSUP+GSUP
      IRRIGATION=(IRRIVOL*APPEFF*12.0*25.4)/FAREA
      GENERGY=(GSUP*62.4*(GTDH+IRRTDH+AVHD)/WELLEFF)*((.0003766)/1000.0)
      SENERGY=(SSUP*62.4*(MAXDEPTH+FBD+IRRTDH)
     &/IRREFF)*((.0003766)/1000.0)
      GIVOL(IYEAR)=GIVOL(IYEAR)+GSUP
      SIVOL(IYEAR)=SIVOL(IYEAR)+SSUP
      GPSVOL(IYEAR)=GPSVOL(IYEAR)+GSUP+SSUP
      GIFOLCOST(IYEAR)=GIFOLCOST(IYEAR)+(1.0+LUBCOST)*GENERGY*FUELCOST
      SIFOLCOST(IYEAR)=SIFOLCOST(IYEAR)+(1+LUBIRRP)*SENERGY*FUELCOST
      TIFOLCOST(IYEAR)=TIFOLCOST(IYEAR)+(GENERGY+SENERGY)*FUELCOST*(1.0
     &+LUBCOST)
      HRSLABS=(SSUP*12.0/43560.0)*ISYSLAB
      HRSLABG=(GSUP*12.0/43560.0)*ISYSLAB
      IRLBS(IYEAR)=IRLBS(IYEAR)+HRSLABS*ISYSLCOST
      IRLBG(IYEAR)=IRLBG(IYEAR)+HRSLABG*ISYSLCOST
C     ------------------------------------------------------------------
C     COMPUTE EFFECTIVE RAINFALL FOR RITCHIE'S ET ALGORITHM
C     ------------------------------------------------------------------
4230  RAINEFF=RAIN+IRRIGATION
C     ------------------------------------------------------------------
C     USE RITCHIES ALGORITHM TO COMPUTE CROP ET AND RESERVOIR
C     EVAPORATION
C     ------------------------------------------------------------------
C
```

```
C     ------------------------------------------------------------------
C     COMPUTE DEL, GAM
C     ------------------------------------------------------------------
      LAT=595.0-0.51*TMEAN
      PRE=1013.0-0.1055*ELEV
      GAM=(.386*PRE)/LAT
      DEL=2.0*((0.00738*TMEAN+.8072)**7.0)-0.00116
C     ------------------------------------------------------------------
C     COMPUTE SURFACE ALBEDO
C     ------------------------------------------------------------------
      IF(LAI.GT.4.) LAIA=4.0
      ALBEDO=ALBSOIL+0.25*(0.23-ALBSOIL)*LAIA
C     ------------------------------------------------------------------
C     COMPUTE SATURATION VAPOR PRESSURES
C     ------------------------------------------------------------------
      T=TMEAN
      F1=(0.00738*T+0.8072)**8.0
      F2=((1.8*T+48.0)**2.0)**0.5
      EO=33.8639*(F1-0.000019*F2+0.001316)
      T=TMIN
      F1=(0.00738*T+0.8072)**8.0
      F2=((1.8*T+48.0)**2.0)**0.5
      EA=33.8639*(F1-0.000019*F2+0.001316)
C     ------------------------------------------------------------------
C     COMPUTE NET SOLAR RADIATION ABOVE CANOPY AND AT SOIL SURFACE
C     ------------------------------------------------------------------
C
C     LONG WAVE LOSSES
C
      EPS=(0.35-0.046*(EA)**0.5)
      RBO=EPS*1.171E-07*((TMEAN+273.0)**4.0)
      RBO=RBO/59.0
      RSO=WAVEMEAN+AMPLITUDE*SIN((6.28*FLOAT(IDAY)/365.0)-PSHIFT)
      RSO=RSO/59.0
      RAT=RS/RSO
      IF(RAT.GT.1.) RAT=1.0
      RB=RBO*(1.35*RAT-0.35)
C
C     NET RADIATION
C
      RNET=(RS*(1.0-ALBEDO))-RB
      RNETW=(RS*(1.0-ALBEDOWAT))-RB
      RNETSOIL=(RNET*EXP(-0.398 * LAI))
C     ------------------------------------------------------------------
C     COMPUTE TOTAL POTENTIAL EVAPORATION
C     ------------------------------------------------------------------
      F1=(DEL/GAM)*RNET
      F1W=(DEL/GAM)*RNETW
      F2=0.262*((1.0+0.0061*WIND)*(EO-EA))
      F3=((DEL/GAM)+1.0)**(-1.0)
      POTEVAP=((F1+F2)*F3)
      PVAPW=((F1W+F2)*F3)
C     ------------------------------------------------------------------
C     COMPUTE POTENTIAL EVAPORATION FROM SOIL
```

```
C     ------------------------------------------------------------------
      PVAPS=(DEL/(DEL+GAM))*RNETSOIL
C     ------------------------------------------------------------------
C     MAKE RITCHIE'S MODIFICATION TO PVAPS
C     ------------------------------------------------------------------
      ALPHA=0.92+0.4*(RNETSOIL/RNET)
      PVAPS=ALPHA*PVAPS
C     ------------------------------------------------------------------
C     LOGIC TO DETERMINE ACTUAL SOIL EVAPORATION AND PLANT TRANSPIRATION
C     ------------------------------------------------------------------
      IF(SUMS1.GT.USOIL) GO TO 9000
      IF(RAINEFF.GE.SUMS1) SUMS1=0.0
      IF(RAINEFF.LT.SUMS1) SUMS1=SUMS1-RAINEFF
8920  SUMS1=SUMS1+PVAPS
      IF(SUMS1.GT.USOIL) GO TO 8960
      EVAPSOIL=PVAPS
      GO TO 9160
8960  EVAPSOIL=PVAPS-0.4*(SUMS1-USOIL)
      SUMS2=0.6*(SUMS1-USOIL)
      TS2=(SUMS2/ALPHASOIL)**2.0
      GO TO 9160
9000  IF (RAINEFF.LT.SUMS2) GO TO 9050
      RAINEFF=RAINEFF-SUMS2
      SUMS1=USOIL-RAINEFF
      IF (RAINEFF.GT.USOIL) SUMS1 = 0.0
      GO TO 8920
9050  TS2=TS2+1.0
      EVAPSOIL=(ALPHASOIL*(TS2**0.5))-(ALPHASOIL*((TS2-1.0)**0.5))
      IF (RAINEFF.EQ.0.) GO TO 9130
      ESX=0.8*RAINEFF
      IF (ESX.LE.EVAPSOIL) ESX=EVAPSOIL+RAINEFF
      IF (ESX.GT.PVAPS) ESX=PVAPS
      EVAPSOIL=ESX
      GO TO 9140
9130  IF (EVAPSOIL.GT.PVAPS) EVAPSOIL=PVAPS
9140  SUMS2=SUMS2+EVAPSOIL-RAINEFF
      TS2=(SUMS2/ALPHASOIL)**2.0
9160  IF (LAI.LT.0.1) THEN
         POTEVAPPLANT=0.0
         EVAPPLANT=0.0
         GO TO 9220
      ENDIF
      IF((LAI.GE.2.7).AND.(SDEF.LT.(0.75*RMWTR))) THEN
         POTEVAPPLANT=POTEVAP-EVAPSOIL
         EVAPPLANT=POTEVAP-EVAPSOIL
         GO TO 9220
      ENDIF
      IF((LAI.GE.2.7).AND.(SDEF.GE.(0.75*RMWTR))) THEN
         POTEVAPPLANT=POTEVAP-EVAPSOIL
         EVAPPLANT=4.0*POTEVAP*((RMWTR-SDEF)/RMWTR)
         GO TO 9210
      ENDIF
      IF(SDEF.LT.(0.75*RMWTR)) THEN
         EVAPPLANT=POTEVAP*(-0.21+0.7*LAI**0.5)
```

```
         POTEVAPPLANT=EVAPPLANT
      ENDIF
      IF(SDEF.GT.(0.75*RMWTR)) THEN
         EVAPPLANT=4.0*POTEVAP*((RMWTR-SDEF)/RMWTR)*(-0.21+0.7*LAI**0.5)
         POTEVAPPLANT=POTEVAP*(-0.21+0.7*LAI**0.5)
      ENDIF
9210  IF(EVAPPLANT.GT.(POTEVAP-EVAPSOIL)) THEN
         EVAPPLANT=POTEVAP-EVAPSOIL
         POTEVAPPLANT=EVAPPLANT
      ENDIF
9220  EVAPTOT=EVAPPLANT+EVAPSOIL
C     -----------------------------------------------------------------
C     UPDATE SOIL MOISTURE DEFICIT
C     -----------------------------------------------------------------
      SDEF=SDEF-RAIN-IRRIGATION+EVAPTOT
      IF(SDEF.LT.0.) THEN
         SDEF=0.0
         IIND=0
      ENDIF
      IF(SDEF.GE.RMWTR) SDEF=RMWTR
C     -----------------------------------------------------------------
C     UPDATE RESERVOIR LEVEL
C     -----------------------------------------------------------------
      IF(AA(1).LE.0.) GO TO 4640
      RAINVOL=((X(1)+((EXDEPTH+X(2)+FBD)*XN2*2.0))**2.0)*RAIN/304.8
      IF (RELEV.GE.EXDEPTH) THEN
         VSEEPAREA=(X(1)+2.0*EXDEPTH*XN2)**2.0
      ELSE
         VSEEPAREA=(X(1)+2.0*RELEV*XN2)**2.0
      ENDIF
      VSEEPVOL=SEEP*VSEEPAREA
      IF(RELEV.LE.EXDEPTH) THEN
         LATSEEP=0.0
         GO TO 4510
      ENDIF
      XM=(RELEV-EXDEPTH)*XN2
      E=(RELEV-EXDEPTH)/3.0
      E2=(E/2.0)*XN1
      LTOT=((X(2)+FBD)*XN2)+TWD+((X(2)+FBD)*XN1)
      LSEEP=LTOT-XM+0.3*XM-E2
      QUNIT=(4.0*SEEP*(RELEV-EXDEPTH)**2.0)/(9.0*LSEEP)
      SEEPLENGTH=4.0*(X(1)+((RELEV-EXDEPTH)*XN2))
      LATSEEP=QUNIT*SEEPLENGTH
4510  SEEPVOL=VSEEPVOL+LATSEEP
      EVAPVOL=((X(1)+(RELEV*XN2*2.0))**2.0)*(PVAPW/304.8)
      DELTVOL=RAINVOL+RSVRVOL-SSUP-SEEPVOL-EVAPVOL
      IF((CAVAIL+DELTVOL).LE.0.) THEN
         CAVAIL=0.0
         RELEV=0.0
         GO TO 4640
      ENDIF
      CAVAIL=CAVAIL+DELTVOL
      XX=RELEV
4570  FOF1=X(1)**2.0*XX+2.0*X(1)*XN2*XX**2.0+(4.0/3.0)*XN2**2.0*
```

```
     &XX**3.0-CAVAIL
      FOF2=X(1)**2.0+4.0*X(1)*XX*XN2+4.0*XX**2.0*XN2**2.0
      XX2=XX-(FOF1/FOF2)
      IF(ABS(XX-XX2).LT.0.001) GO TO 4630
      XX=XX2
      GO TO 4570
4630  RELEV=XX2
C     -----------------------------------------------------------------
C     DISPLAY INTERMEDIATE OUTPUT
C     -----------------------------------------------------------------
4640  ATRA=BTRA
      IF(OPTIND.EQ.1) GO TO 4700
      WRITE(6,4650) IYEAR,IDAY,SDEF,SSTATUS,GTDH+DDN,RELEV,RSTATUS,RREM
4650  FORMAT(1X,I2,2X,I3,2X,F6.2,2X,A2,2X,F7.3,2X,F6.2,2X,A15,2X,A8)
      RREM = ’  ’
C     -----------------------------------------------------------------
C     SUM ANNUAL ARRAYS
C     -----------------------------------------------------------------
4700  TRAIN(IYEAR)=TRAIN(IYEAR)+RAIN
      IF((IDAY.GE.IPLANTDATE).AND.(IDAY.LE.(IPLANTDATE+125))) THEN
         GTRAIN(IYEAR)=GTRAIN(IYEAR)+RAIN
         POTTRANSP(IYEAR)=POTTRANSP(IYEAR)+POTEVAPPLANT
         TRANSP(IYEAR)=TRANSP(IYEAR)+EVAPPLANT
         PGETS(IYEAR)=PGETS(IYEAR)+POTEVAP
         GETS(IYEAR)=GETS(IYEAR)+EVAPTOT
      ENDIF
      PETS(IYEAR)=PETS(IYEAR)+POTEVAP
      ETS(IYEAR)=ETS(IYEAR)+EVAPTOT
      PETW(IYEAR)=PETW(IYEAR)+PVAPW
      IRRIG(IYEAR)=IRRIG(IYEAR)+IRRIGATION
      IF(CAVAIL.GT.0.) THEN
         ETW(IYEAR)=ETW(IYEAR)+PVAPW
         SPVOL(IYEAR) = SPVOL(IYEAR) + SEEPVOL
         EVPVOL(IYEAR) = EVPVOL(IYEAR) + EVAPVOL
      ENDIF
      RNVOL(IYEAR)=RNVOL(IYEAR)+RAINVOL
2490  CONTINUE
C     -----------------------------------------------------------------
C     COMPUTE YIELD AND INCOME
C     -----------------------------------------------------------------
      YIELD(IYEAR)=(TRANSP(IYEAR)/POTTRANSP(IYEAR))*YIELDMAX
2400  CONTINUE
C     -----------------------------------------------------------------
C     CONVERT INCOME AND EXPENSES TO PRESENT WORTH
C     -----------------------------------------------------------------
      TADDOPINT=0.0
      GTOTALINC=0.0
      DO 4930 I=1, NYEARS
      YINCOME(I)=(FAREAC)*SBPRICE*YIELD(I)
      OWNEXPENSE(I)=TOWNCOST+RESOWNCOST
      OPEXPENSE(I)=TOPCOST+(YIELD(I)*FAREAC*(HAULCOST+DRYGCOST))
      OPEXPENSE(I)=OPEXPENSE(I)+TIFOLCOST(I)+IRLBS(I)+RESMAINTCOST+
     &SURFREPCOST
      OPEXPENSE(I)=OPEXPENSE(I)+RFOLCOST(I)+IRLBG(I)
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      ADDOPINT=((TIFOLCOST(I)+IRLBS(I)+RESMAINTCOST+SURFREPCOST+
     &IRLBG(I)+RFOLCOST(I)+(HAULCOST+DRYGCOST)*YIELD(I)*FAREAC)/2.0)*
     &INTRATE
      OPEXPENSE(I)=OPEXPENSE(I)+ADDOPINT
      NETINC(I)=YINCOME(I)-OWNEXPENSE(I)-OPEXPENSE(I)
      PWNETINC(I)=NETINC(I)*(1.0+DISRATE)**(-FLOAT(I))
      TADDOPINT=TADDOPINT+ADDOPINT
      GTOTALINC=GTOTALINC+PWNETINC(I)
4930  CONTINUE
      IF(OPTIND.EQ.1) GO TO 9998
9997  OPEN(2,FILE='OUTDATA.OUT')
      WRITE(2,4931) SIMNAME
4931  FORMAT(/////1X,A20)
      WRITE(2,4932)
4932  FORMAT(/1X,'*** SUMMARY OF METEOROLOGICAL DATA ***'/)
      WRITE(2,4933)
4933  FORMAT(1X,'YR',2X,'TOTAL',2X,'GS',4X,'POT',3X,'ACT',2X,
     &'GS POT',2X,
     &'GS ACT',2X,'PLANT',2X,'YIELD',3X,'POT R',3X,'ACT R')
      WRITE(2,4934)
4934  FORMAT(5X,'RAIN',2X,'RAIN',3X,'ET',4X,'ET',5X,'ET',6X,'ET',4X,
     &'TRANS',10X,'EVAP',4X,'EVAP')
      WRITE(2,4935)
4935  FORMAT(5X,'(IN)',2X,'(IN)',2X,'(IN)',2X,'(IN)',3X,'(IN)',4X,'(IN)'
     &,4X,'(IN)',2X,'(BU/AC)',1X,'(IN)',4X,'(IN)')
      WRITE(2,4936)
4936  FORMAT(1X,'--',2X,'----',2X,'----',2X,'----',2X,'----',3X,'----',
     &4X,'----',4X,'----',3X,'----',3X,'----',4X,'----')
      DATA SUM/20*0.0/
      AX=25.4
      DO 4937 I=1, NYEARS
         SUM(1)=SUM(1)+TRAIN(I)
         SUM(2)=SUM(2)+GTRAIN(I)
         SUM(3)=SUM(3)+PETS(I)
         SUM(4)=SUM(4)+ETS(I)
         SUM(5)=SUM(5)+PGETS(I)
         SUM(6)=SUM(6)+GETS(I)
         SUM(7)=SUM(7)+TRANSP(I)
         SUM(8)=SUM(8)+YIELD(I)
         SUM(9)=SUM(9)+PETW(I)
         SUM(10)=SUM(10)+ETW(I)
         WRITE(2,4938) I,TRAIN(I)/AX,GTRAIN(I)/AX,PETS(I)/AX,ETS(I)/AX,
     &   PGETS(I)/AX,GETS(I)/AX,TRANSP(I)/AX,
     &   YIELD(I),PETW(I)/AX,ETW(I)/AX
4938     FORMAT(1X,I2,2X,F4.1,2X,F4.1,2X,F4.1,2X,F4.1,3X,F4.1,4X,F4.1,
     &          4X,F4.1,3X,F4.1,3X,F4.1,4X,F4.1)
4937  CONTINUE
      WRITE(2,4936)
      BX=FLOAT(NYEARS)*25.4
      CX=FLOAT(NYEARS)
      WRITE(2,4939) SUM(1)/BX,SUM(2)/BX,SUM(3)/BX,SUM(4)/BX,SUM(5)/BX,
     &SUM(6)/BX,SUM(7)/BX,SUM(8)/CX,SUM(9)/BX,SUM(10)/BX
4939  FORMAT(1X,'AVG',1X,F4.1,2X,F4.1,2X,F4.1,2X,F4.1,3X,F4.1,4X,F4.1,
     &          4X,F4.1,3X,F4.1,3X,F4.1,4X,F4.1)
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```
      SIMAVYIELD=SUM(8)/FLOAT(NYEARS)
      WRITE(2,4931) SIMNAME
      WRITE(2,4940)
4940  FORMAT(/1X,'*** SUMMARY OF IRRIGATION DELIVERY OPERATING COSTS ***
     &'/)
      WRITE(2,4941)
4941  FORMAT(1X,'YR',4X,'NET',4X,'GROSS',3X,'SUP',5X,'SUP',6X,'TOTAL',
     &5X,'GND',6X,'SURF')
      WRITE(2,4942)
4942  FORMAT(6X,'IRRIG',3X,'IRRIG',3X,'GND',5X,'SURF',6X,'COST*',4X,
     &'COST*',5X,'COST*')
      WRITE(2,4943)
4943  FORMAT(6X,'(IN)',4X,'(IN)',4X,'(IN)',4X,'(IN)',6X,'($)',6X,'($)',
     &7X,'($)')
      WRITE(2,4944)
4944  FORMAT(1X,'--',3X,'----',4X,'----',4X,'----',4X,'----',4X,'------'
     &,4X,'------',4X,'------')
      DO 49441 I=1,20
         SUM(I)=0.0
49441 CONTINUE
      DO 4945 I=1,NYEARS
      AX=IRRIG(I)/25.4
      BX=GPSVOL(I)*12.0/FAREA
      CX=GIVOL(I)*12.0/FAREA
      DX=SIVOL(I)*12.0/FAREA
      EX=TIFOLCOST(I)+IRLBG(I)+IRLBS(I)+GWREPCOST+IRRREP*IRRPCOST
      FX=GIFOLCOST(I)+IRLBG(I)+GWREPCOST
      GX=SIFOLCOST(I)+IRLBS(I)+IRRPCOST*IRRREP
      WRITE(2,4946) I,AX,BX,CX,DX,EX,FX,GX
4946  FORMAT(1X,I2,3X,F4.1,4X,F4.1,4X,F4.1,4X,F4.1,4X,F6.0,4X,F6.0,4X,
     &F6.0)
      SUM(1)=SUM(1)+AX
      SUM(2)=SUM(2)+BX
      SUM(3)=SUM(3)+CX
      SUM(4)=SUM(4)+DX
      SUM(5)=SUM(5)+EX
      SUM(6)=SUM(6)+FX
      SUM(7)=SUM(7)+GX
4945  CONTINUE
      ZX=FLOAT(NYEARS)
      AX=SUM(1)/ZX
      BX=SUM(2)/ZX
      CX=SUM(3)/ZX
      DX=SUM(4)/ZX
      EX=SUM(5)/ZX
      FX=SUM(6)/ZX
      GX=SUM(7)/ZX
      WRITE(2,4944)
      WRITE(2,4947) AX,BX,CX,DX,EX,FX,GX
4947  FORMAT(1X,'AVG',2X,F4.1,4X,F4.1,4X,F4.1,4X,F4.1,4X,F6.0,4X,
     &F6.0,4X,F6.0)
      SIMAVSIC=SUM(7)/ZX
      SIMAVGIC=SUM(8)/ZX
      WRITE(2,4948)
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4948  FORMAT(//1X,'* COSTS ARE FOR FUEL, LUBRICANTS, AND LABOR')
      WRITE(2,4950)
4950  FORMAT(3X,'DOES NOT INCLUDE RESERVOIR OR IRRIGATION SYSTEM COSTS')
      WRITE(2,4931) SIMNAME
      WRITE(2,4951)
4951  FORMAT(/1X,'*** SUMMARY OF RESERVOIR FILL, LOSSES, AND OPERATING C
     &OST DATA ***'/)
      WRITE(2,4952)
4952  FORMAT(1X,'YEAR',5X,'SEEPAGE',4X,'EVAPORATION',5X,'RAINFALL',5X,
     &'VOLUME',5X,'COST OF')
      WRITE(2,4953)
4953  FORMAT(10X,'LOSSES',7X,'LOSSES',8X,'ADDITIONS',4X,'OF FILL',6X,
     &'FILL*')
      WRITE(2,4954)
4954  FORMAT(10X,'(AC-FT)',6X,'(AC-FT)',8X,'(AC-FT)',5X,'(AC-FT)',6X,
     &'($)')
      WRITE(2,4955)
4955  FORMAT(1X,'----',5X,'-------',6X,'-------',8X,'-------',5X,
     &'-------',5X,'-------')
      DO 49551 I=1,20
         SUM(I)=0.0
49551 CONTINUE
      ZX=43560.0
      DO 4956 I=1,NYEARS
      AX=SPVOL(I)/ZX
      BX=EVPVOL(I)/ZX
      CX=RNVOL(I)/ZX
      DX=FVOL(I)/ZX
      EX=RFOLCOST(I)+(LIFTPCOST*LIFTREP)
      WRITE(2,4957) I, AX, BX, CX, DX, EX
4957  FORMAT(1X,I4,5X,F6.1,7X,F6.1,9X,F6.1,6X,F6.1,6X,F7.0)
      SUM(1)=SUM(1)+SPVOL(I)
      SUM(2)=SUM(2)+EVPVOL(I)
      SUM(3)=SUM(3)+RNVOL(I)
      SUM(4)=SUM(4)+FVOL(I)
      SUM(5)=SUM(5)+RFOLCOST(I)+(LIFTPCOST*LIFTREP)
4956  CONTINUE
      WRITE(2,4955)
      ZX=43560.0*FLOAT(NYEARS)
      AX=SUM(1)/ZX
      BX=SUM(2)/ZX
      CX=SUM(3)/ZX
      DX=SUM(4)/ZX
      EX=SUM(5)/FLOAT(NYEARS)
      WRITE(2,4958) AX, BX, CX, DX, EX
4958  FORMAT(1X,'AVG',6X,F6.1,7X,F6.1,9X,F6.1,6X,F6.1,6X,F7.0)
      WRITE(2,4959)
4959  FORMAT(//1X,'* FUEL, LUBRICANTS, AND REPAIRS USED TO FILL RESERVOI
     &R')
      WRITE(2,4960)
4960  FORMAT(3X,'DOES NOT INCLUDE RESERVOIR MAINTENANCE COSTS')
      WRITE(2,4931) SIMNAME
      WRITE(2,4961)
4961  FORMAT(1X,'*** SUMMARY OF COST DATA ***'/)
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      WRITE(2,4962)
4962  FORMAT(1X,'YEAR',4X,'OWNERSHIP',5X,'OPERATING',5X,'RETURNS',4X,
     &'NET',5X,'PRESENT')
      WRITE(2,4963)
4963  FORMAT(11X,'COSTS',9X,'COSTS',17X,'INCOME',4X,'WORTH')
      WRITE(2,4964)
4964  FORMAT(12X,'($)',11X,'($)',10X,'($)',6X,'($)',7X,'($)')
      WRITE(2,4965)
4965  FORMAT(1X,'----',4X,'---------',5X,'---------',5X,'-------',3X,
     &'------',3X,'------')
      DO 49651 I=1,20
         SUM(I)=0.0
49651 CONTINUE
      DO 4966 I=1, NYEARS
      AX=OWNEXPENSE(I)
      BX=OPEXPENSE(I)
      CX=YINCOME(I)
      DX=NETINC(I)
      EX=PWNETINC(I)
      WRITE(2,4967) I,AX,BX,CX,DX,EX
4967  FORMAT(1X,I4,6X,F6.0,8X,F6.0,7X,F6.0,3X,F6.0,3X,F6.0)
      SUM(1)=SUM(1)+AX
      SUM(2)=SUM(2)+BX
      SUM(3)=SUM(3)+CX
      SUM(4)=SUM(4)+DX
      SUM(5)=SUM(5)+EX
4966  CONTINUE
      SUMTINC=SUM(3)
      SUMPWTINC=SUM(5)
      WRITE(2,4965)
      ZX=FLOAT(NYEARS)
      AX=SUM(1)/ZX
      BX=SUM(2)/ZX
      CX=SUM(3)/ZX
      DX=SUM(4)/ZX
      EX=SUM(5)/ZX
      WRITE(2,4968) AX,BX,CX,DX,EX
4968  FORMAT(1X,'AVG    ',3X,F6.0,8X,F6.0,7X,F6.0,3X,F6.0,3X,F6.0)
      WRITE(2,4931) SIMNAME
      WRITE(2,4969)
4969  FORMAT(1X,'*** SUMMARY OF RESERVOIR CHARACTERISTICS ***'//)
      IF(AA(1).LE.0.) THEN
         MAXDEPTH=0.
         X(1)=0.
         X(2)=0.
         EXDEPTH=0.
         FBD=0.
         TWD=0.
         XN1=0.
         XN2=0.
      ENDIF
      WRITE(2,4970)
4970  FORMAT(1X,'DESIGN CHARACTERISTICS:'/)
      AX=AA(1)/43560.0
```

```
      WRITE(2,4971) AX
4971  FORMAT(1X,'CAPACITY                            = ',F11.2,
     &' ACRE-FEET')
      WRITE(2,4972) EXDEPTH
4972  FORMAT(1X,'EXCAVATED DEPTH                     = ',F11.2,
     &' FEET')
      WRITE(2,4973) X(2)
4973  FORMAT(1X,'STORAGE HEIGHT ABOVE GROUND LEVEL   = ',F11.2,
     &' FEET')
      WRITE(2,4974) FBD
4974  FORMAT(1X,'FREEBOARD                           = ',F11.2,
     &' FEET')
      AX=EXDEPTH+X(2)+FBD
      WRITE(2,4975) AX
4975  FORMAT(1X,'TOTAL DEPTH                         = ',F11.2,
     &' FEET')
      WRITE(2,4976) XN1
4976  FORMAT(1X,'LEVEE SLOPE OUTSIDE                 = ',F11.2,
     &':1')
      WRITE(2,4977) XN2
4977  FORMAT(1X,'LEVEE SLOPE INSIDE                  = ',F11.2,
     &':1')
      WRITE(2,4978) X(1)
4978  FORMAT(1X,'BOTTOM BASE OF RESERVOIR            = ',F11.2,
     &' FEET')
      AX=X(1)+(EXDEPTH+X(2)+FBD)*XN2+TWD+(X(2)+FBD)*XN1
      WRITE(2,4979) AX
4979  FORMAT(1X,'TOTAL BASE OF RESERVOIR             = ',F11.2,
     &' FEET')
      BX=(AX**2.0)/43560.0
      WRITE(2,4980) BX
4980  FORMAT(1X,'AREA OCCUPIED                       = ',F11.2,
     &' ACRES')
      AX = 10.0+X(1)+(EXDEPTH+X(2)+FBD)*XN2+TWD+(X(2)+FBD)*XN1
      BX=(AX**2.0)/43560.0
      IF(AA(1).LE.0.) BX=0.
      WRITE(2,4981) BX
4981  FORMAT(1X,'AREA OF FOREGONE PRODUCTION         = ',F11.2,
     &' ACRES')
      AFGP=BX
      FAREA=TFAREA-(AFGP*43560.0)
      BX=FAREA/43560.0
      WRITE(2,4982) BX
4982  FORMAT(1X,'REMAINING IRRIGATED AREA            = ',F11.2,' ACRES'
     &//)
      WRITE(2,4983)
4983  FORMAT(1X,'ASSOCIATED COSTS:'/)
      WRITE(2,4984) EXCOST, CONCOST
4984  FORMAT(1X,'EXCAVATION COST AT ',F4.2,'/CU YD     = $ ',F11.2)
      BX=SEEDCOST*43560.0
      WRITE(2,4985) BX,SDCOST
4985  FORMAT(1X,'SEEDING COST AT ',F5.0,'/AC          = $ ',F11.2)
      WRITE(2,4986) LIFTPCOST
4986  FORMAT(1X,'COST OF LIFT PUMP                 = $ ',F11.2)
```

```
      WRITE(2,4987) IRRPCOST
4987  FORMAT(1X,'COST OF SURFACE IRRIGATION PUMP   = $ ',F11.2)
      WRITE(2,4988)
4988  FORMAT(1X,'                                      -----------')
      AX = CONCOST + SDCOST + LIFTPCOST + IRRPCOST
      WRITE(2,4989) AX
4989  FORMAT(1X,'TOTAL CONSTRUCTION COST           = $ ',F11.2)
      WRITE(2,4931) SIMNAME
      WRITE(2,4990)
4990  FORMAT(1X,54('-'))
      WRITE(2,4991)
4991  FORMAT(1X,'AVERAGE ANNUAL OPERATING COSTS')
      WRITE(2,4990)
      WRITE(2,4992)
4992  FORMAT(1X,'RESOURCE OR INPUT          COST          COST PER ACRE'
     &)
      WRITE(2,4990)
      DO 4993 I=1,20
         SUM(I)=0.
4993  CONTINUE
      WRITE(2,4994) SSEEDCOST*FAREAC,SSEEDCOST
4994  FORMAT(1X,'SEED                      ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+SSEEDCOST*FAREAC
      WRITE(2,4995) FERTCOST*FAREAC,FERTCOST
4995  FORMAT(1X,'FERTILIZER                ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+FERTCOST*FAREAC
      WRITE(2,4996) LIMECOST*FAREAC,LIMECOST
4996  FORMAT(1X,'LIME + APPLICATION        ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+LIMECOST*FAREAC
      WRITE(2,4997) HERBCOST*FAREAC,HERBCOST
4997  FORMAT(1X,'HERBICIDE                 ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+HERBCOST*FAREAC
      WRITE(2,4998) FUNGCOST*FAREAC,FUNGCOST
4998  FORMAT(1X,'FUNGICIDE                 ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+FUNGCOST*FAREAC
      WRITE(2,4999) INSECOST*FAREAC,INSECOST
4999  FORMAT(1X,'INSECTICIDE               ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+INSECOST*FAREAC
      WRITE(2,5000) DEFOCOST*FAREAC,DEFOCOST
5000  FORMAT(1X,'DEFOLIANT                 ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+DEFOCOST*FAREAC
      WRITE(2,5001) AEAPCOST*FAREAC,AEAPCOST
5001  FORMAT(1X,'AERIAL APPLICATION        ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+AEAPCOST*FAREAC
      WRITE(2,5002)
5002  FORMAT(1X,'MACHINERY:')
      WRITE(2,5003) MFOLCOST*FAREAC,MFOLCOST
5003  FORMAT(1X,'  FUEL, OIL, LUBRICANTS   ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+MFOLCOST*FAREAC
      WRITE(2,5004) MREPCOST*FAREAC,MREPCOST
5004  FORMAT(1X,'  REPAIRS                 ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+MREPCOST*FAREAC
      WRITE(2,5005) CLABCOST*FAREAC,CLABCOST
5005  FORMAT(1X,'LABOR                     ',F6.0,'           ',F6.2)
```

```
      SUM(1)=SUM(1)+CLABCOST*FAREAC
      WRITE(2,5006)
5006  FORMAT(1X,'IRRIGATION FROM WELL:')
      AX=0.0
      BX=0.0
      DO 5007 I=1,NYEARS
         AX=AX+GIFOLCOST(I)
         BX=BX+IRLBG(I)
5007  CONTINUE
      AX=AX/FLOAT(NYEARS)
      BX=BX/FLOAT(NYEARS)
      WRITE(2,5008) AX,AX/FAREAC
5008  FORMAT(1X,'   FUEL, OIL, LUBRICANTS  ',F6.0,'           ',F6.2)
      CX=GWREPCOST
      DX=CX/FAREAC
      SUM(1)=SUM(1)+AX
      WRITE(2,5009) CX,DX
5009  FORMAT(1X,'   REPAIRS                ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+CX
      WRITE(2,5010) BX,BX/FAREAC
5010  FORMAT(1X,'   IRRIGATION LABOR       ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+BX
      AX=RESMAINTCOST
      BX=AX/FAREAC
      WRITE(2,5011) AX,BX
5011  FORMAT(1X,'RESERVOIR MAINTENANCE     ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+AX
      WRITE(2,5012)
5012  FORMAT(1X,'RESERVOIR FILL')
      AX=0.0
      DO 5013 I=1,NYEARS
         AX=AX+RFOLCOST(I)
5013  CONTINUE
      AX=AX/FLOAT(NYEARS)
      WRITE(2,5014) AX,AX/FAREAC
5014  FORMAT(1X,'   FUEL, OIL, LUBRICANTS  ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+AX
      AX=LIFTPCOST*LIFTREP
      BX=AX/FAREAC
      WRITE(2,5015) AX,BX
5015  FORMAT(1X,'   REPAIRS                ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+AX
      WRITE(2,5016)
5016  FORMAT(1X,'IRRIGATION FROM RESERVOIR:')
      AX=0.0
      DO 5017 I=1,NYEARS
         AX=AX+SIFOLCOST(I)
5017  CONTINUE
      AX=AX/FLOAT(NYEARS)
      WRITE(2,5018) AX,AX/FAREAC
5018  FORMAT(1X,'   FUEL, OIL, LUBRICANTS  ',F6.0,'           ',F6.2)
      SUM(1)=SUM(1)+AX
      AX=IRRPCOST*IRRREP
      BX=AX/FAREAC
```

```
      WRITE(2,5019) AX,BX
5019  FORMAT(1X,'   REPAIRS                ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+AX
      AX=0.0
      DO 5020 I=1,NYEARS
         AX=AX+IRLBS(I)
5020  CONTINUE
      AX=AX/FLOAT(NYEARS)
      BX=AX/FAREAC
      WRITE(2,5021) AX,BX
5021  FORMAT(1X,'   IRRIGATION LABOR       ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+AX
      WRITE(2,5022) SPRDCOST*FAREAC,SPRDCOST
5022  FORMAT(1X,'CUSTOM SPREAD             ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+SPRDCOST*FAREAC
      AX=SIMAVYIELD*HAULCOST
      BX=AX*FAREAC
      WRITE(2,5023) BX,AX
5023  FORMAT(1X,'CUSTOM HAUL               ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+BX
      AX=DRYGCOST*SIMAVYIELD
      BX=AX*FAREAC
      WRITE(2,5024) BX,AX
5024  FORMAT(1X,'CUSTOM DRY OR GINNING     ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+BX
      WRITE(2,5025) MISCCOST*FAREAC,MISCCOST
5025  FORMAT(1X,'MISCELLANEOUS             ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+MISCCOST*FAREAC
      WRITE(2,5026) CRINCOST*FAREAC,CRINCOST
5026  FORMAT(1X,'CROP INSURANCE PREMIUM    ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+CRINCOST*FAREAC
      WRITE(2,5027) OTHRCOST*FAREAC,OTHRCOST
5027  FORMAT(1X,'OTHER                     ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+OTHRCOST*FAREAC
      TADDOPINT=TADDOPINT/FLOAT(NYEARS)
      AX=OPINT+TADDOPINT
      BX=AX/FAREAC
      WRITE(2,5028) AX,BX
5028  FORMAT(1X,'INTEREST ON OP CAPITAL    ',F6.0,'            ',F6.2)
      SUM(1)=SUM(1)+AX
      WRITE(2,4990)
      WRITE(2,5029) SUM(1),SUM(1)/FAREAC
5029  FORMAT(1X,'TOTAL SPECIFIED OP COST   ',F6.0,'            ',F6.2)
      WRITE(2,4990)
      WRITE(2,4931) SIMNAME
      WRITE(2,4990)
      WRITE(2,5059)
5059  FORMAT(1X,'AVERAGE ANNUAL OWNERSHIP COSTS')
      WRITE(2,4990)
      WRITE(2,4992)
      WRITE(2,4990)
      SUM(2)=0.0
      WRITE(2,5030)
5030  FORMAT(1X,'TRACTORS:')
```

```
      WRITE(2,5031) TRACDEP*FAREAC,TRACDEP
5031  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+TRACDEP*FAREAC
      WRITE(2,5032) TRACINT*FAREAC,TRACINT
5032  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+TRACINT*FAREAC
      WRITE(2,5033)
5033  FORMAT(1X,'EQUIPMENT:')
      WRITE(2,5034) EQUIPDEP*FAREAC,EQUIPDEP
5034  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+EQUIPDEP*FAREAC
      WRITE(2,5035) EQUIPINT*FAREAC,EQUIPINT
5035  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+EQUIPINT*FAREAC
      WRITE(2,5036)
5036  FORMAT(1X,'SPECIAL EQUIPMENT:')
      WRITE(2,5037) SEQUIPDEP*FAREAC,SEQUIPDEP
5037  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+SEQUIPDEP*FAREAC
      WRITE(2,5038) SEQUIPINT*FAREAC,SEQUIPINT
5038  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+SEQUIPINT*FAREAC
      WRITE(2,5039)
5039  FORMAT(1X,'MISCELLANEOUS:')
      WRITE(2,5040) MQPDEP*FAREAC,MQPDEP
5040  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+MQPDEP*FAREAC
      WRITE(2,5041) MQPINT*FAREAC,MQPINT
5041  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+MQPINT*FAREAC
      WRITE(2,5042)
5042  FORMAT(1X,'IRRIGATION:')
      AX=WDEP+POWDEP+PUMPDEP+ISYSDEP
      BX=AX/FAREAC
      WRITE(2,5043) AX,BX
5043  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+AX
      AX=WINT+POWINT+PUMPINT+ISYSINT
      BX=AX/FAREAC
      WRITE(2,5044) AX,BX
5044  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+AX
      WRITE(2,5045)
5045  FORMAT(1X,'RESERVOIR:')
      AX=RESDEP+LFTPDEP+SIRPDEP
      BX=AX/FAREAC
      WRITE(2,5046) AX,BX
5046  FORMAT(1X,'   DEPRECIATION           ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+AX
      AX=RESINT+LFTPINT+SIRPINT
      BX=AX/FAREAC
      WRITE(2,5047) AX,BX
5047  FORMAT(1X,'   INTEREST               ',F6.0,'           ',F6.2)
      SUM(2)=SUM(2)+AX
```

```
      AX=TOTALTXI+RESTX
      BX=AX/FAREAC
      WRITE(2,5048) AX,BX
5048  FORMAT(1X,'TAXES AND INSURANCE       ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+AX
      AX=AX*INTRATE
      BX=AX/FAREAC
      WRITE(2,5049) AX,BX
5049  FORMAT(1X,'   INTEREST               ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+AX
      WRITE(2,5050) OHLACOST*FAREAC,OHLACOST
5050  FORMAT(1X,'OVERHEAD LABOR            ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+OHLACOST*FAREAC
      WRITE(2,5051) LAPRCOST*FAREAC,LAPRCOST
5051  FORMAT(1X,'LAND AND PROPERTY TAX     ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+LAPRCOST*FAREAC
      WRITE(2,5052) OTOHCOST*FAREAC,OTOHCOST
5052  FORMAT(1X,'OTHER OVERHEAD            ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+OTOHCOST*FAREAC
      WRITE(2,5053) MANACOST*FAREAC,MANACOST
5053  FORMAT(1X,'MANAGEMENT                ',F6.0,'            ',F6.2)
      SUM(2)=SUM(2)+MANACOST*FAREAC
      WRITE(2,4990)
      WRITE(2,5054) SUM(2),SUM(2)/FAREAC
5054  FORMAT(1X,'TOTAL SPECIFIED OWN COSTS ',F6.0,'            ',F6.2)
      WRITE(2,4990)
      AX=SUMTINC/FLOAT(NYEARS)
      BX=AX/FAREAC
      WRITE(2,5055) AX,BX
5055  FORMAT(/1X,'AVERAGE ANNUAL RETURNS    ',F6.0,'            ',F6.2)
      AX=SUM(1)+SUM(2)
      BX=AX/FAREAC
      WRITE(2,5056) AX,BX
5056  FORMAT(1X,'TOTAL OP AND OWN COSTS    ',F6.0,'            ',F6.2)
      WRITE(2,5057)
5057  FORMAT(1X,'                         -------           ------')
      AX=(SUMTINC/FLOAT(NYEARS))-(SUM(1)+SUM(2))
      BX=AX/FAREAC
      WRITE(2,5058) AX,BX
5058  FORMAT(1X,'DIFFERENCE                ',F6.0,'            ',F6.2)
      CLOSE(2,STATUS='KEEP')
      GO TO 5220
C     ------------------------------------------------------------------
C     CALL SUBROUTINE OPT TO OPTIMIZE RESERVOIR CAPACITY
C     ------------------------------------------------------------------
9998  OPTIM=GTOTALINC
      IF(AA(1).LT.0.) OPTIM=-1.0E+08
      CALL OPT
      IF(ISTOP.EQ.1) GO TO 9997
C     ------------------------------------------------------------------
C     RESET ANNUAL ARRAYS
C     ------------------------------------------------------------------
      DO 5200 I=1, NYEARS
      YINCOME(I)=0.0
```

```
      RFOLCOST(I)=0.0
      ETS(I)=0.0
      ETW(I)=0.0
      GETS(I)=0.0
      TRAIN(I)=0.0
      PGETS(I)=0.0
      IRRIG(I)=0.0
      GTRAIN(I)=0.0
      PETS(I)=0.0
      PETW(I)=0.0
      FVOL(I)=0.0
      TIFOLCOST(I)=0.0
      PWNETINC(I)=0.0
      GIVOL(I)=0.0
      SIVOL(I)=0.0
      GPSVOL(I)=0.0
      GIFOLCOST(I)=0.0
      SIFOLCOST(I)=0.0
      SPVOL(I)=0.0
      EVPVOL(I)=0.0
      RNVOL(I)=0.0
      TRANSP(I)=0.0
      POTTRANSP(I)=0.0
      YIELD(I)=0.0
      NETINC(I)=0.0
      IRLBS(I)=0.0
      IRLBG(I)=0.0
      OWNEXPENSE(I)=0.0
      OPEXPENSE(I)=0.0
5200  CONTINUE
      GO TO 1960
5220  STOP
      END
C     ******************************************************************
C     ******************************************************************
      SUBROUTINE XLEAREA(IDPP,LAI)
C     ******************************************************************
C     ******************************************************************
      REAL LAI
      XDP=FLOAT(IDPP)
      IF (XDP.LE.0.) LAI = 0.0
      IF ((XDP.GT.0.).AND.(XDP.LE.20.)) LAI=0.025*XDP
      IF ((XDP.GT.20.).AND.(XDP.LE.40.)) LAI=0.5+0.08*(XDP - 20.)
      IF ((XDP.GT.40.).AND.(XDP.LE.60.)) LAI=2.1+0.11*(XDP - 40.)
      IF ((XDP.GT.60.).AND.(XDP.LE.80.)) LAI=4.3+0.07*(XDP - 60.)
      IF ((XDP.GT.80.).AND.(XDP.LE.100.)) LAI=5.7-0.085*(XDP-80.)
      IF ((XDP.GT.100.).AND.(XDP.LE.120.)) LAI=4.0-0.185*(XDP-100.)
      IF ((XDP.GT.120.).AND.(XDP.LE.125.)) LAI=0.3-0.06*(XDP-120.)
      IF (IDPP.GT.125) LAI = 0.0
      RETURN
      END
C     ******************************************************************
C     ******************************************************************
      SUBROUTINE NONLIN(X,XN1,XN2,FBD,TWD,EXDEPTH)
```

```
C      ******************************************************************
C      ******************************************************************
       REAL X(2),F(2),DELTA,XTOL,FTOL
       INTEGER N, MAXIT, I
       COMMON AA(18)
       DATA I,N,MAXIT,DELTA/ 0, 2, 100, 0.01 /
       DATA XTOL,FTOL/ 0.0001, 0.0005 /
       CALL NLSYST(N,MAXIT,X,F,DELTA,XTOL,FTOL,I,XN1,XN2,FBD,TWD,EXDEPTH)
       RETURN
       END
C      ******************************************************************
C      ******************************************************************
       SUBROUTINE NLSYST(N,MAXIT,X,F,DELTA,XTOL,FTOL,I,XN1,XN2,FBD,TWD,
     &EXDEPTH)
C      ******************************************************************
C      ******************************************************************
C      THIS SUBROUTINE SOLVES A SYSTEM OF N NON-LINEAR EQUATIONS BY
C      NEWTON'S METHOD.  THE PARTIAL DERIVATIVES OF THE FUNCTIONS ARE
C      ESTIMATED BY DIFFERENCE QUOTIENTS WHEN A VARIABLE IS PERTURBED BY
C      AN AMOUNT EQUAL TO DELTA (DELTA IS ADDED).  THIS IS DONE FOR EACH
C      VARIABLE IN EACH FUNCTION.  INCREMENTS TO IMPROVE THE ESTIMATES
C      FOR THE X-VALUES ARE COMPUTED FROM A SYSTEM OF EQUATIONS USING
C      SUBROUTINE ELIM.
C      ------------------------------------------------------------------
C      PARAMETERS ARE:
C
C      FCN   - SUBROUTINE THAT COMPUTES VALUES OF THE FUNCTIONS.  MUST
C              BE DECLARED EXTERNAL IN THE CALLING PROGRAM.
C      N     - THE NUMBER OF EQUATIONS.
C      MAXIT - THE LIMIT TO THE NUMBER OF ITERATIONS THAT WILL BE USED.
C      X     - ARRAY TO HOLD X VALUES.  INITIALLY THIS ARRAY HOLDS
C              THE INITIAL GUESSES.  IT RETURNS THE FINAL VALUES.
C      F     - AN ARRAY THAT HOLDS VALUES OF THE FUNCTIONS.
C      DELTA - A SMALL VALUE USED TO PERTURB THE X VALUES SO PARTIAL
C              DERIVATIVES CAN BE COMPUTED BY DIFFERENCE QUOTIENT.
C      XTOL  - TOLERANCE VALUE FOR CHANGE IN X VALUES TO STOP ITERATIONS.
C              WHEN THE LARGEST CHANGE IN ANY X MEETS XTOL, THE
C              SUBROUTINE TERMINATES.
C      FTOL  - TOLERANCE VALUE ON F TO TERMINATE.  WHEN THE LARGEST F
C              VALUE IS LESS THAN FTOL, SUBROUTINE TERMINATES.
C      I     - RETURNS VALUES TO INDICATE HOW THE ROUTINE TERMINATED.
C
C         I=1  XTOL WAS MET
C         I=2  FTOL WAS MET
C         I=-1 MAXIT EXCEEDED BUT TOLERANCES NOT MET
C         I=-2 VERY SMALL PIVOT ENCOUNTERED IN GAUSSIAN ELIMINATION
C              STEP - NO RESULTS OBTAINED.
C         I=-3 INCORRECT VALUE OF N WAS SUPPLIED - N MUST BE BETWEEN
C              2 AND 10
C      ------------------------------------------------------------------
       REAL X(N),F(N),DELTA,XTOL,FTOL
       INTEGER N,MAXIT,I
       REAL A(10,11),XSAVE(10),FSAVE(10)
       INTEGER NP,IT,IVBL,ITEST,IFCN,IROW,JCOL
```

```
      COMMON AA(18)
C     ------------------------------------------------------------------
C     CHECK VALIDITY OF VALUE OF N
C     ------------------------------------------------------------------
      IF((N.LT.2).OR.(N.GT.10)) THEN
         I=-3
C        PRINT 1004,N
         RETURN
      ENDIF
C     ------------------------------------------------------------------
C     BEGIN ITERATIONS - SAVE X VALUES, THEN GET F VALUES
C     ------------------------------------------------------------------
      NP=N+1
      DO 100 IT=1,MAXIT
         DO 10 IVBL=1,N
            XSAVE(IVBL)=X(IVBL)
10       CONTINUE
      HB=EXDEPTH+X(2)
      F(1)=(HB*X(1)**2.0+2.0*X(1)*XN2*HB**2.0+(4.0/3.0)*(XN2**2)*(HB**
     &3.0))-AA(1)
      RT3=EXDEPTH
     &*X(1)**2.0+2.0*X(1)*XN2*EXDEPTH**2.0+(4.0/3.0)*(XN2**2.0)*
     &(EXDEPTH**3.0)
      RT4=.5*(XN1+XN2)*(FBD+X(2))**2.0+TWD*(X(2)+FBD)
      RT5=X(1)+XN2*(EXDEPTH+X(2)+FBD)+TWD+XN1*(X(2)+FBD)
      F(2)=4.0*RT5*RT4-RT3
C     ------------------------------------------------------------------
C     TEST F VALUES AND SAVE THEM
C     ------------------------------------------------------------------
      ITEST=0
      DO 20 IFCN=1,N
         IF(ABS(F(IFCN)).GT.FTOL) ITEST=ITEST+1
         FSAVE(IFCN)=F(IFCN)
20    CONTINUE
      IF(I.EQ.0) THEN
C        PRINT 1000,IT,X
C        PRINT 1001,F
      ENDIF
C     ------------------------------------------------------------------
C     SEE IF FTOL IS MET.  IF NOT, CONTINUE.  IF SO, SET I=2 AND RETURN.
C     ------------------------------------------------------------------
      IF(ITEST.EQ.0) THEN
         I=2
         RETURN
      ENDIF
C     ------------------------------------------------------------------
C     THIS DOUBLE LOOP COMPUTES THE PARTIAL DERIVATIVES OF EACH FUNCTION
C     FOR EACH VARIABLES AND STORES THEM IN A COEFFICIENT ARRAY.
C     ------------------------------------------------------------------
      DO 50 JCOL=1,N
         X(JCOL)=XSAVE(JCOL)+DELTA
         HB=EXDEPTH+X(2)
         F(1)=(HB*X(1)**2.0+2.0*X(1)*XN2*HB**2.0+(4.0/3.0)*(XN2**2.0)*
     &   (HB**3.0))-AA(1)
```

```
         RT3=EXDEPTH*X(1)**2.0+2.0*X(1)*XN2*EXDEPTH**2.0+(4.0/3.0)*
     &   (XN2**2.0)*(EXDEPTH**3.0)
         RT4=.5*(XN1+XN2)*(FBD+X(2))**2.0+TWD*(X(2)+FBD)
         RT5=X(1)+XN2*(EXDEPTH+X(2)+FBD)+TWD+XN1*(X(2)+FBD)
         F(2)=4.0*RT5*RT4-RT3
         DO 40 IROW=1,N
            A(IROW,JCOL)=(F(IROW)-FSAVE(IROW))/DELTA
40       CONTINUE
C     ------------------------------------------------------------------
C     RESET X VALUES FOR NEXT COLUMN OF PARTIALS
C     ------------------------------------------------------------------
         X(JCOL)=XSAVE(JCOL)
50    CONTINUE
C     ------------------------------------------------------------------
C     NOW WE PUT NEGATIVE OF F VALUES AS RIGHT HAND SIDES AND CALL ELIM
C     ------------------------------------------------------------------
      DO 60 IROW=1,N
         A(IROW,NP)=-FSAVE(IROW)
60    CONTINUE
C     DO 66 MMM=1,10
C        DO 666 NNN=1,11
C           AB(MMM,NNN)=A(MMM,NNN)
C     666      CONTINUE
C     66    CONTINUE
      CALL ELIM(A,N,NP,10)
C     ------------------------------------------------------------------
C     MAKE SURE THAT THE COEFFICIENT MATRIX IS NOT TOO ILL-CONDITIONED
C     ------------------------------------------------------------------
      DO 70 IROW=1,N
         IF(ABS(A(IROW,IROW)).LE.1.0E-06) THEN
            I=-2
            PRINT 1003
            RETURN
         ENDIF
70    CONTINUE
C     ------------------------------------------------------------------
C     APPLY THE CORRECTIONS TO THE X VALUES AND SEE IF XTOL IS MET
C     ------------------------------------------------------------------
      ITEST=0
      DO 80 IVBL=1,N
         X(IVBL)=XSAVE(IVBL)+A(IVBL,NP)
         IF(ABS(A(IVBL,NP)).GT.XTOL) ITEST=ITEST+1
80    CONTINUE
C     ------------------------------------------------------------------
C     IF XTOL IS MET, PRINT LAST VALUES AND RETURN.  ELSE, DO ANOTHER
C     ITERATION
C     ------------------------------------------------------------------
      IF(ITEST.EQ.0) THEN
         I=1
C        IF(I.EQ.0) PRINT 1002, IT,X
         RETURN
      ENDIF
100   CONTINUE
C     ------------------------------------------------------------------
```

```
C     WHEN WE HAVE DONE MAXIT ITERATIONS, SET I=-1 AND RETURN
C     ------------------------------------------------------------------
      I=-1
      RETURN
C     ------------------------------------------------------------------
C     FORMAT FOR PRINT STATEMENTS
C     ------------------------------------------------------------------
1000  FORMAT(/' AFTER ITERATION NUMBER',I3,' X AND F VALUES ARE'
     &       //10F13.5)
1001  FORMAT(/10F13.5)
1002  FORMAT(/' AFTER ITERATION NUMBER',I3,' X VALUES MEETING XTOL ARE '
     &       //10F13.5)
1003  FORMAT(/' CANNOT SOLVE SYSTEM.  MATRIX NEARLY SINGULAR.')
1004  FORMAT(/' NUMBER OF EQUATIONS PASSED TO NLSYST IS INVALID.',
     &       ' MUST BE 1 < N < 11.  VALUE WAS ',I3)
      END
C     ******************************************************************
C     ******************************************************************
      SUBROUTINE ELIM(AB,N,NP,NDIM)
C     ******************************************************************
C     ******************************************************************
C     THIS SUBROUTINE SOLVES A SET OF LINEAR EQUATIONS AND GIVES AND LU
C     DECOMPOSITION OF THE COEFFICIENT MATRIX.  THE GAUS ELIMINATION
C     METHOD IS USED WITH PARTIAL PIVOTING.  MULTIPLE RIGHT HAND SIDES
C     ARE PERMITTED, AND THEY SHOULD BE SUPPLIED AS COLUMNS THAT AUGMENT
C     THE COEFFICIENT MATRIX.
C     ------------------------------------------------------------------
C     PARAMETERS ARE:
C
C     AB      - COEFFICIENT MATRIX AUGMENTED WITH R.H.S. VECTORS
C     N       - NUMBER OF EQUATIONS
C     NP      - TOTAL NUMBER OF COLUMNS IN THE AUGMENTED MATRIX
C     NDIM    - THE FIRST DIMENSION OF MATRIX AB IN THE CALLING PROGRAM
C
C     THE SOLUTION VECTOR(S) ARE RETURNED IN THE AUGMENTATION COLUMNS OF
C     AB
C     ------------------------------------------------------------------
      REAL AB(NDIM,NP)
      INTEGER N, NP, NDIM
      REAL SAVE,RATIO,VALUE
      INTEGER NM1,IPVT,IP1,J,NVBL,L,KCOL,JCOL,JROW
C     ------------------------------------------------------------------
C     BEGIN THE REDUCTION
C     ------------------------------------------------------------------
      NM1=N-1
      DO 35 I=1,NM1
C     ------------------------------------------------------------------
C     FIND THE ROW NUMBER OF THE PIVOT ROW.  WE WILL THEN INTERCHANGE
C     ROWS TO PUT THE PIVOT ELEMENT ON THE DIAGONAL
C     ------------------------------------------------------------------
         IPVT=I
         IP1=I+1
         DO 10 J=IP1,N
            IF(ABS(AB(IPVT,I)).LT.ABS(AB(J,I))) IPVT=J
```

```
10       CONTINUE
C     ------------------------------------------------------------------
C     CHECK FOR A NEAR SINGULAR MATRIX
C     ------------------------------------------------------------------
         IF(ABS(AB(IPVT,I)).LT.1.0E-06) THEN
            PRINT 100
            RETURN
         ENDIF
C     ------------------------------------------------------------------
C     NOW INTERCHANGE UNLESS THE PIVOT ELEMENT IS ALREADY ON THE
C     DIAGONAL
C     ------------------------------------------------------------------
         IF(IPVT.NE.I) THEN
            DO 20 JCOL=I,NP
               SAVE=AB(I,JCOL)
               AB(I,JCOL)=AB(IPVT,JCOL)
               AB(IPVT,JCOL)=SAVE
20          CONTINUE
         ENDIF
C     ------------------------------------------------------------------
C     NOW REDUCE ALL ELEMENTS BELOW THE DIAGONAL IN THE I-TH ROW.  CHECK
C     FIRST TO SEE IF A ZERO ALREADY PRESENT.  IF SO, CAN SKIP REDUCTION
C     ON THAT ROW.
C     ------------------------------------------------------------------
         DO 32 JROW=IP1,N
            IF(AB(JROW,I).EQ.0.) GO TO 32
            RATIO=AB(JROW,I)/AB(I,I)
            AB(JROW,I)=RATIO
            DO 30 KCOL=IP1,NP
               AB(JROW,KCOL)=AB(JROW,KCOL)-RATIO*AB(I,KCOL)
30          CONTINUE
32       CONTINUE
35    CONTINUE
C     ------------------------------------------------------------------
C     WE STILL NEED TO CHECK AB(N,N) FOR SIZE
C     ------------------------------------------------------------------
      IF(ABS(AB(N,N)).LT.1.0E-06) THEN
         PRINT 100
         RETURN
      ENDIF
C     ------------------------------------------------------------------
C     NOW BACK SUBSTITUTE
C     ------------------------------------------------------------------
      NP1=N+1
      DO 50 KCOL=NP1,NP
         AB(N,KCOL)=AB(N,KCOL)/AB(N,N)
         DO 45 J=2,N
            NVBL=NP1-J
            L=NVBL+1
            VALUE=AB(NVBL,KCOL)
            DO 40 K=L,N
               VALUE=VALUE-AB(NVBL,K)*AB(K,KCOL)
40          CONTINUE
         AB(NVBL,KCOL)=VALUE/AB(NVBL,NVBL)
```

```
45          CONTINUE
50       CONTINUE
C        DO 67 MMM=1,10
C           DO 677 NNN=1,11
C              A(MMM,NNN)=AB(MMM,NNN)
C        677      CONTINUE
C        67    CONTINUE
         RETURN
100      FORMAT(/' SOLUTION NOT FEASIBLE.  A NEAR ZERO PIVOT ',
     &        'WAS ENCOUNTERED.')
         END
C        *****************************************************************
C        *****************************************************************
         SUBROUTINE OPT
C        *****************************************************************
C        *****************************************************************
C        PATTERN SEARCH WITH MODIFICATIONS
C        -----------------------------------------------------------------
C        DEFINITION OF PROGRAM VARIABLES
C
C        NUMA = NUMBER OF AA(I) COEFFICIENTS TO BE OPTIMIZED
C
C        AA(I) = VALUE OF COEFFICIENT I AFTER LAST PATTERN MOVE
C
C        B(I) = VALUE OF COEFFICIENT I AFTER PREVIOUS LOCAL EXCURSION
C
C        BA(I) = VALUE OF COEFFICIENT I AFTER PRESENT LOCAL EXCURSION
C
C        NPER = IF = 1 DDELTA(I) MUST BE IN PERCENT/100
C               IF = 0 DDELTA(I) MUST BE AN ABSOLUTE VALUE
C
C        DDELTA(I) = WHEN NPER = 1  DELTA(I) = ABS(DDELTA(I)*A(I))
C                    WHEN NPER = 0  DELTA(I) = DDELTA(I)
C
C        DELTA(I) = INCREMENT ADDED OR SUBTRACTED TO AA(I) DURING A LOCAL
C        EXCURSION
C
C        CHECKL(I) = LOWER CONSTRAINT ON AA(I)
C
C        CHECKH(I) = UPPER CONSTRAINT ON AA(I)
C
C        OPTIM = VALUE OF THE OPTIMIZATION CRITERION
C
C        NN = NUMBER OF TIMES MAIN PROGRAM HAS CALLED OPT
C
C        NSIGN(I) =  NSIGN(I) = 0  THEN + DELTA(I) APPLIED FIRST
C                    NSIGN(I) = 1  THEN - DELTA(I) APPLIED FIRST
C
C        MAXN = MAXIMUM NUMBER OF TIMES MAIN PROGRAM MAY CALL OPT BEFORE
C        OPTIMIZATION IS ABORTED
C
C        KC = MAXIMUM NUMBER OF TIMES DELTA(I) MAY BE HALVED BEFORE
C        OPTIMIZATION IS TERMINATED (MAXN OVER-RIDES KC)
C
```

```
C     -----------------------------------------------------------------
C     THIS PROGRAM IN ITS PRESENT FORM IS FOR MAXIMIZATION.  TO
C     CONVERT IT TO A MIXIMIZATION FORMAT,
C     WITH                                   REPLACE
C
C     IF(YS.GT.YY) GO TO 1008            IF(YS.LT.YY) GO TO 1008
C   8 IF(YX.GT.YS) GO TO 11            8 IF(YX.LT.YS) GO TO 11
C     IF(YS.GT.YY) GO TO 4007            IF(YS.LT.YY) GO TO 4007
C  16 IF(YX.GT.YS) GO TO 19           16 IF(YX.LT.YS) GO TO 19
C     -----------------------------------------------------------------
      COMMON AA(18),DDELTA(18),CHECKL(18),CHECKH(18)
      COMMON OPTIM,NUMA,NSTART,NPER,KC,MAXN,ISTOP
      DIMENSION DELTA(18),BA(18),B(18),NSIGN(18),LES(18)
      DIMENSION ICLOSL(18),NCLOSEH(18)
      IF (NSTART.GT.0) GO TO 2
C     -----------------------------------------------------------------
C     INITIALIZATION ROUTINE
C     -----------------------------------------------------------------
      DO 1 I=1,NUMA
      LES(I)=0
      BA(I)=AA(I)
      B(I)=AA(I)
      ICLOSL(I)=0
      NCLOSEH(I)=0
      IF (NPER.GT.0) GO TO 100
      DELTA(I)=DDELTA(I)
      GO TO 101
  100 DELTA(I)=ABS(DDELTA(I)*AA(I))
  101 CC=AA(I)-1.01*DELTA(I)
      IF(CC.LE.CHECKL(I)) GO TO 3000
      CC=AA(I)+1.01*DELTA(I)
      IF(CC.GE.CHECKH(I)) GO TO 3000
    1 CONTINUE
      WRITE (6,4000)
 4000 FORMAT(1H1)
      LC=0
      IT=1
      IZY=0
      NN=0
      NCOUN=1
      ICOUN=0
      IFIRS=0
      LDELT=0
      NSTART=1
      NSAVE=0
      WRITE (6,3)
      WRITE (6,221)
  221 FORMAT(21X,'INITIAL VALUES OF THE COEFFICIENTS')
C     -----------------------------------------------------------------
    2 YS=OPTIM
      NN=NN+1
      IF (NN.GT.MAXN) GO TO 7000
      IF (IFIRS.EQ.1) GO TO 4
      YX=OPTIM
```

```
      YY=YX
      IFIRS=1
    4 WRITE (6,5) NCOUN,NN,YS,(AA(I),I=1,NUMA)
    5 FORMAT(I6,I5,E10.3,2X,18(F10.0,2X))
    3 FORMAT(' TRIAL  RUN CRITERION   A(1)    A(2)    A(3)    A(4)')
   44 IF (LES(IT).EQ.1) GO TO 14
      IF (IZY.GT.0) GO TO 8
      IF (YS.LT.YY) GO TO 4008
      NSAVE=1
      YX=YS
      YY=YS
 4008 WRITE (6,3)
    6 IZY=IZY+1
      IT=IZY
      IF(LES(IZY).EQ.1) GO TO 107
  108 LL=0
C     ---------------------------------------------------------------
C     LOCAL EXCURSION ROUTINE
C     ---------------------------------------------------------------
C     LOCAL EXCURSION WITH + DELTA(I) FIRST
C     ---------------------------------------------------------------
      AA(IZY)=AA(IZY)+DELTA(IZY)
      NSIGN(IZY)=0
      IF(NCLOSEH(IZY).EQ.0) GO TO 7
      LL=LL+1
      GO TO 88
    7 LL=LL+1
      GO TO 6000
    8 IF (YX.LT.YS) GO TO 11
   88 GO TO (9,10,12), LL
    9 AA(IZY)=AA(IZY)-2.0*DELTA(IZY)
      NSIGN(IZY)=1
      IF(ICLOSL(IZY).EQ.1) GO TO 10
      GO TO 7
   10 AA(IZY)=AA(IZY)+DELTA(IZY)
      NSIGN(IZY)=0
      GO TO 12
   11 YX=YS
   12 IF(IZY.LT.NUMA) GO TO 6
      IT=1
      IZY=0
      IF(YY.EQ.YX) GO TO 25
      YY=YX
      GO TO 210
C     ---------------------------------------------------------------
C     LOCAL EXCURSION WITH - DELTA FIRST
C     ---------------------------------------------------------------
   14 IF (IZY.GT.0) GO TO 16
      IF(YS.LT.YY) GO TO 4007
      NSAVE=1
      YX=YS
      YY=YS
 4007 WRITE (6,3)
  106 IZY=IZY+1
```

```
      IT=IZY
      IF(LES(IZY).EQ.0) GO TO 108
  107 LL=0
      AA(IZY)=AA(IZY)-DELTA(IZY)
      NSIGN(IZY)=1
      IF(ICLOSL(IZY).EQ.0) GO TO 15
      LL=LL+1
      GO TO 166
   15 LL=LL+1
      GO TO 6000
   16 IF (YX.LT.YS) GO TO 19
  166 GO TO (17,18,20), LL
   17 AA(IZY)=AA(IZY)+2.0*DELTA(IZY)
      NSIGN(IZY)=0
      IF(NCLOSEH(IZY).EQ.1) GO TO 18
      GO TO 15
   18 AA(IZY)=AA(IZY)-DELTA(IZY)
      NSIGN(IZY)=1
      GO TO 20
   19 YX=YS
   20 IF(IZY.LT.NUMA) GO TO 106
      IT=1
      IZY=0
      IF(YY.EQ.YX) GO TO 25
      YY=YX
C     ------------------------------------------------------------
  210 IF(NPER.EQ.0) GO TO 22
      DO 21, I=1,NUMA
      DELTA(I)=ABS(DDELTA(I)*AA(I))
   21 CONTINUE
   22 LC=0
      NSAVE=0
      WRITE (6,5) NCOUN,NN,YY,(AA(I),I=1,NUMA)
      WRITE (6,220)
  220 FORMAT(21X,'PATTERN MOVE')
      NCOUN=NCOUN+1
C     ------------------------------------------------------------
C     PATTERN MOVE ROUTINE
C     ------------------------------------------------------------
      DO 24, I=1, NUMA
      LES(I)=NSIGN(I)
      BA(I)=AA(I)
      AA(I)=2.0*AA(I)-B(I)
C     ------------------------------------------------------------
C     CHECK UPPER AND LOWER CONSTRAINTS
C     ------------------------------------------------------------
      CC=AA(I)-1.01*DELTA(I)
      CD=AA(I)+1.01*DELTA(I)
      IF(CC.GT.CHECKL(I)) GO TO 103
      ICLOSL(I)=1
      AA(I)=BA(I)
      GO TO 104
  103 ICLOSL(I)=0
  104 IF(CD.LT.CHECKH(I)) GO TO 105
```

```
      NCLOSEH(I)=1
      AA(I)=BA(I)
      GO TO 23
  105 NCLOSEH(I)=0
   23 B(I)=BA(I)
   24 CONTINUE
      GO TO 6000
C     ----------------------------------------------------------------
   25 LC=LC+1
C     ----------------------------------------------------------------
C     DESTROY PRESENT PATTERN
C     ----------------------------------------------------------------
      IF(LC-1) 7000,26,28
   26 IF(NSAVE.EQ.1) GO TO 260
      DO 27, I=1,NUMA
      AA(I)=BA(I)
   27 CONTINUE
      ICOUN=ICOUN+1
      GO TO 30
   28 IF(LDELT.GE.KC) GO TO 7000
C     ----------------------------------------------------------------
C     HALVE DELTA(I) RESOLUTION
C     ----------------------------------------------------------------
  260 NSAVE=0
      DO 29, I=1,NUMA
      DDELTA(I)=DDELTA(I)*0.5
      DELTA(I)=DELTA(I)*0.5
   29 CONTINUE
      LDELT=LDELT+1
   30 WRITE (6,31) ICOUN,LDELT
   31 FORMAT(20X,'PATTERN=',I4,'   RESOLUTION=',I5)
      WRITE (6,5) NCOUN,NN,YY,(AA(I),I=1,NUMA)
      GO TO 44
 6000 RETURN
 3000 WRITE (6,5000) I
 5000 FORMAT(1X,'THE INITIAL VALUE FOR A(',I2,') IS TOO CLOSE TO ITS
     1CONSTRAINT. CHECK ALL INITIAL VALUES, MAKE APPROPRIATE CORRECT
     2IONS, AND RESTART')
      WRITE(6,3)
      WRITE(6,5) NCOUN,NN,YS,(AA(I),I=1,NUMA)
7000  WRITE(6,7001)
7001  FORMAT(1X,'CONDITION MET: ISTOP=1')
      ISTOP=1
      RETURN
      END
C     ****************************************************************
C     ****************************************************************
```

APPENDIX B

INPUT VARIABLES REQUIRED FOR EXECUTION

Table B1

Required General Simulation Input Data

Variable	Description
NYEARS	Number of years to simulate
OPTIND	Execution mode. 1 = Optimizing, 0 = Non-optimizing

Table B2

Required Field and Crop Input Data

Variable	Description
TFARAC	Area of field (ac)
CN2	SCS Curve Number for average moisture conditions.
ELEV	Average elevation of field (ft)
WAVEMEAN	Mean of solar radiation sine wave
AMPLITUDE	Amplitude of solar radiation sine wave
PSHIFT	Phase shift of solar radiation sine wave
ALPHASOIL	Soil evaporation parameter (mm)
USOIL	Soil evaporation parameter (mm)
ROOTZONE	Depth of root zone (in)
AVAILWAT	Available water in root zone (in/in)
ALBSOIL	Average albedo of bare soil
IPLANTDATE	Day of year of planting
IMATDATE	Days past planting until maturity
YIELDMAX	Maximum expected crop yield (bu/ac)

Table B3

Required Common Economic Input Data

Variable	Description
INTRATE	Interest rate (decimal)
DISRATE	Discount rate (decimal)
INSRATE	Insurance rate as fraction of initial costs (decimal)
TAXRATE	Tax rate as fraction of initial costs (decimal)
SBPRICE	Price of soybeans ($/bu)

Table B4

Required Operating Cost Input Data

Variable	Description
SSEEDCOST	Seed cost ($/ac)
FERTCOST	Fertilizer cost ($/ac)
LIMECOST	Cost of lime and application ($/ac)
HERBCOST	Herbicide cost ($/ac)
FUNGCOST	Fungicide cost ($/ac)
INSECOST	Insecticide cost ($/ac)
DEFOCOST	Defoliant cost ($/ac)
AEAPCOST	Aerial application cost ($/ac)
MFOLCOST	Machinery fuel, oil, and lubricants cost ($/ac)
MREPCOST	Annual machinery repair cost ($/ac)
CLABCOST	Labor cost ($/ac)
SPRDCOST	Custom spread cost ($/ac)
HAULCOST	Custom haul cost ($/bu)
DRYGCOST	Custom dry or ginning cost ($/bu)
MISCCOST	Miscellaneous costs ($/ac)
CRINCOST	Crop insurance cost ($/ac)
OTHRCOST	Other costs ($/ac)

Table B5

Required Ownership Input Data

Variable	Description
TRACDEP	Tractor depreciation (\$/ac)
TRACINT	Tractor interest (\$/ac)
EQUIPDEP	Equipment depreciation (\$/ac)
EQUIPINT	Equipment interest (\$/ac)
SEQUIPDEP	Special equipment depreciation (\$/ac)
SEQUIPINT	Special equipment interest (\$/ac)
MQPDEP	Miscellaneous equipment depreciation (\$/ac)
MQPINT	Miscellaneous equipment interest (\$/ac)
TAXINS	Taxes and insurance (\$/ac)
COMINT	Interest (\$/ac)
OHLACOST	Overhead labor (\$/ac)
OTOHCOST	OTHER OVERHEAD (\$/AC)
LAPRCOST	Land and property tax (\$/ac)
MANACOST	Management (\$/ac)

Table B6

Required Well Input Data

Variable	Description
IGWDEPTH	Initial depth to potentiometric surface (ft)
GWDECLINE	Rate of annual decline of potentiometric surface (ft/yr)
STORCON	Storage coefficient (decimal)
GWKSAT	Saturated hydraulic conductivity of aquifer (ft/day)
SATDEPTH	Initial saturated thickness of aquifer (ft)
WELLDIAM	Well diameter (ft)
WELLCOST	Cost of well ($)
WELLLIFE	Expected life of well (yr)
WELLREP	Annual repair cost of well as fraction of initial cost (decimal)
WELLFLOW	Pump flow rate (gal/min)
WELLEFF	Well pumping plant efficiency (decimal)
PUMPCOST	Cost of pump and gearhead ($)
PUMPLIFE	Expected life of pump and gearhead (yr)
PUMPREP	Annual repair cost of pump and gearhead as fraction of initial cost (decimal)
DISDIAM	Discharge diameter of well pump (ft)
POWCOST	Cost of power unit ($)
POWLIFE	Expected life of power unit (yr)
POWREP	Annual repair cost of power unit as fraction of initial cost (decimal)
FUELCOST	Energy cost ($/kW-hr)
LUBCOST	Lubrication cost as fraction of fuel cost (decimal)

Table B7

Required Irrigation System Input Data

Variable	Description
APPEFF	Application efficiency (decimal)
ISYSCOST	Cost of irrigation system ($)
ISYSLIFE	Expected life of irrigation system (yr)
ISYSREP	Annual repair cost of irrigation system as fraction of initial cost (decimal)
ISYSLAB	Irrigation labor (hr/ac-in irrigation)
ISYSLCOST	Cost of labor ($/hr)
ISYSPRES	Operating pressure of irrigation system (psi)
CRITSMD	Soil moisture deficit at which irrigation will be applied (mm)

Table B8

Required Reservoir Input Data

Variable	Description
FBD	Reservoir freeboard (ft)
TWD	Top width of reservoir levees (ft)
XN1	Outside slope (horizontal to vertical) of reservoir levee.
XN2	Inside slope (horizontal to vertical) of reservoir levee.
EXCST	Excavation cost ($/cubic yd)
SEEDCST	Levee seeding cost ($/ac)
RESLIFE	Expected life of reservoir (yr)
RESMAINT	Annual cost of reservoir maintenance as fraction of construction cost (decimal)
SEEP	Saturated hydraulic conductivity of reservoir levee/bottom (ft/day)
ALBEDOWAT	Average albedo of water (decimal)
BEGFILL	Day of year on which reservoir fill will begin.

Table B9

Required Reservoir Pump Input Data

Variable	Description
LIFTTDH	Operating head for relift pump (ft)
LIFTFLOW	Capacity of relift pump (gal/min)
LIFTEFF	Efficienty of relift pump station (decimal)
LIFTPCST	Cost of relift pump station ($)
LIFTLIFE	Expected life of relift pump station (yr)
LIFTREP	Annual cost of relift pump station repairs as fraction of initial cost (decimal)
LUBLIFTP	Relift pump station lubrication cost as fraction of fuel cost (decimal)
IRRTDH	Operating head for irrigation pump (ft)
IRRFLOW	Capacity of irrigation pump (gal/min)
IRRPEFF	Efficiency of irrigation pump (decimal)
IRRPCST	Cost of irrigation pump station ($)
IRRLIFE	Expected life of irrigation pump station (yr)
IRRREP	Annual cost of irrigation pump station repair as fraction of initial cost (decimal)
LUBIRRP	Irrigation pump station lubrication cost as fraction of fuel cost (decimal)

Table B10

Required Optimization Algorithm Input Data

Variable	Description
AA(1)	Starting value of reservoir capacity (ac-ft)
DDELTA(1)	Search increment on AA(1) (ac-ft)
CHECKL(1)	Minimum allowable value of AA(1) (ac-ft)
CHECKH(1)	Maximum allowable value of AA(1) (ac-ft)

APPENDIX C

REFERENCE VALUES FOR ARORA INPUTS

Table C1

Fitted Parameters for Sinusoid to Estimate Clear Day Solar Radiation

Location	WAVEMEAN	AMP	PSHIFT
Camden	575.68	228.5	1.29
Eudora	578.25	225.5	1.25
Hope	574.69	229.5	1.25
Hot Springs	569.89	235.0	1.23
Keiser	563.04	242.5	1.30
Marianna	569.22	235.5	1.21
Rowher	574.66	229.5	1.25
Stuttgart	570.46	234.5	1.22

Table C2

Soil Evaporation Parameters (Ritchie, 1972)

Soil Texture	ALPHASOIL (mm/day)	USOIL (mm)
Clay Loam	5.08	12
Loam	4.04	9
Clay	3.50	6
Sand	3.34	6

Table C3

Representative Values of Soil Albedo
(Rosenberg, et al., 1983)

Soil	Albedo
Sand	0.25-0.45
Dark Soils	0.16-0.17
Clay	0.20-0.35

Table C4

Average Pumping Plant Efficiencies
(Soil Conservation Service, 1987)

Pump Type	Total Dynamic Head (ft)	Efficiency
Electric	< 60	0.399
Electric	> 60	0.457
Diesel	< 60	0.133
Diesel	60 - 110	0.177
Diesel	> 110	0.180
Natural Gas	< 100	0.098
Natural Gas	> 100	0.127
LP Gas	< 60	0.085

Table C5

Average Irrigation System Efficiencies
(Soil Conservation Service, 1987)

System	Efficiency
Flood	0.65
Furrow	0.66
Sprinkler	0.83

Table C6

Suggested Values of Critical Soil Moisture Deficit
(Ferguson, et al., 1988)

Soil Texture	Critical Deficit (mm)
Clay	50.8
Silt Loam with Pan	44.5
Silt Loam without Pan	63.5
Sandy Loam	57.2
Sandy	50.8

Table C7

Relative Flow at Selected Stations in Eastern Arkansas (USGS, 1980-1990)

Sta*	Relative Flow, %											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10.0	15.6	11.4	11.1	8.4	4.9	2.4	2.3	3.5	3.5	9.8	17.1
2	11.5	14.4	14.6	13.9	12.3	4.5	3.4	0.9	0.5	3.7	4.5	15.8
3	12.2	14.1	12.0	12.9	10.7	5.8	2.1	2.2	1.6	2.7	8.2	15.5
4	10.5	17.1	13.7	12.1	9.6	4.5	1.3	0.6	0.9	2.6	8.4	18.8
5	14.1	13.2	13.4	11.7	8.5	6.0	5.0	2.4	0.8	3.4	7.1	14.5
6	10.4	16.1	10.0	9.2	10.3	4.4	3.0	3.6	3.2	3.8	8.4	17.7
7	16.8	13.0	12.2	14.9	11.7	6.2	0.3	1.7	0.9	0.5	7.4	14.3
8	8.7	14.4	12.1	12.3	9.5	5.9	4.0	3.0	2.7	3.8	8.0	15.8
9	8.9	12.1	10.7	12.3	9.8	7.6	5.5	4.4	3.9	4.5	7.0	13.3
10	11.9	12.8	11.0	12.6	9.2	6.7	4.2	3.5	3.5	4.2	6.2	14.1

Station Key:

1. Languille River
2. Saline River
3. Big Creek
4. Bayou Meto
5. Bayou Bartholomew
6. Cache River
7. Cypress Bayou
8. Spring River
9. Eleven Point River
10. Black River

APPENDIX D

INPUT VARIABLE VALUES FOR DEMONSTRATIONS

Table D1

General Simulation Variable Values

Variable	Value
NYEARS	30
OPTIND	1

Table D2

Field and Crop Variable Values

Variable	Value
TFARAC	160
CN2	75
ELEV	200
WAVEMEAN	570.46
AMPLITUDE	234.50
PSHIFT	1.22
ALPHASOIL	Variable
USOIL	Variable
ROOTZONE	Variable
AVAILWAT	0.22
ALBSOIL	0.27
IPLANTDATE	140
IMATDATE	145
YIELDMAX	52.6

Table D3

Economic Variable Values

Variable	Value
INTRATE	Variable
DISRATE	Variable
INSRATE	0.025
TAXRATE	0.01
SBPRICE	Variable

Table D4

Operating Cost Variable Values

Variable	Value
SSEEDCOST	9.54
FERTCOST	14.00
LIMECOST	7.91
HERBCOST	15.03
FUNGCOST	1.46
INSECOST	0.00
DEFOCOST	0.00
AEAPCOST	0.00
MFOLCOST	10.69
MREPCOST	20.82
CLABCOST	8.65
SPRDCOST	2.50
HAULCOST	0.15
DRYGCOST	0.00
MISCCOST	0.00
CRINCOST	0.00
OTHRCOST	0.00

Table D5

Ownership Cost Variable Values

Variable	Value
TRACDEP	8.49
TRACINT	7.01
EQUIPDEP	7.30
EQUIPINT	4.00
SEQUIPDEP	10.98
SEQUIPINT	4.02
MQPDEP	0.00
MQPINT	0.00
TAXINS	3.42
COMINT	0.37
OHLACOST	0.00
OTOHCOST	0.00
LAPRCOST	0.00
MANACOST	0.00

Table D6

Well Variable Values

Variable	Value
IGWDEPTH	120.00
GWDECLINE	Variable
STORCON	0.30
GWKSAT	270.00
SATDEPTH	50.00
WELLDIAM	1.33
WELLCOST	4320.00
WELLLIFE	25.0
WELLREP	0.01
WELLFLOW	Variable
WELLEFF	0.18
PUMPCOST	6060.00
PUMPLIFE	15.00
PUMPREP	0.025
DISDIAM	0.83
POWCOST	5600.00
POWLIFE	15.00
POWREP	0.025
FUELCOST	0.0154
LUBCOST	0.03

Table D7

Irrigation System Variable Values

Variable	Value
APPEFF	0.66
ISYSCOST	11715.00
ISYSLIFE	15.00
ISYSREP	0.005
ISYSLAB	0.18
ISYSLCOST	4.15
ISYSPRES	15.00
CRITSMD	Variable

Table D8

Reservoir Variable Values

Variable	Value
FBD	1.50
TWD	12.00
XN1	3.00
XN2	3.00
EXCST	0.65
SEEDCST	1000.00
RESLIFE	30.00
RESMAINT	0.02
SEEP	0.009
ALBEDOWAT	0.36
BEGFILL	105.00

Table D9

Reservoir Pump Variable Values

Variable	Value
LIFTTDH	20.00
LIFTFLOW	2200.00
LIFTEFF	0.18
LIFTPCST	8000.00
LIFTLIFE	15.00
LIFTREP	0.025
LUBLIFTP	0.03
IRRTDH	10.00
IRRFLOW	1200.00
IRRPEFF	0.18
IRRPCST	10500.00
IRRLIFE	15.00
IRRREP	0.025
LUBIRRP	0.03

Table D10

Optimization Algorithm Variable Values

Variable	Value
AA(1)	240.0
DDELTA(1)	10.0
CHECKL(1)	-1000.0
CHECKH(1)	10000.0

APPENDIX E

SAMPLE OUTPUT

```
 *** SUMMARY OF METEOROLOGICAL DATA ***

 YR  TOTAL  GS    POT   ACT   GS POT  GS ACT  PLANT  YIELD    POT R  ACT R
     RAIN  RAIN   ET    ET     ET      ET     TRANS           EVAP   EVAP
     (IN)  (IN)  (IN)  (IN)   (IN)    (IN)    (IN)  (BU/AC)  (IN)   (IN)
 --  ----  ----  ----  ----   ----    ----    ----   ----    ----   ----
  1  49.8  15.3  47.8  38.5   25.7    24.1    15.7   52.6    41.2   25.0
  2  48.7  15.8  47.4  37.9   24.8    23.5    15.3   52.6    39.6   25.7
  3  44.9  15.6  48.9  37.2   25.8    23.5    15.6   52.6    40.8   27.7
  4  42.3  14.3  49.6  38.6   26.2    24.7    15.9   52.6    41.4   23.7
  5  50.5  15.0  49.7  38.7   26.4    23.3    16.2   52.6    41.5   29.6
  6  42.3  11.6  50.5  37.1   27.5    23.1    14.1   44.8    42.1   24.8
  7  34.0  13.4  50.7  36.8   26.5    23.5    15.1   49.1    42.3   22.4
  8  33.8   5.6  49.3  32.4   25.8    20.8    13.4   45.2    41.0   21.6
  9  60.1  17.4  48.1  39.3   25.8    23.8    15.7   52.6    40.2   27.4
 10  57.4  18.9  49.9  39.9   26.1    24.5    15.9   51.5    41.7   29.5
 11  43.3  10.6  50.9  38.7   26.7    23.8    15.7   50.6    42.4   26.1
 12  41.6   7.9  50.0  36.7   26.0    21.2    14.2   46.9    41.6   23.3
 13  51.6  17.3  50.0  38.0   25.8    24.1    16.1   52.6    41.6   26.8
 14  38.8  12.0  50.9  37.1   27.1    23.0    15.4   48.3    42.2   26.5
 15  52.0  21.1  49.1  39.3   26.3    24.4    16.1   52.6    40.9   28.8
 16  47.9  15.8  48.7  36.8   25.8    23.2    15.9   52.6    40.5   27.3
 17  42.4   9.6  49.8  36.7   26.8    23.1    15.5   49.3    41.6   25.4
 18  45.0   9.9  49.0  39.0   26.8    24.2    16.3   52.6    40.9   22.6
 19  33.8  13.3  50.3  34.3   25.4    22.0    14.6   48.6    41.9   19.8
 20  33.1   8.8  49.0  34.6   25.4    22.2    14.7   49.9    41.0   22.4
 21  33.7  11.7  48.9  36.7   26.3    24.1    15.2   49.7    40.9   20.1
 22  40.4  12.7  49.2  38.3   25.3    23.4    14.9   50.3    41.0   23.6
 23  42.1  16.7  47.4  36.9   24.2    22.9    14.9   52.6    39.5   22.5
 24  45.8  10.7  49.9  36.0   25.4    21.5    14.1   46.9    41.7   27.8
 25  45.8  10.4  49.5  36.5   26.0    22.0    14.6   49.3    41.2   27.2
 26  45.1  13.8  49.1  38.8   25.7    23.7    15.5   52.6    40.9   23.2
 27  50.5  21.3  48.2  37.0   25.3    22.5    15.4   52.6    40.2   32.8
 28  62.8  23.0  48.8  39.7   26.0    23.9    15.8   52.6    40.8   30.8
 29  52.0  16.1  48.0  37.7   25.5    23.4    15.7   52.6    40.1   26.2
 30  37.6   5.6  49.6  35.6   26.2    21.5    13.5   44.1    41.5   23.4
 --  ----  ----  ----  ----   ----    ----    ----   ----    ----   ----
AVG  45.0  13.7  49.3  37.4   26.0    23.2    15.2   50.5    41.1   25.5

KEY:
     YR          = YEAR
     TOTAL RAIN  = ANNUAL TOTAL PRECIPITATION
     GS RAIN     = PRECIPITATION OCCURRING DURING GROWING SEASON
     POT ET      = ANNUAL POTENTIAL EVAPOTRANSPIRATION
     ACT ET      = ANNUAL ACTUAL EVAPOTRANSPIRATION
     GS POT ET   = POTENTIAL EVAPOTRANSPIRATION DURING THE GROWING SEASON
     GS ACT ET   = ACTUAL EVAPOTRANSPIRATION DURING THE GROWING SEASON
     PLANT TRANS = CROP TRANSPIRATION DURING THE GROWING SEASON
     YIELD       = CROP YIELD
     POT R EVAP  = ANNUAL POTENTIAL RESERVOIR EVAPORATION
     ACT R EVAP  = ANNUAL ACTUAL RESERVOIR EVAPORATION
```

```
*** SUMMARY OF RESERVOIR FILL, LOSSES, AND OPERATING COST DATA ***

YEAR     SEEPAGE    EVAPORATION     RAINFALL    VOLUME     COST OF
          LOSSES       LOSSES       ADDITIONS   OF FILL      FILL*
         (AC-FT)      (AC-FT)        (AC-FT)    (AC-FT)       ($)
----     -------      -------        -------    -------     -------
   1       17.2         17.2           38.2       50.6         291.
   2       19.6         17.7           37.4       50.2         291.
   3       18.0         19.1           34.5       45.8         283.
   4       16.0         16.3           32.4       50.8         292.
   5       20.4         20.2           38.7       49.4         289.
   6       17.7         17.2           32.5       50.5         291.
   7       14.5         15.6           26.1       50.1         290.
   8       15.7         14.9           26.0       49.4         289.
   9       19.3         18.7           46.1       49.5         289.
  10       20.7         20.3           44.1       43.6         279.
  11       18.2         17.9           33.2       45.0         281.
  12       16.3         16.2           32.0       48.5         288.
  13       18.7         18.5           39.6       49.2         289.
  14       18.4         18.3           29.8       48.6         288.
  15       19.7         19.8           39.9       50.2         291.
  16       19.3         18.7           36.7       50.4         291.
  17       19.1         17.5           32.5       47.9         286.
  18       16.7         15.5           34.5       48.0         287.
  19       13.2         13.8           25.9       50.9         292.
  20       17.2         15.3           25.4       50.8         292.
  21       15.6         13.7           25.9       50.8         292.
  22       17.1         16.4           31.0       50.5         291.
  23       15.2         15.7           32.3       50.6         291.
  24       19.5         19.3           35.1       48.4         287.
  25       19.4         18.7           35.2       43.8         279.
  26       15.7         16.0           34.6       47.7         286.
  27       22.1         22.5           38.8       48.8         288.
  28       20.9         21.3           48.2       45.4         282.
  29       18.6         18.0           39.9       46.8         284.
  30       17.2         16.1           28.8       47.7         286.
----     -------      -------        -------    -------     -------
AVG        17.9         17.5           34.5       48.7         288.

* FUEL, LUBRICANTS, AND REPAIRS USED TO FILL RESERVOIR
  DOES NOT INCLUDE RESERVOIR MAINTENANCE COSTS
```

```
*** SUMMARY OF COST DATA ***

YEAR     OWNERSHIP      OPERATING      RETURNS    NET     PRESENT
           COSTS          COSTS                  INCOME    WORTH
            ($)            ($)           ($)      ($)       ($)
----     ---------      ---------      -------  ------    ------
   1       16167.         21098.        59283.  22018.    20017.
   2       16167.         20654.        59283.  22462.    18564.
   3       16167.         20271.        59283.  22845.    17164.
   4       16167.         20954.        59283.  22163.    15137.
   5       16167.         20290.        59283.  22826.    14173.
   6       16167.         20923.        50537.  13447.     7591.
   7       16167.         21042.        55333.  18124.     9301.
   8       16167.         21555.        50999.  13276.     6194.
   9       16167.         20239.        59283.  22877.     9702.
  10       16167.         20638.        57990.  21185.     8168.
  11       16167.         21962.        57070.  18942.     6639.
  12       16167.         21501.        52877.  15209.     4846.
  13       16167.         21095.        59283.  22021.     6379.
  14       16167.         21009.        54392.  17216.     4534.
  15       16167.         20570.        59283.  22546.     5397.
  16       16167.         20595.        59283.  22522.     4901.
  17       16167.         21860.        55533.  17506.     3463.
  18       16167.         21685.        59283.  21431.     3855.
  19       16167.         21370.        54788.  17251.     2821.
  20       16167.         21927.        56252.  18158.     2699.
  21       16167.         22014.        56029.  17848.     2412.
  22       16167.         21291.        56715.  19256.     2366.
  23       16167.         20547.        59283.  22569.     2520.
  24       16167.         21033.        52817.  15616.     1585.
  25       16167.         21088.        55575.  18320.     1691.
  26       16167.         21598.        59283.  21518.     1805.
  27       16167.         18829.        59283.  24288.     1853.
  28       16167.         19880.        59283.  23236.     1611.
  29       16167.         20791.        59283.  22326.     1407.
  30       16167.         21714.        49684.  11803.      676.
----     ---------      ---------      -------  ------    ------
AVG        16167.         21001.        56861.  19694.     6316.
```

```
*** SUMMARY OF RESERVOIR CHARACTERISTICS ***

DESIGN CHARACTERISTICS:

CAPACITY                              =       50.00 ACRE-FEET
EXCAVATED DEPTH                       =        1.50 FEET
STORAGE HEIGHT ABOVE GROUND LEVEL     =        4.48 FEET
FREEBOARD                             =        2.00 FEET
TOTAL DEPTH                           =        7.98 FEET
LEVEE SLOPE OUTSIDE                   =        3.00:1
LEVEE SLOPE INSIDE                    =        3.00:1
BOTTOM BASE OF RESERVOIR              =      585.51 FEET
TOTAL BASE OF RESERVOIR               =      640.89 FEET
AREA OCCUPIED                         =        9.43 ACRES
AREA OF FOREGONE PRODUCTION           =        9.73 ACRES
REMAINING IRRIGATED AREA              =      150.27 ACRES


ASSOCIATED COSTS:

EXCAVATION COST AT  .65/CU YD       = $    12571.01
SEEDING COST AT 1000./AC            = $     3302.73
COST OF LIFT PUMP                   = $     8000.00
COST OF SURFACE IRRIGATION PUMP     = $    10500.00
                                         -----------
TOTAL CONSTRUCTION COST             = $    34373.74
```

```
------------------------------------------------------
AVERAGE ANNUAL OPERATING COSTS
------------------------------------------------------
RESOURCE OR INPUT          COST          COST PER ACRE
------------------------------------------------------
SEED                       1434.             9.54
FERTILIZER                 2104.            14.00
LIME + APPLICATION         1189.             7.91
HERBICIDE                  2259.            15.03
FUNGICIDE                   219.             1.46
INSECTICIDE                   0.              .00
DEFOLIANT                     0.              .00
AERIAL APPLICATION            0.              .00
MACHINERY:
  FUEL, OIL, LUBRICANTS    1606.            10.69
  REPAIRS                  3129.            20.82
LABOR                      1300.             8.65
IRRIGATION FROM WELL:
   FUEL, OIL, LUBRICANTS   2046.            13.61
   REPAIRS                  334.             2.23
   IRRIGATION LABOR        1413.             9.40
RESERVOIR MAINTENANCE       317.             2.11
RESERVOIR FILL
   FUEL, OIL, LUBRICANTS     88.              .58
   REPAIRS                  200.             1.33
IRRIGATION FROM RESERVOIR:
   FUEL, OIL, LUBRICANTS     76.              .50
   REPAIRS                  263.             1.75
   IRRIGATION LABOR         418.             2.78
CUSTOM SPREAD               376.             2.50
CUSTOM HAUL                1137.             7.57
CUSTOM DRY OR GINNING         0.              .00
MISCELLANEOUS                 0.              .00
CROP INSURANCE PREMIUM        0.              .00
OTHER                         0.              .00
INTEREST ON OP CAPITAL     1095.             7.29
------------------------------------------------------
TOTAL SPECIFIED OP COST   21001.           139.75
------------------------------------------------------
```

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------------------------------------------------------
AVERAGE ANNUAL OWNERSHIP COSTS
------------------------------------------------------
RESOURCE OR INPUT          COST          COST PER ACRE
------------------------------------------------------
TRACTORS:
   DEPRECIATION            1276.              8.49
   INTEREST                1053.              7.01
EQUIPMENT:
   DEPRECIATION            1097.              7.30
   INTEREST                 601.              4.00
SPECIAL EQUIPMENT:
   DEPRECIATION            1650.             10.98
   INTEREST                 604.              4.02
MISCELLANEOUS:
   DEPRECIATION               0.               .00
   INTEREST                   0.               .00
IRRIGATION:
   DEPRECIATION            1730.             11.52
   INTEREST                1523.             10.13
RESERVOIR:
   DEPRECIATION            1762.             11.73
   INTEREST                1890.             12.57
TAXES AND INSURANCE        2686.             17.87
   INTEREST                 295.              1.97
OVERHEAD LABOR                0.               .00
LAND AND PROPERTY TAX         0.               .00
OTHER OVERHEAD                0.               .00
MANAGEMENT                    0.               .00
------------------------------------------------------
TOTAL SPECIFIED OWN COSTS 16168.            107.59
------------------------------------------------------

AVERAGE ANNUAL RETURNS    56861.            378.38
TOTAL OP AND OWN COSTS    37169.            247.34
                         -------            ------
DIFFERENCE                19693.            131.05
```