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PLATTE RIVER FORUM FOR THE FUTURE WORKSHOP MODEL DOCUMENTATION

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INTRODUCTION

The Platte River Forum for the Future (PRFF) is an effort by the Nebraska Natural Resources Commission (NNRC) to bring together representatives of interests and agencies concerned with management of the Platte River and, assisted by various computer technologies, to reach some degree of agreement on the "best uses" of the remaining waters of the Platte. Simulation modeling is being used in this effort as a focal point for developing a common understanding of the behavior of the Platte River system, synthesizing existing information, identifying additional needed information, and analyzing the potential consequences of various management alternatives.

The NNRC initiated the project in August 1982 by convening a workshop for interested parties in Grand Island, Nebraska. This workshop was devoted to construction of a preliminary simulation model describing the Platte River system. A group of facilitators/modelers from the U.S. Fish and Wildlife Service (FWS) assisted participants in translating their understanding of the Platte River into the framework of the model. In October 1982, FWS personnel began a process of training several people from Nebraska in the use of the model. At that time, minor revisions and corrections were made in the model and various development scenarios were prepared for discussion with participants at a second workshop, which was held in early November 1982.

The purpose of this report is to document the status of the PRFF simulation model as of the end of the November 1982 meeting. We emphasize that the intent is <u>not</u> to describe a final product. Except for minor revisions and correction of obvious errors, the model described herein is that which existed at the end of the August workshop. The model contains the foundation for a

comprehensive aid to decisionmakers, but at this time it is preliminary in nature, needing refinement and verification before it can be truly useful in analyzing management alternatives. The purpose of this report is to provide a solid foundation for that important future work.

The report is divided into three basic parts. The first is a brief overview of the various components of the model and how they fit together. It is intended for those who are not particularly interested in the details of model formulation. The second is a detailed discussion of the logic, assumptions, equations, and data used in constructing the model. This detailed description is also referenced to specific sections of the third part, which is a set of appendices containing listings of the computer code as it presently exists.

OVERVIEW

SYSTEM MODEL

Resource development and management issues, such as those being addressed by the PRFF, typically involve complex interactions among a variety of economic, social, and environmental factors. Although some individual components of such a system may be well understood, the complexity of component interactions generally results in poor understanding of the system as a whole. Simple representations of poorly understood systems can often provide valuable insight into system behavior under different management or development alternatives; they may not provide sufficient detail and credibility for actual decisionmaking. The representation used in a simulation model must therefore be sufficiently detailed and flexible to address all concerns adequately, yet must remain simple enough to be understandable. Problem simplification for better understanding is stressed in the early phases of the workshop modeling process being used by the PRFF; addition of realistic complexity is stressed in later phases to provide a level of detail consistent with management and decision needs.

The process of simplification, or bounding, was initiated in the PRFF August workshop by describing management alternatives (actions) for the Platte River, identifying performance measures (indicators) used to evaluate the effects of those actions, and putting the actions and indicators in a manageable spatial and temporal framework.

Actions and Indicators

Actions and indicators identified at the August PRFF workshop are listed in Table 1. For purposes of clarity they are organized into six major groups corresponding to the submodels discussed in this report. The majority of the actions pertain to potential water development and management decisions and represent the parameters and/or mechanisms that can be changed when using the model to test alternatives. The indicators represent a variety of environmental, social, and economic outputs produced by the model for the purpose of evaluating the relative desirability of alternatives that are tested.

Space and Time

The spatial area considered in the model is shown in Figure 1. It includes the Platte River basin from the Julesburg (South Platte) and Lewellen (North Platte) gauging stations in the west to the Louisville gauging station in the East. The river itself is further divided into eight reaches at additional gauging stations: (1) Julesburg to North Platte; (2) Lewellen to North Platte; (3) North Platte to Brady; (4) Brady to Overton; (5) Overton to Grand Island; (6) Grand Island to Duncan; (7) Duncan to North Bend; and (8) North Bend to Louisville. Lines drawn approximately orthogonal to the river from each gauging station to the basin boundaries north and south of the river are used to define 16 spatial subunits for use in calculating agricultural production and groundwater levels. In addition, the model considers, but in less detail, the Enders, Little Blue, and Big Blue proposed project areas.

The basic time step of the model is 1 month; that is, most of the variables calculated by the model (e.g., stream flow, groundwater levels, agricultural withdrawals and returns, municipal/industrial withdrawals and returns, and wildlife habitat indices) are updated monthly. Economic variables (e.g., net returns to agriculture) are calculated only at the end of each simulation year.

Table 1. Actions and indicators identified at the first PRFF workshop.

Surface Water Submodel

Actions	Indicators
Alter interstate transfers	Instream flows
Alter interbasin transfers	Nitrate concentrations
Build storage reservoirs	Urban and agricultural withdrawals and returns
Alter management of stored water	Water available for meeting water rights
Alter withdrawal and return patterns	Acres flooded
Use water management to:	
1) stabilize existing uses	
2) expand irrigated acres	
3) maintain recharge rates	
4) maintain water quality (nitrates)	
5) maintain waterfowl habitat	

Agriculture Submodel

Actions	Indicators
Alter crop acreages	Demand for agricultural water withdrawals
Alter irrigation practices (type and acreages)	Crop yields
Change water utilization of crops	Crop and irrigation practice acreages
Change soil management practices[a]	Livestock production
Limit irrigation withdrawals	Subirrigated acreages
	Water-use efficiency

Municipal/Industrial Submodel

Actions	Indicators
Alter municipal/industrial water withdrawals	Municipal/industrial water requirements
Alter electric power water withdrawals	Electric power water requirements
	Electric power production
	Human population
	Flood damage[a]

Table 1. (continued)

Wildlife/Recreation Submodel

Actions	Indicators
Clear woody riparian vegetation	Acreages of four riparian habitat types
Alter channel width	Relative amount of crane habitat[b]
	Relative amount of least tern nesting habitat[b]
	Relative amount of duck migration/hunting habitat[b]
	Relative amount of overwintering, spawning, and production habitat for channel catfish and a representative forage fish[b]
	Relative amount of habitat for a generalized forest mammal[b]
	Recreation use-days for hunting, fishing, boating, crane viewing, and other general recreation

Groundwater Submodel

Actions	Indicators
Alter groundwater augmentation	Groundwater levels
1) injection[a]	Urban and agricultural withdrawal and recharge
2) irrigation seepage	Nitrate concentrations
3) storage seepage	Well yields
Integrate surface and groundwater management	Groundwater exchanges with Platte River

Table 1. (concluded)

Economics Submodel	
Actions	Indicators
Alter crop prices	Economic costs and benefits of water management alternatives
Alter demand for agricultural products[a]	Net returns to agriculture, recreation, and electric power generation
Alter availability of state/federal funds[a]	Level of industrial activity[a]
	Employment and income by economic sector[c]
	Energy efficiences[a]

[a]Identified at the workshop but not included in the model due to lack of time or information.

[b]Relative is defined as a proportion of the amount present in 1982.

[c]Employment and income are included in the model only for the agricultural sector.

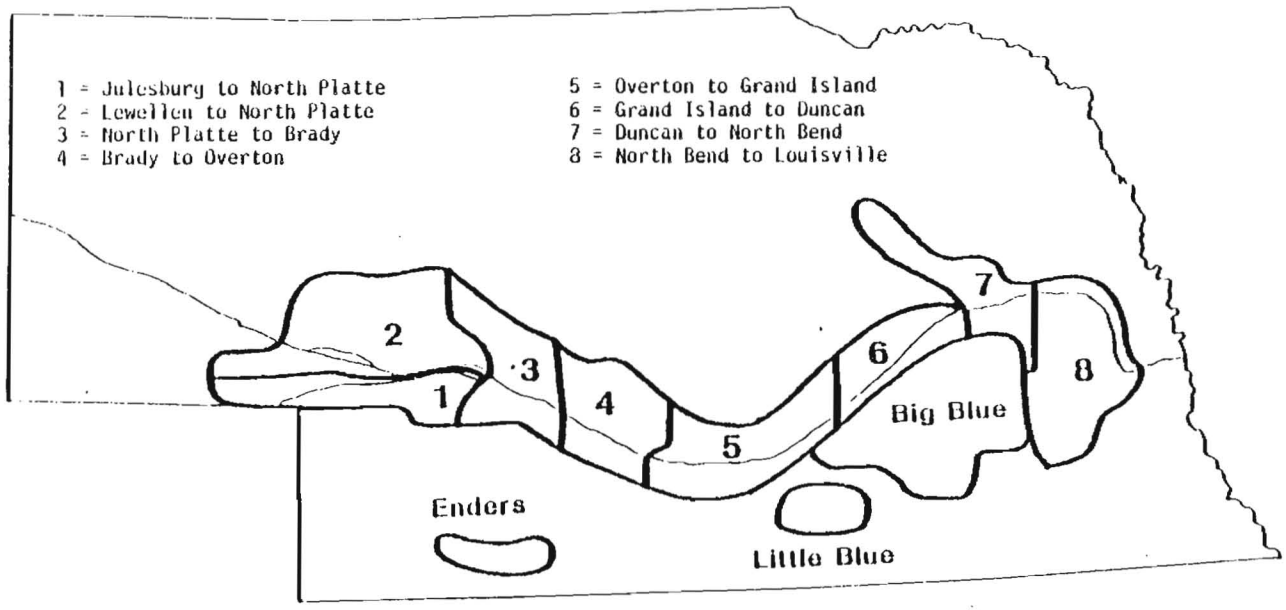


Figure 1. River reaches and project areas used in the PRFF workshop model.

The length of projections produced by the model is chosen by the user when the model is run. These may be as short as 1 month, or as long as 50-100 years.

Submodel Definition

Based on the discussions of actions and indicators at the August workshop, the Platte River system was divided into six subsystems or submodels for more detailed discussion by small groups of workshop participants. These subsystems were surface water, groundwater, agriculture, wildlife/recreation, municipal/industrial, and economics. Criteria used in selecting these subgroups included:

(1) minimizing information transfers between submodels (each subgroup considered a relatively isolated part of the whole system);

(2) efficient allocation of understanding (each subgroup represented the concerns and subject matter expertise of a group of participants); and

(3) equal distribution of work among the workshop facilitators (each participant had an opportunity to incorporate an appropriate amount of depth in his area of expertise).

Submodel Interactions

Following submodel definition, workshop participants discussed the interactions between submodels by constructing a Looking Outward Matrix. The six submodels were arrayed as both the row and column headings of a matrix. For each column of the matrix (i.e., for each component or submodel), participants were asked what information they needed from all of the other components (i.e., row elements within that column) in order to predict how their component would behave under various management alternatives. In other words, they were

asked to "look outward" at the ways in which other hydrologic, biological, economic, and social aspects of the system affect the areas of concern to them.

The information from the Looking Outward Matrix developed at the August workshop is summarized in Figure 2. Boxes represent the six submodels and arrows represent the information exchanges between submodels. This diagram thus illustrates the basic structure of the PRFF simulation model. The submodel descriptions that constitute the remainder of this report are simply elaborations of the general theme shown in Figure 2. They describe, in each case, how information from other submodels is used to produce both information transferred to other submodels and indicator variables identified in the bounding exercise (Table 1).

BRIEF SUBMODEL DESCRIPTIONS

Surface Water Submodel

Responsibilities. The Surface Water submodel is responsible for calculating monthly Platte River flows in the eight river reaches under historical conditions and changes in those flows as a result of alternative water development projects. In addition, the Surface Water submodel produces flow-related information required by other submodels (e.g., maximum daily flow, number of no-flow days, stream width, and acres flooded).

General structure. The Surface Water submodel is based on a regression approach currently being used by the Nebraska Department of Water Resources to predict the effects of proposed water projects on downstream flows. The regression approach was developed from gauge data on river flow, diversions, and tributary inflows for the period 1954-1979. The form of the model is:

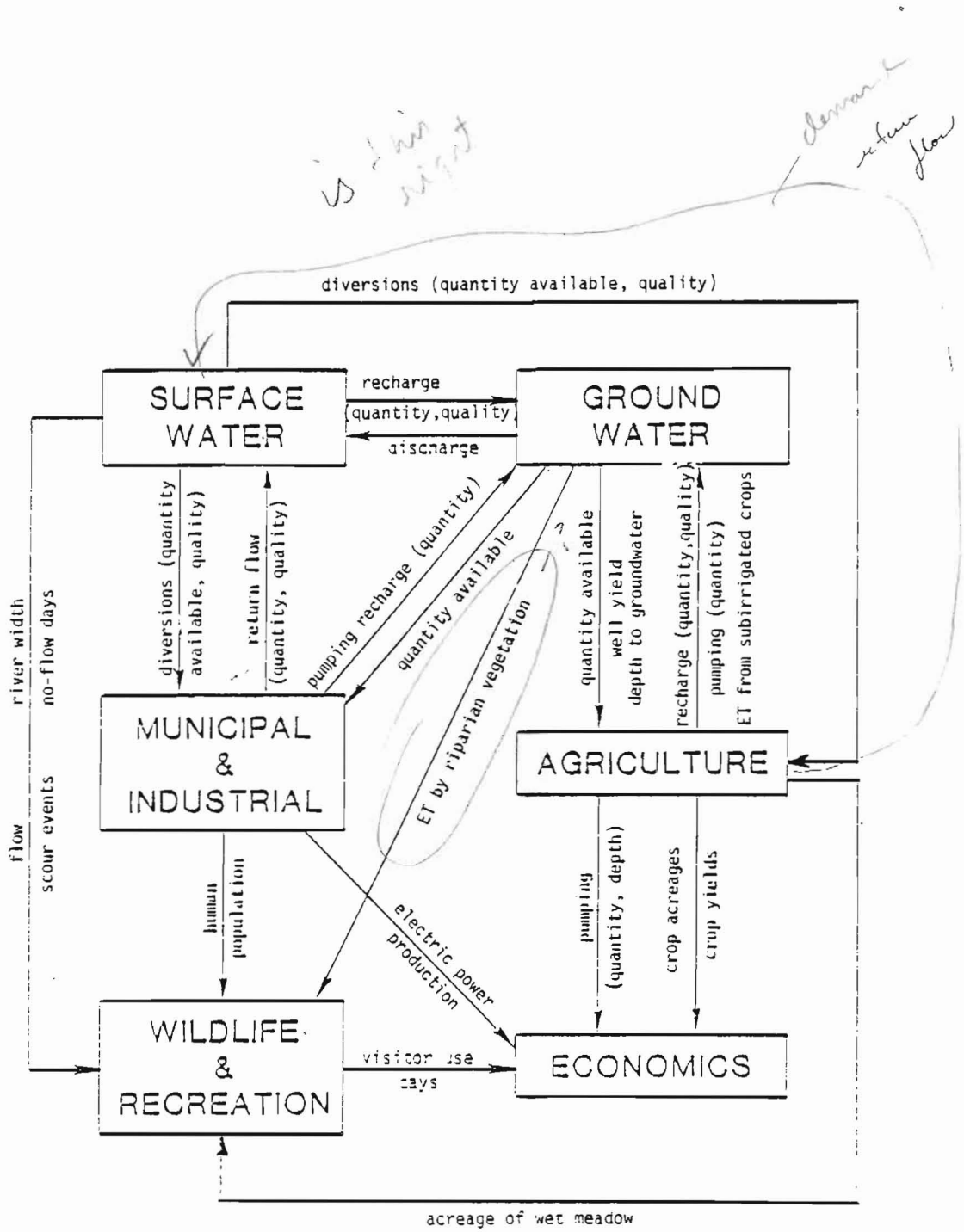


Figure 2. Submodel interactions identified at the first PRFF workshop.

$$D2 = aD1 + bO + cI + d$$

where

D2 = flow at the bottom of a reach;

D1 = flow at the top of a reach;

O = gauged diversions from the reach;

I = gauged inflows (e.g., tributaries) to the reach; and

a,b,c,d = regression coefficients.

Regression coefficients vary by reach and by month of the year. Other inflows and outflows for a reach (e.g., ungauged tributaries, recharge to or discharge from groundwater) are implicit in the regression. The equations are applied successively to reaches moving down the river with the D2 calculated for one reach being used as the D1 for the next lower reach. Additional diversions and return flows that might result from proposed projects of interest are added to the O and I terms of the equations for the appropriate reaches and months. For the workshop, another factor was included in this model. Additional recharge to or discharge from groundwater over historical levels (i.e., the time period 1954-1979 from which regression coefficients were determined) is added to the appropriate O or I term of the equation. These values are calculated by the Groundwater submodel. The primary input data for the regression model are historical flows at the Julesburg and Keystone gauging stations.

Additional information required by other subgroups (stream width at Grand Island, acres flooded in each reach, maximum daily flow in June at Grand Island, number of days during the year that flow at Overton exceeds 3,800 cfs) is computed from predicted river flow using regressions developed during the workshop. Nitrate concentrations in surface water are crudely calculated from the amount of surface water and nitrate concentration entering the top of a

reach mixing with an amount of water, if any, entering the river from groundwater and its nitrate concentration. The calculated surface water concentration is then used as input to the next lower reach.

The regression model does a good job of implicitly representing a complex water allocation procedure and producing good estimates of streamflows. The model also does a reasonably good job of evaluating consequences of most of the proposed water projects. However, as with all models, it will not answer all questions for all people. Two questions arose during the workshop which were concerned with the fact that water rights and operating rules for existing reservoirs are implicit in the regression equations. First, the operation of Kingsley Dam was evidently changed around 1973 as a result of wind damage to the face of the dam. The extent to which this, or future changes in operating criteria, might influence values of the regression coefficients and predictions of flow at the bottom of each reach is not known. Second, projects that would alter seniority of existing water rights cannot be easily evaluated. For example, the Twin Platte project as presently conceived would acquire a 1921 water right that would be senior to some of the water rights implicit in the regression coefficients. A surface water model could be built to account explicitly for reservoir operating and water allocation rules. This type of model would be much more complex, might or might not give any better predictions of streamflows, but would answer different types of questions concerning future water management. One of the primary decisions the Platte River Forum for the Future must make concerning the workshop model is what types of water management questions are most important to address and what types of surface and groundwater models are most pertinent to those questions.

Agriculture Submodel

Responsibilities. The Agriculture submodel is responsible for calculating the following variables as model indicators (Table 1) or for use by other submodels (Figure 2): (1) agricultural demand for surface and groundwater withdrawals; (2) groundwater pumping for agriculture; (3) evapotranspiration (ET) from subirrigated croplands; (4) crop yields; (5) crop acreages;

(6) water-use efficiencies; and (7) quantity and quality (nitrate concentration) of agricultural recharge to groundwater. One indicator, livestock production, was identified but not included in the model.

The Agriculture submodel also incorporates, as actions (Table 1), alterations in the following: (1) acreage in various irrigation types; (2) crop acreages; (3) water-use efficiencies; and (4) irrigation withdrawals. One action, change in soil management practices, was identified but not incorporated except to the extent that changes in crop acreages, irrigation practices, and water-use efficiencies imply different soil management policies.

Other submodels provide the following variables to the Agriculture submodel: (1) quantity and quality (nitrate concentration) of surface water diversions for agriculture; (2) quantity and quality (nitrate concentration) of groundwater available for agricultural pumping; (3) depth to groundwater; and (4) well yield.

General structure. Land in each spatial subunit is classified as one of six water-use types: surface water-irrigated; groundwater-irrigated; dryland production; subirrigated; pasture; and other. Six crops are distinguished for the irrigated and dryland types: alfalfa; corn; milo or grain sorghum; soybeans; wheat; and other. Two crops, alfalfa and native hay, are possible for subirrigated land. Gradual changes in crop proportions are interpolated from 1980 proportions and an estimate of crop proportions in 2020.

In the absence of specific projects or groundwater declines, general increases in the amount of groundwater irrigation are interpolated from estimates of groundwater-irrigated acres in 1980 and 2020. Acres in each reach are removed from groundwater irrigation due to groundwater declines using a relationship based on average well yield in the respective spatial subunits.

Irrigation water requirements are calculated from annual net crop water requirements and a set of proportions to distribute the requirement over

months. These amounts of water are then divided by field irrigation efficiencies, and delivery efficiencies in the case of surface water irrigation, to obtain the volume of water needed. Surface water irrigators are assumed to supplement surface water with groundwater if insufficient surface water is available (as calculated by the Surface Water submodel). Groundwater withdrawals (evapotranspiration) by subirrigated crops are assumed to equal the respective crop irrigation requirements with reductions applied if there has been a decline in groundwater in a given spatial subunit.

Average crop yields are calculated by interpolation between current yields and projected future yields. In the case of subirrigated crops, these yields are then reduced as a function of groundwater declines.

Monthly runoff and groundwater recharge are calculated from field and delivery irrigation efficiencies for irrigated land during the irrigation season; they are calculated from monthly coefficients applied to precipitation for cases in which irrigation is not occurring. Nitrate concentrations in groundwater recharge are obtained as a volume-weighted average of field percolation (at concentrations specific to each crop) and irrigation delivery losses to groundwater (at the concentration of surface water in each reach).

Municipal/Industrial Submodel

Responsibilites. The Municipal/Industrial submodel simulates three general processes: (1) human population growth; (2) withdrawals and returns of water for municipal/industrial use and energy production; and (3) electric power production. Because water use for municipal purposes is in part a function of water quality, a crude representation of nitrate concentrations in municipal well fields is also incorporated. Quantity and quality (nitrate concentration) of surface water and groundwater available are the basic pieces of information utilized from other submodels.

General structure. In each reach, the monthly municipal/industrial demand for water is calculated by multiplying the human population size times

an estimate of per capita water use. Current populations and projected growth rates are used to make new estimates of human population size each year. Monthly per capita water use is calculated from average annual per capita use partitioned according to a seasonal water use pattern and an assumed increase of 1 gal/day each year.

Water for municipal/industrial use is assumed to come from groundwater sources. The amount pumped each month is the smaller of the calculated demand and the amount of groundwater available. Return flows, which are assumed to be discharged to the river, are simply a proportion of the amount pumped.

A crude estimate of the nitrate concentration in water pumped for municipal/industrial purposes is obtained by taking a weighted average of the concentrations in surface water and groundwater. The relative contribution of surface water and groundwater to the well field nitrate concentration depends on the direction of exchange between the groundwater reservoir and the river (see discussion in the Groundwater submodel below). In a losing reach, where water is moving from the river to groundwater, the relative contribution of surface water to the well field nitrate concentration is assumed to be large. In a gaining reach it is assumed to be small.

Both hydroelectric and thermal plants are considered in the energy production section of the Municipal/Industrial submodel. All plants are assumed to produce at their current levels with the exception of the thermal plant at Sutherland, which is assumed to increase production at the rate of 2% per year. Monthly production is obtained by multiplying annual production times a monthly distribution pattern. Only thermal plants are considered to use water consumptively. The amount of consumptive use in each month is obtained by multiplying the number of megawatt-hours (MWh) produced times an average consumption rate (600 gal/MWh).

Wildlife/Recreation Submodel

Responsibilities. The Wildlife/Recreation submodel is responsible for representing a variety of actions and indicators (Table 1) and producing several types of information required by other submodels (Figure 2). These responsibilities can be grouped into three categories: (1) succession of four riparian vegetation types, the amount of evapotranspiration expected from each type, and the estimated value of each type in current (1982) dollars; (2) the amount of wildlife habitat, relative to the amount present at the beginning of the analysis (1982), for sandhill cranes, least terns, ducks, channel catfish, a generalized forage fish, and a generalized forest mammal; and (3) the estimated number of recreational use-days generated by hunting, fishing, boating, crane viewing, and general activities, such as picnicking, swimming, and bird watching.

For each river reach (Figure 1), estimates of riparian succession, riparian habitat value, crane habitat, forest wildlife habitat, and recreational use-days are calculated once each simulation year. The remaining variables are calculated monthly or in selected months as appropriate (see detailed submodel description).

General structure. The riparian vegetation section of the submodel addresses one of the two actions this submodel controls. Although this action was identified in the bounding exercise as "clear woody riparian vegetation" (Table 1), the approach taken is a more general one in which any of the four riparian habitat types may be manipulated.

If no actions are implemented during a model run, riparian succession determining the number of acres in each reach in sand bar, wet meadow, shrub, and riparian tree habitat types is calculated annually based on the following assumptions. Sand bars are converted to wet meadow at a maximum rate of 5% annually. The maximum conversion rate is decreased as a function of the number of times during the year the maximum daily flow exceeds 3,800 cfs. Wet meadow type is converted to shrub type in 3 years. Shrub type becomes tree

type in 5 years. Tree type has no successional stages. Dollar values for each habitat type in each reach are calculated based on estimated 1982 selling prices. Finally, evapotranspiration (acre-ft/month) is estimated monthly for each successional stage.

Crane habitat is estimated only in reaches 4 and 5 because there is insignificant crane usage in the other model reaches. The relative (amount estimated compared to amount in 1982) amount of crane habitat is calculated as the minimum of the relative amount of feeding or roosting habitat. More simply, the percentage loss (or gain) of each habitat type is used. Because there is currently much more feeding habitat available than roosting habitat and because the relative change in these habitats is used to indicate probable trends in crane populations, the question of how fully cranes are utilizing each of these habitats is not addressed. However, the unanimous opinion of the subgroup participants was that cranes are currently saturating only a small part of the available feeding habitat. Therefore, a 10% loss in feeding habitat does not reflect the same potential for reduced capacity of the Platte system to support cranes as does a 10% loss in roosting habitat. A better estimate of the relationship of these variables to crane populations should be included as a model revision. This deficiency does not produce unacceptable model behavior under the conditions tested to date because feeding habitat, which is estimated by the number of acres of subirrigated native hay (Agriculture submodel), tends to remain stable.

At the present state of understanding, sandhill crane roosting habitat is defined as consisting of the following characteristics: (1) located within 3.5 miles of sufficient feeding habitat; (2) at least visually isolated from human activities; (3) an unobstructed view (i.e., vegetation less than 1 meter in height) of approximately 50 meters in all directions; and (4) a water depth of less than about 0.5 meter (which usually occurs in the Platte River over inundated sand bars in the river channel). In the model, proximity to feeding habitat is addressed by the assumptions associated with roosting habitat (i.e., all available feeding habitat occurs within 3.5 miles of the river). Visual isolation from human disturbance is not addressed in the model because:

(1) the general screening characteristics of the shrubs and woody riparian vegetation usually meet this requirement; and (2) the sources of most human disturbances are too local in nature to be addressed with the spatial resolution of this model. Unobstructed view is usually estimated in the model by the surrogate of active channel width. For the purposes of this model, the conservative approach of the water surface width (Surface Water submodel) during the months the cranes are present is used to determine channel width and hence unobstructed view. At this point, the second action for which this submodel is responsible is contained in the code as user controlled channel width. The Surface Water submodel value for channel width can be overridden with user input to represent such activities as riparian vegetation manipulation for improving crane habitat. If this option is used, care must be taken to coordinate vegetation manipulation for roosting habitat improvement with the acreages of the various riparian habitat types and their successional stages. A major omission in the current model is that calculated sand bar loss is never linked to impact on available roosting habitat. This omission can be easily corrected and should have a high priority among possible submodel revisions.

Least tern nesting success is dependent on availability of nesting habitat during July and August and is represented in the model as an "all or none" condition. Sufficient habitat is available to accommodate all terns attempting to nest if: (1) flows during the nesting months remain low enough to expose sandbars; and (2) flows during the nesting months do not exceed the maximum flow observed during June when nest site selection is assumed to occur.

Duck migratory habitat as a function of flow is calculated for two periods, February to April and October to November. The latter period is important for waterfowl hunting activity. An attempt to estimate amount of duck overwintering habitat based on water surface levels in the various reaches did not result in satisfactory model behavior and is not currently in the submodel.

Relative amount of riverine habitat as a function of flow is calculated for key life stages (spawning, summer production, and overwintering) of channel catfish and a representative forage fish (Cyprinid minnow). The channel catfish is included in the model because of its importance to the recreational fishery. Inclusion of a small cyprinid is justified because of dependence of other species (e.g., waterfowl, other fish) on an aquatic forage base.

Habitat available to species preferring a forest habitat (e.g., whitetail deer, squirrels) is estimated by the number of acres of shrub and tree habitat (riparian habitat types) in the current year relative to the amount of these habitats in 1982.

Recreational use-days are estimated using an approch that attributes recreational activity to the land area on both sides of the river as well as the river reach itself. Estimates are generated for boating, hunting, fishing, general nonconsumptive activities (e.g., picnicking and swimming) and sandhill crane viewing. Except for crane viewing, which is a function of both human population and crane habitat availability, all estimates of future recreational activity are based only on human population change in the various spatial subunits.

Groundwater Submodel

Responsibilities. The Groundwater submodel computes three basic pieces of information for each of the 16 spatial subunits (eight reaches, both north and south of the river): (1) exchanges between the Platte River and the groundwater "reservoir"; (2) amount of groundwater in storage; (3) nitrate concentrations in groundwater. Exchanges between the Platte and the proposed Big Blue project area are also computed. The amount of groundwater in storage is used to calculate water table elevation and depth to groundwater. Basic information utilized from other submodels includes: groundwater pumping, recharge, nitrate concentrations in recharge, and evapotranspiration from subirrigated lands (from the Agriculture submodel); groundwater pumping (from

the Municipal/Industrial submodel); evapotranspiration by riparian vegetation (from the Wildlife/Recreation submodel); and nitrate concentrations in surface water (from the Surface Water submodel).

General structure. The regression approach used in the Surface Water submodel implicitly incorporates historic levels of pumping, recharge, and exchanges between groundwater and the Platte River; that is, all of these processes were occurring during the period of record (1954-1979) from which data were used to develop the regression coefficients. In projecting future conditions, the Groundwater submodel therefore uses only changes from "historic" pumping and recharge levels to calculate additional changes in groundwater in storage. "Historic" levels for the various pumping and recharge factors can be set in two ways; they can be entered as data or they can be set equal to the values calculated by the other submodels in the first year of simulation.

Each of the 16 spatial subunits is then treated as a linear groundwater "reservoir". Pumping losses, evapotranspiration losses, and recharge gains (produced by the other submodels) are subtracted from historic levels to determine a net change in these factors. If the net change is positive (i.e., additional recharge exceeds additional pumping), groundwater is added to the river; if negative (i.e., additional pumping exceeds additional recharge), water is removed from the river to groundwater storage. The amount of water exchanged in either case is calculated by multiplying the net change times a coefficient (hence the term "linear reservoir") determined from the surface area, average transmissivity, and storage coefficient of the aquifer. The exchange of water calculated in this manner thus represents only an increment, due to additional changes in pumping and recharge, over and above that which occurred historically.

The amount of groundwater in storage is then adjusted by the net change in pumping and recharge and the amount of loss or gain to the river. The height of the water table is calculated using the surface area of the subunit, the elevation of the base of the aquifer, and a storage coefficient (inches of

water per inch of soil). Nitrate concentrations in the groundwater are calculated by a simple mass balance, taking into account the average initial concentration in the groundwater, loadings from agricultural recharge, and loadings due to inflow (if any) of surface water from the Platte River.

The use of the net change in pumping and recharge factors from historic levels to calculate changes in groundwater storage and exchanges with the Platte River essentially implies an assumption that groundwater levels are currently at steady-state, neither declining or rising. In the model, if pumping and recharge in a particular subunit do not change from their historic values (i.e., the net change from historic levels is zero), groundwater levels remain the same and there is no additional (above historic) movement of water to or from the Platte. This is the desired result in terms of exchange with the river, because the regression approach used in the Surface Water submodel implicitly incorporates historic section gains and losses. However, field observations indicate that groundwater levels are changing due to current rates of pumping and recharge, which is inconsistent with the steady-state assumption. Revisions to the Groundwater Submodel will likely have to deal with this inconsistency.

Economics Submodel

Responsibilities. The responsibility of the Economics submodel is to calculate economic indicators (Table 1) for the base scenario and various proposed actions. The following economic attributes are included in the model: (1) net returns to agriculture, water related recreation, and electric power generation; (2) indirect economic impacts from the agriculture and recreation sectors; (3) employment in the agriculture sector; and (4) costs and benefits of alternative proposed actions.

The Economics submodel utilizes visitor use-days from the Wildlife/Recreation submodel, electric power generation from the Municipal/Industrial submodel, and groundwater pumping and crop production from the Agriculture submodel to complete these calculations. However, the Economics submodel does

not provide information to other submodels, even though in the real world there obviously are feedbacks to other elements of the system. For example, in the real world cropping patterns and irrigation practices are influenced by expected net returns. But regional economic variables are very sensitive to external market forces such as interest rates, the world demand for commodities, and the level of national economic activity. Because movements in these conditions are so difficult to predict, the influence of changes in such things as commodity prices and net returns are not currently "fed back" to other submodels.

General Structure. Net returns that might accrue to alternative water management proposals are calculated for agriculture, recreation, and electric power generation in the following way: (1) estimated crop prices are applied to crop production provided by the Agriculture submodel, and crop production costs are subtracted, leaving net returns or profits; (2) recreation use-days, provided by the Wildlife/Recreation submodel, are multiplied by a net visitor use value, resulting in net returns to recreation; and (3) net returns to electric power generation are estimated as the amount of electricity generated times its net price. The sum of net returns from agriculture, recreation, and electric power generation provides an estimate of project benefits.

Project costs include the construction, engineering, contingency, legal, and administrative costs of the project. These costs are amortized over the life of the project and, along with annual operation, maintenance, and replacement charges, are subtracted from annual benefits to provide an estimate of net project benefits.

In addition to the direct benefits described above, indirect benefits may accrue to a project. These indirect benefits can result from additional economic activity generated by the project. For example, agricultural support industries are enhanced whenever net returns to agriculture increase. Expenditures in one sector ripple through the regional economy, leading to further economic activity. These indirect effects are estimated in the economic

submodel by applying multipliers to direct returns from agriculture and recreation. Both the agricultural multiplier and the recreation multiplier are regional in nature, and do not vary among separate spatial subunits. In future model refinements, more disaggregated multipliers should be estimated for each project area by using input-output models already developed for the study area. Accounting for indirect benefits in this way provides an estimate of how gross regional products may change with alternative water policy actions.

Benefits from various projects can be measured in terms of jobs as well as dollars. In the current model, employment in agriculture is estimated by assuming that each million dollars of gross returns in agriculture represents 12 jobs. More accurate estimates of agricultural employment as well as estimates of employment in other sections of the regional economy should be made from the input-output studies.

Both net benefits and gross regional products can be used to compare different projects or modeling scenarios. Before such comparisons are taken seriously, however, more careful estimates of economic parameters, more accurate information from other submodels, and better correspondence between project boundaries and geographical reaches would be needed. Hence, results of the current economics submodel must be viewed as a format for making comparisons between alternative water resource allocation scenarios and not a tool for making current water allocation decisions.

DETAILED MODEL DOCUMENTATION

The following section presents a detailed description of the system model and each of the submodels in computational sequence. Each section of the description is referenced to one or more lines of code in the computer listings found in Appendices A through G. Data shown in tables, figures, or text for each submodel can also be found in SIMCON format (see SIMCON documentation) in the appropriate appendix. Equations are written in FORTRAN notation using the same variable names found in the computer code. Equations must therefore be interpreted as FORTRAN replacement statements in which the value of the variable on the left side is replaced by the value of the expression on the right side. The same variable may thus appear on both sides, as in the equation:

```
X = X * Y
```

This is interpreted as: the new value of X (left side) is equal to the old value of X times the value of Y. The old value of X may be: (1) the value remaining from the previous time step; (2) the value computed earlier in the submodel under discussion; or (3) the value computed in a previously executed submodel. Subscripts pertaining to time (e.g., t-1, t, t+1) are therefore omitted from most of the equations; they are implicit in the concept of a replacement statement.

THE SIMCON SIMULATION CONTROLLER

The PRFF workshop model described in this report is presently being run on an Amdahl computer, equipped with the Michigan Terminal System (MTS) operating system, using a general simulation controller called SIMCON. The

SIMCON package performs five basic functions: (1) reads a free-format data set from a user-defined MTS file; (2) reads a set of FORTRAN COMMON statements from a user-defined MTS file; (3) executes iteratively a user-defined simulation model utilizing the data provided by the user; (4) preserves the results of the simulation at the end of each iteration by writing the entire COMMON block to a temporary MTS file (-DDSS#); and (5) accesses that temporary file at the end of the simulation to allow the user to print or plot results.

In order to perform these functions for the PRFF model, SIMCON uses the following MTS files (Appendix A): PLATTE.S, which contains the source code for the model; PLATTE.D, which contains the data for the model; and PLATTE.C, which contains the COMMON block for the model. In addition, the PRFF model uses three other files: PLATTE.O, which contains the object module resulting from the FORTRAN compilation of the file PLATTE.S; RCOEF, which contains the regression coefficients used in the Surface Water submodel; and RDATA, which contains historic flows at the Julseburg and Keystone gauges, historic gauged inflows, and historic gauged outflows, also used by the Surface Water submodel.

THE $CONTINUE STATEMENT

Throughout the PRFF model, extensive use is made of the MTS $CONTINUE statement. The form of the statement is:

```
$CONTINUE WITH FILENAME RETURN
```

This statement implicitly concatenates the contents of FILENAME at the location of the $CONTINUE statement at execution time and returns control to the next line of the program. Its utility lies in the fact that it allows individual modules (i.e., submodels) to be constructed independently and linked together easily for execution.

THE SLP FUNCTION

The PRFF model also makes extensive use of a function called SLP, which simply performs an interpolation between the breakpoints of a piecewise linear function (Figure 3). The function is called as follows:

```
YVALUE = SLP(XVALUE,XARRAY,YARRAY,NPTS)
```

where

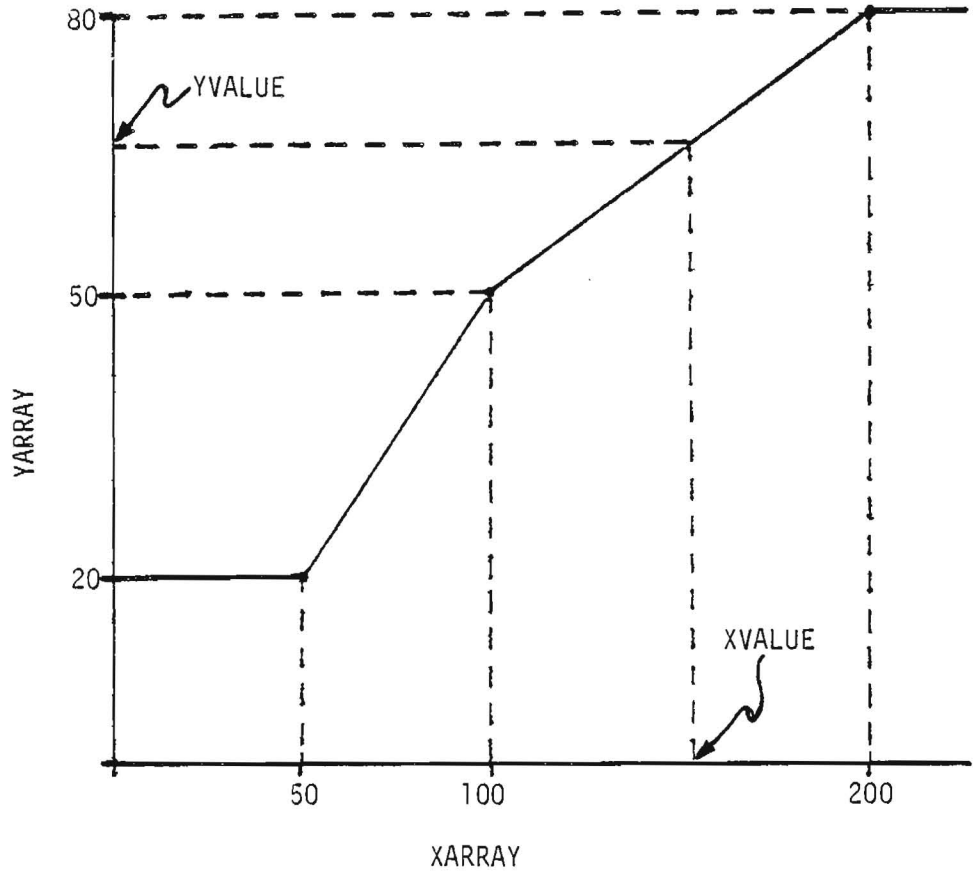
YVALUE = a variable containing the result of the interpolation;
XVALUE = the X value to be interpolated;
XARRAY = an array containing the X coordinates of the points in the piecewise linear function;
YARRAY = an array containing the Y coordinates of the points in the piecewise linear function; and
NPTS = the number of breakpoints in the function.

XVALUE, XARRAY, and YARRAY must be real variables; NPTS must be an integer. No two elements of XARRAY can have identical values, since this would result in an infinite slope. As indicated in Figure 3, the slope of the function is assumed to be zero below the minimum and above the maximum value in XARRAY.

SYSTEM MODEL

The following section describes the program (PLATTE.S), data (PLATTE.D), and COMMON (PLATTE.D) files for the PRFF system model. Computer listings of these files can be found in Appendix A. In addition, the listing of the file PLATTE.DEF in Appendix A contains definitions of variables used in the system model. Line numbers in the following section refer to the appropriate files in Appendix A.

Graphic Representation



Data Values

XARRAY(1) = 50	YARRAY(1) = 20
XARRAY(2) = 100	YARRAY(2) = 50
XARRAY(3) = 200	YARRAY(3) = 80

NPTS = 3

Figure 3. An example of the SLP function.

The Program File (PLATTE.S)

The file PLATTE.S contains two basic subroutines that read data, read the COMMON block, and execute the various submodels.

Subroutine UINIT (lines 1-10). Subroutine UINIT is called only once at the start of each simulation. Calls to the subroutine DFAULT assign logical unit numbers to specific MTS files. PLATTE.D (logical unit 1) contains the basic data for the model. RCOEF (logical unit 15) contains the regression coefficients used by the Surface Water submodel. RDATA (logical unit 16) contains the historic flows at Julesburg and Keystone, historic gauged inflows, and historic gauged outflows, which are also used by the Surface Water submodel. The call to CMREAD instructs SIMCON to read the COMMON block from the MTS file PLATTE.C.

Subroutine UMODEL (lines 11-29). Subroutine UMODEL is executed once for each iteration of the model. The variable ITIME, which is passed as a parameter in the call to UMODEL, contains the number of the current iteration. The COMMON block is concatenated in UMODEL (line 15) using the $CONTINUE statement. The simulation year (IYEAR) and month (IMONTH) are calculated from the number of the iteration using the FORTRAN functions INT and MOD, respectively (lines 17-18). IYEAR is simply incremented by one at the start of each 12-month period. IMONTH, which varies from 1 to 12, is reset to 1 at the start of each 12-month period. The simulation year is considered to begin in January. The remainder of subroutine UMODEL (lines 19-29) simply calls the subroutines RIVER, AG, XMIND, WILD, GWAT, and ECON, which represent, respectively, the Surface Water, Agriculture, Municipal/Industrial, Wildlife/Recreation, Groundwater, and Economics submodels. Note that the Economics submodel is called only at the end of each simulation year (lines 25-27). The remainder of the file PLATTE.S contains only $CONTINUE statements that implicitly concatenate the MTS files containing the various submodels at execution time. That is, the file RIVER.S contains the subroutine RIVER, and so on.

The Data File (PLATTE.D)

The data file contains three basic parts. The first (lines 1-6) simply constructs a complete data file by concatenating data files for each of the submodels. The second (line 7) is a SAVE FILE command that instructs SIMCON to preserve a copy of the data (i.e., make a copy of the COMMON block) on the MTS file -S. The user can then return to the conditions represented by the initial data at any time by using the SIMCON command:

```
RESET FILE=-S
```

The remainder of the file (lines 8-140) consists of a series of SIMCON MACROs. A MACRO is simply a partial data set that can be implemented in SIMCON just by typing the MACRO name. Note that each MACRO must be ended with a blank line.

In the PRFF model, these MACROs generally contain changes in variables necessary to implement one or more projects that have been suggested as scenarios. For example, the MACRO PRBEND (lines 8-23) contains the data changes necessary to approximate the conditions of the Prairie Bend project. Line 9 (IRES) implements a reservoir in reach 5 north of the river. Lines 10-13 indicate that the reservoir has 352,000 acre-ft of storage (STOMAX), a surface area of 7,000 acres (SURFAC), a groundwater storage recharge rate of 2,000 acre-ft per month (STRCH), and first priority for filling among the new projects being implemented (IPRIOR). Lines 14-19 set the additional monthly diversions (ADDDIV) from regression reach 7 (see discussion of Surface Water submodel below) and the additional monthly return flows (ADDRET) to regression reaches 8 and 9. Lines 20-22 add 68,600 acres to the surface water-irrigated category by removing 56,000 acres from groundwater irrigation and 12,600 acres from dryland crops.

The COMMON File (PLATTE.C)

The file PLATTE.C simply constructs the model COMMON block by concatenating the COMMON files of the individual submodels.

SURFACE WATER SUBMODEL

The general structure of the Surface Water submodel is diagrammed in Figure 4. A more detailed narrative description is provided below. Line number notations refer to the FORTRAN code file RIVER.S in Appendix B. Variable definitions, data, and COMMON files are also listed in Appendix B. Unless otherwise noted, subscript J denotes direction from the river, M or IMONTH represents month of the year, and I is used for river reaches. In general, I represents reaches for the regression equation prior to line 146 in the FORTRAN code and represents reaches as defined at the workshop (Figure 1) subsequently.

Read and Convert Historic Data for Current Month (Lines 16-41)

This section of code reads regression coefficients A(I,M), B(I,M), C(I,M), ZZD(I,M) (Table 2) from file RCOEF (logical unit 15) and the historical average monthly flows at Keystone (FK(M)) and Julesburg (FJ(M)) (Table 3) and gauged inflows (RI(I,M)) and outflows (RO(I,M)) (Table 4) from file RDATA (logical unit 16). The flows, inflows, and outflows are then modified by a historic water year factor (Table 5) to simulate actual flows observed in the period 1950-1979. If the simulation run is longer than this 29-year period, the sequence of factors is repeated.

Apply Regression Equations to Compute Flows (Lines 42-144)

Initialization (lines 42-49). A counter (ICOUNT) used in the diversion deficit calculation is initialized and the initial values, if any, of diversions associated with new projects (ADDDIV(I,IMONTH)) are saved.

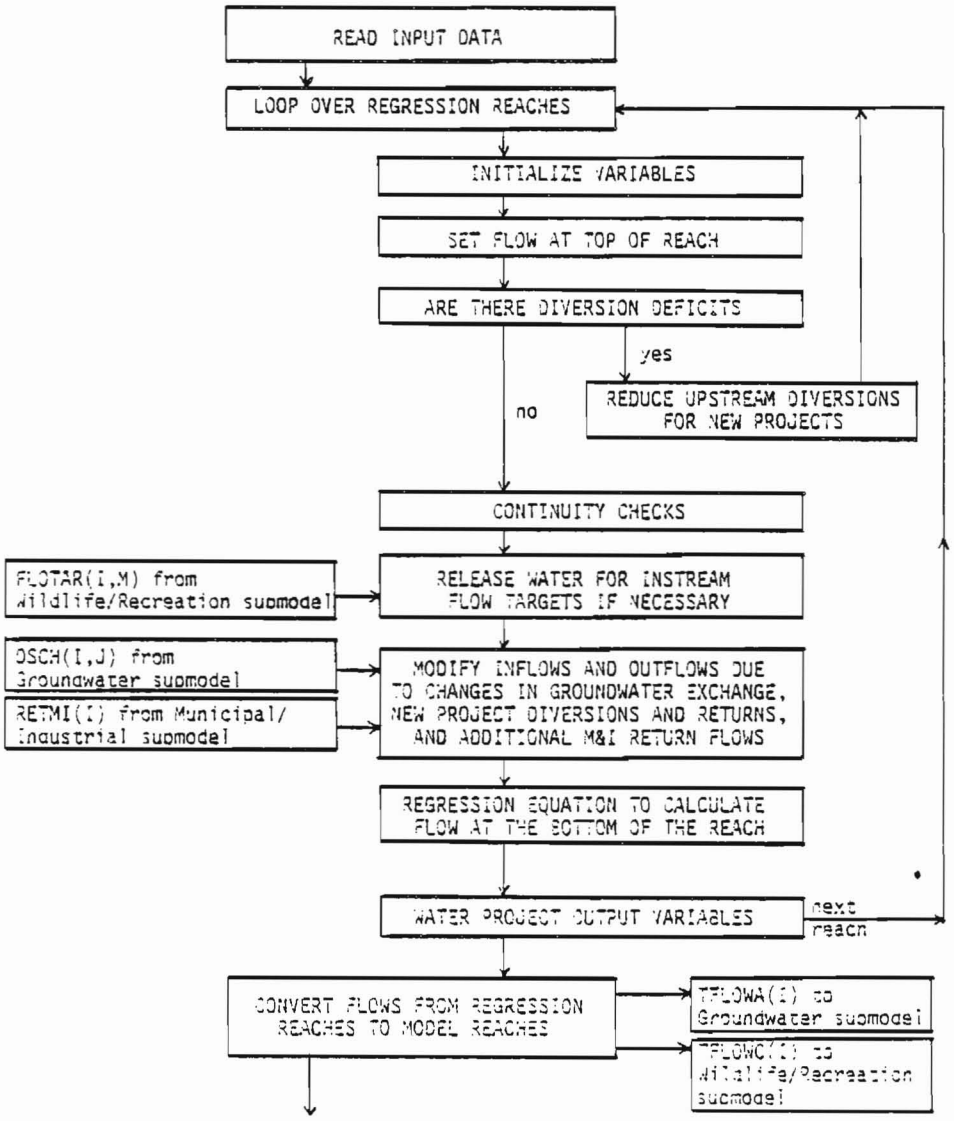


Figure 4. General structure of the Surface Water submodel.

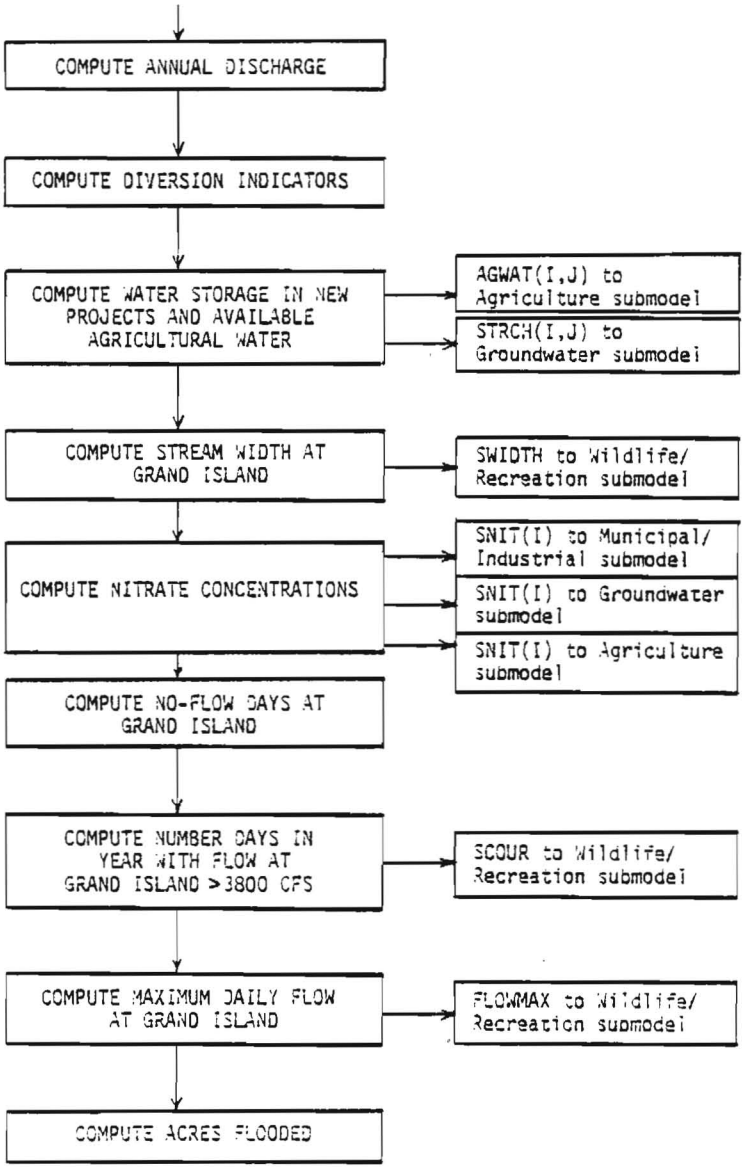


Figure 4. (concluded)

Table 2. Regression coefficients used in the Surface Water submodel (from Nebraska Department of Water Resources).

	Reach 1			
	A	B	C	ZZD
Jan	1.059	0.000	0.000	7,888.58
Feb	0.967	0.000	0.000	7,910.36
Mar	0.943	0.000	-3.915	10,053.98
Apr	0.997	0.000	-1.503	9,351.73
May	0.932	0.000	-1.469	14,622.41
Jun	1.026	0.000	-2.097	18,800.47
Jul	0.956	0.000	-1.095	8,528.14
Aug	0.934	0.000	-1.560	23,455.66
Sep	1.028	0.000	-1.629	14,982.03
Oct	0.997	0.000	-1.054	8,295.04
Nov	1.015	0.000	-0.237	8,538.23
Dec	0.994	0.000	0.000	8,486.38

	Reach 2			
	A	B	C	ZZD
Jan	1.189	0.595	0.000	4,606.50
Feb	1.052	0.576	0.000	6,922.56
Mar	1.029	1.316	0.000	86.06
Apr	1.062	0.929	-0.917	4,094.49
May	0.962	0.814	-0.806	7,451.89
Jun	0.989	0.465	-2.517	18,683.96
Jul	1.033	1.494	-2.436	4,563.23
Aug	1.004	0.525	-1.180	13,587.51
Sep	1.046	0.111	-2.194	23,565.37
Oct	1.049	0.354	-0.292	9,493.78
Nov	1.053	0.482	-0.250	8,467.69
Dec	1.045	0.538	0.000	7,502.86

	Reach 3			
	A	B	C	ZZD
Jan	0.638	0.000	-0.737	9,363.68
Feb	1.084	0.000	-1.065	9,607.44
Mar	0.934	0.000	-0.902	11,806.02
Apr	0.718	0.000	-0.796	14,507.07
May	0.881	0.000	-1.174	19,008.35
Jun	0.794	0.000	-0.724	15,802.76
Jul	0.619	0.000	0.000	7,175.13
Aug	0.268	0.000	0.068	7,926.38
Sep	0.818	0.000	-0.343	7,146.47
Oct	0.950	0.000	-0.904	9,266.60
Nov	0.872	0.000	-0.851	7,649.76
Dec	0.211	0.000	-0.166	7,671.37

	Reach 4			
	A	B	C	ZZD
Jan	1.396	0.674	-0.513	-14,509.46
Feb	1.156	0.829	-0.756	468.72
Mar	1.357	0.452	-0.379	-14,055.44
Apr	1.227	0.565	-0.437	-11,881.56
May	1.167	0.968	-1.015	13,051.33
Jun	1.209	0.934	-1.130	21,552.21
Jul	0.861	1.078	-0.829	-12,028.78
Aug	0.956	1.071	-0.897	-12,582.45
Sep	1.022	0.977	-0.946	2,088.96
Oct	1.004	0.956	-0.576	-25,091.93
Nov	1.026	0.858	-0.684	-9,488.76
Dec	1.076	0.228	-0.186	-12,065.24

Table 2. (continued)

	Reach 5			
	A	B	C	ZZD
Jan	1.090	-0.452	0.124	4,403.92
Feb	1.186	0.751	-0.640	2,600.86
Mar	0.993	1.045	-1.289	9,077.09
Apr	1.002	1.061	-1.254	8,803.10
May	0.973	0.112	-0.730	8,652.62
Jun	1.048	0.631	-0.668	1,405.33
Jul	1.227	1.673	-1.328	719.28
Aug	0.815	0.897	-0.745	111.34
Sep	0.971	0.833	-0.921	4,679.70
Oct	1.054	1.296	-1.213	3,948.06
Nov	0.957	1.684	-1.624	5,420.74
Dec	0.964	-0.240	0.067	5,156.18

	Reach 6			
	A	B	C	ZZD
Jan	1.071	1.412	0.000	-19,579.31
Feb	1.125	1.135	0.000	-4,373.08
Mar	1.043	1.198	0.000	-5,563.81
Apr	1.057	1.087	0.000	5,074.88
May	0.923	1.139	0.000	7,274.67
Jun	1.073	1.234	0.000	413.95
Jul	1.319	0.956	0.000	2,933.22
Aug	1.057	0.880	0.000	6,066.39
Sep	1.128	1.024	0.000	105.35
Oct	1.180	0.836	0.000	10,737.50
Nov	1.361	0.757	0.000	14,221.15
Dec	1.675	0.829	0.000	7,423.33

	Reach 7			
	A	B	C	ZZD
Jan	0.974	0.000	-0.135	496.28
Feb	0.991	0.000	-0.215	3,507.34
Mar	0.982	0.000	-1.233	9,875.44
Apr	1.015	0.000	-1.095	1,661.22
May	0.965	1.833	-0.522	-1,905.03
Jun	0.912	3.176	-1.573	4,226.23
Jul	0.987	2.292	-0.334	-9,992.24
Aug	0.962	1.653	-1.145	-1,211.23
Sep	0.917	1.928	-0.954	-2,612.30
Oct	1.031	0.000	-0.703	-5,679.23
Nov	0.985	0.000	-0.534	-4,802.70
Dec	0.944	0.000	-0.475	1,528.98

	Reach 8			
	A	B	C	ZZD
Jan	0.971	0.042	0.000	-9,105.18
Feb	1.055	1.357	0.000	-4,558.85
Mar	0.814	-2.584	0.000	39,863.74
Apr	0.975	0.811	0.000	9,209.86
May	0.872	1.697	0.000	6,718.37
Jun	0.970	2.045	0.000	-5,373.34
Jul	1.199	0.835	0.000	-4,958.20
Aug	0.941	0.338	0.000	-2,838.29
Sep	1.000	0.764	0.000	-10,088.14
Oct	1.145	1.317	0.000	-20,300.84
Nov	1.069	0.624	0.000	-7,339.58
Dec	1.084	0.868	0.000	-16,955.55

Table 2. (concluded)

	Reach 9			
	A	B	C	ZZD
Jan	1.112	0.000	0.000	-9,110.09
Feb	1.250	0.000	0.000	-18,528.27
Mar	1.115	0.000	0.000	7,948.46
Apr	1.003	0.000	0.000	16,260.86
May	0.896	0.000	0.000	22,016.79
Jun	1.084	0.000	0.000	5,719.76
Jul	1.094	0.000	0.000	3,155.74
Aug	0.850	0.000	0.000	322.65
Sep	1.015	0.000	0.000	-5,231.71
Oct	0.978	0.000	0.000	-488.37
Nov	1.196	0.000	0.000	-10,123.79
Dec	1.131	0.000	0.000	-7,573.34

	Reach 10			
	A	B	C	ZZD
Jan	0.886	0.980	0.000	-1,012.19
Feb	0.989	1.189	0.000	-2,264.42
Mar	1.092	1.215	0.000	-3,724.31
Apr	1.084	1.153	0.000	-899.56
May	1.137	1.132	0.000	627.73
Jun	1.078	1.316	0.000	-6,425.14
Jul	1.211	1.181	0.000	-1,851.32
Aug	1.115	1.167	0.000	-432.86
Sep	0.976	1.220	0.000	-4,914.77
Oct	1.137	1.014	0.000	-215.52
Nov	1.084	1.022	0.000	-427.18
Dec	0.925	0.967	0.000	-100.67

	Reach 11			
	A	B	C	ZZD
Jan	1.147	0.449	0.000	940.42
Feb	1.061	0.863	0.000	1,948.69
Mar	1.170	0.669	0.000	544.15
Apr	0.981	1.346	0.000	2,864.54
May	0.938	1.360	0.000	3,400.24
Jun	0.935	1.251	0.000	7,176.24
Jul	0.931	1.282	0.000	2,715.18
Aug	0.828	1.428	0.000	-2,044.82
Sep	0.819	1.571	0.000	-2,687.12
Oct	0.914	1.383	0.000	-677.79
Nov	0.997	1.209	0.000	-1,035.64
Dec	1.115	0.705	0.000	-1,305.62

Table 3. Average monthly flows at Keystone and Julesburg (acre-ft) (from Nebraska Department of Water Resources).

	Keystone (FK(M))	Julesburg (FJ(M))
Jan	1,691.82	29,113.07
Feb	2,337.48	29,672.88
Mar	9,207.27	29,000.01
Apr	11,069.51	28,372.68
May	40,081.50	63,652.59
Jun	54,775.05	68,039.78
Jul	96,632.85	14,432.37
Aug	72,960.37	8,022.98
Sep	27,400.30	8,282.97
Oct	23,785.15	17,478.82
Nov	8,301.14	19,917.77
Dec	2,183.96	20,252.87

Table 4. Average gauged inflows and outflows (acre-ft) (from Nebraska Department of Water Resources).

	Reach 1		Reach 2		Reach 3	
	RI	RO	RI	RO	RI	RO
Jan	0.00	0.00	11,702.32	0.00	0.00	20,510.59
Feb	0.00	0.00	11,030.00	0.00	0.00	24,829.72
Mar	0.00	95.68	12,335.92	0.00	0.00	26,342.87
Apr	0.00	2,210.54	12,070.77	201.76	0.00	24,585.19
May	0.00	10,306.43	13,643.02	3,176.73	0.00	21,360.78
Jun	0.00	13,472.44	13,095.74	4,241.85	0.00	29,391.38
Jul	0.00	22,104.11	13,249.03	7,177.54	0.00	15,184.51
Aug	0.00	22,407.74	14,307.09	7,042.83	0.00	7,858.35
Sep	0.00	13,852.08	14,538.12	4,912.10	0.00	5,168.37
Oct	0.00	3,209.49	13,157.15	1,577.42	0.00	12,673.74
Nov	0.00	208.58	11,945.09	99.89	0.00	17,345.21
Dec	0.00	0.00	12,030.62	0.00	0.00	17,170.65

	Reach 4		Reach 5		Reach 6	
	RI	RO	RI	RO	RI	RO
Jan	61,439.58	74,001.77	5,573.00	5,903.36	11,608.62	0.00
Feb	59,326.15	75,303.96	4,976.61	4,973.91	9,658.47	0.00
Mar	63,554.36	84,874.20	5,247.31	4,776.91	35,569.42	0.00
Apr	62,948.21	83,784.33	5,639.09	6,562.91	56,257.00	0.00
May	98,290.87	92,800.23	7,012.76	15,665.60	58,600.05	0.00
Jun	101,447.89	97,919.24	10,083.52	25,124.64	60,102.89	0.00
Jul	101,768.80	121,355.54	10,245.68	63,852.76	57,824.20	0.00
Aug	97,801.30	121,499.46	16,253.56	60,861.36	60,441.82	0.00
Sep	69,116.22	92,715.02	10,171.95	18,881.84	68,442.42	0.00
Oct	46,525.08	78,289.48	4,138.87	5,935.65	56,700.28	0.00
Nov	47,645.34	74,124.27	3,818.66	4,374.11	36,941.02	0.00
Dec	56,844.75	76,555.61	4,273.09	4,936.78	28,800.94	0.00

Table 4. (concluded)

	Reach 7		Reach 8		Reach 9	
	RI	RO	RI	RO	RI	RO
Jan	0.00	1,425.48	1,281.16	0.00	0.00	0.00
Feb	0.00	1,396.44	1,197.54	0.00	0.00	0.00
Mar	0.00	2,494.25	2,021.55	0.00	0.00	0.00
Apr	0.00	6,612.81	5,049.12	0.00	0.00	0.00
May	1,903.81	9,716.78	7,160.88	0.00	0.00	0.00
Jun	4,314.52	11,281.35	8,807.08	0.00	0.00	0.00
Jul	3,635.54	11,163.61	6,691.59	0.00	0.00	0.00
Aug	3,488.45	10,796.27	6,450.80	0.00	0.00	0.00
Sep	2,723.23	10,918.13	8,117.71	0.00	0.00	0.00
Oct	0.00	8,221.80	6,170.02	0.00	0.00	0.00
Nov	0.00	6,476.82	5,385.20	0.00	0.00	0.00
Dec	0.00	2,775.91	2,243.07	0.00	0.00	0.00

	Reach 10		Reach 11	
	RI	RO	RI	RO
Jan	113,050.94	0.00	41,984.45	0.00
Feb	140,056.30	0.00	78,811.40	0.00
Mar	208,799.04	0.00	158,684.50	0.00
Apr	161,349.84	0.00	128,687.52	0.00
May	149,962.07	0.00	134,473.62	0.00
Jun	155,120.13	0.00	197,502.22	0.00
Jul	86,120.41	0.00	88,224.00	0.00
Aug	79,068.93	0.00	63,012.57	0.00
Sep	93,763.83	0.00	50,033.77	0.00
Oct	118,381.96	0.00	51,757.25	0.00
Nov	127,620.73	0.00	44,170.00	0.00
Dec	112,690.59	0.00	39,231.79	0.00

Table 5. Historic water year factors (as a fraction of the 29-year average annual flow) (from Nebraska Department of Water Resources).

Year(K)	Keystone WYRFK(K)	Julesburg WYRFJ(K)
1950	0.58	0.54
1951	0.50	0.64
1952	2.04	0.94
1953	0.83	0.45
1954	0.77	0.23
1955	0.70	0.23
1956	0.88	0.18
1957	0.48	1.30
1958	0.35	1.85
1959	0.77	0.72
1960	0.60	0.57
1961	0.55	1.65
1962	0.37	1.33
1963	0.82	0.49
1964	0.72	0.22
1965	0.35	1.87
1966	0.77	0.67
1967	0.66	0.79
1968	1.06	0.62
1969	0.66	1.70
1970	0.90	2.42
1971	2.99	1.71
1972	1.21	0.50
1973	3.90	3.80
1974	2.13	1.03
1975	0.91	0.81
1976	1.46	0.40
1977	0.73	0.34
1978	0.84	0.22
1979	0.45	1.69

Set flow at the top of current reach (lines 54-58). For regression reaches 1 and 2, flows at the top of the reach are set to FLOWK(IMONTH) and FLOWJ(IMONTH), respectively. For all other reaches, the flow is set to the flow calculated by the model at the bottom of the previous reach.

Check for diversion deficits (lines 59-78). Three potential diversion deficits are calculated by the model. T1 represents a deficit if the water entering the reach (D1(I)) plus gauged inflows (RET(I,IMONTH)) is less than historical diversions (DIV(I,IMONTH)) (i.e., diversions for existing appropriations). T2 is a check in case the regression produces a negative flow entering a reach. If instream flow targets are considered in a model run (ISFT = 1), then T3 represents a deficit if flow entering a reach (D1(I)) is less than the specified flow target (FLOTAR(MREACH(I),IMONTH)). The array MREACH(I) is used to convert flow targets specified by PRFF model reaches into the corresponding regression reach (Table 6). This is necessary because the PRFF decided on a spatial resolution appropriate to their needs, but somewhat different from the spatial resolution used by the Nebraska Department of Water Resources to generate the regression equations. The deficit used for subsequent calculations is the maximum of T1, T2, and T3. The manner in which these deficits are calculated should be re-evaluated when model revisions are made.

Eliminate diversion deficits (lines 79-106). The model assumes that given existing appropriations, the regression equation will generate logically consistent flows in all reaches based on historical data. This means that no deficits should occur unless new projects are specified in a model run. When new projects are included and cause deficits in a downstream reach, this section of code decreases the diversion (ADIV(K,IMONTH)) of the lowest priority upstream project by the lesser of the amount of the calculated deficit or the amount of the diversion. If the deficit has not been completely eliminated, diversions for the next lowest priority upstream project are decreased and so on until the deficit is eliminated. The loop over regression reaches is then restarted with the reduced project diversions. Otherwise, calculations for the current reach continue.

Table 6. Relation of PRFF model reaches to regression reaches.

Model reaches		Regression reaches	
1	Julesburg - North Platte	3	same
2	Keystone - North Platte	1	Keystone-Sutherland
		2	Sutherland-North Platte
3	North Platte-Brady	4	same
4	Brady-Overton	5	Brady-Cozad
		6	Cozad-Overton
5	Overton-Grand Island	7	Overton-Odessa
		8	Odessa-Grand Island
6	Grand Island - Duncan	9	same
7	Duncan-North Bend	10	same
8	North Bend-Louisville	11	same

Currently, diversions associated with a new project are entered as data by the user. The model alters these only if they create deficits. However, the model should eventually include other constraints on new diversions. For example, most scenarios received to date state maximum withdrawals (acre-ft) for various months of the year (the data currently required), but also specify that these withdrawals not exceed a certain rate (cfs) or a specified percent of the flow.

Release water for instream flow targets (lines 107-115). If instream flow targets are considered in the current model run (ISFT = 1) and flow in a reach (D1(I)) is less than the specified target (FLOTAR(MREACH(I),IMONTH)), then stored water is released from a specified reservoir to meet the target.

The amount released (RELS) is the lesser of the amount needed to meet the target (FLOTAR(MREACH(I),IMONTH) - D1(I)) or the amount of water available for release (RELWAT). Released water is added to flow in the reach specified for release (D1(IREL(3))) and subtracted from the appropriate reservoir storage (STOWAT(IREL(1),IREL(2))).

Modify gauged inflows and outflows due to changes from historical conditions (lines 116-133). Gauged inflows (RET(I,IMONTH)) and outflows (DIV(I,IMONTH)) for a reach are modified in the model as a result of changes from historical conditions in groundwater exchange (TDSCH(MREACH(I),K)), additional diversions (ADIV(I,IMONTH)) and return flows (ADDRET(I,IMONTH)) associated with new projects, and additional municipal and industrial return flows of pumped groundwater (RFAC * RETMI(MREACH(I)) - HRETMI(I,IMONTH)).

Regression equation (lines 134-139). This section of code calculates flow at the bottom of a reach based on a multiple regression model developed by the Nebraska Department of Water Resources. The form of the equation is:

```
D2(I) = A(I,IMONTH) * D1(I) + C(I,IMONTH) * DIV(I,IMONTH) +
        B(I,IMONTH) * RET(I,IMONTH) + ZZD(I,IMONTH) +
        TDSCH(I)
```

where

```
        D2(I) = flow at the bottom of reach I (acre-ft);
        D1(I) = flow at the top of reach I (acre-ft);
  DIV(I,IMONTH) = diversions from the reach (acre-ft);
  RET(I,IMONTH) = return flows or inflows to the reach (acre-ft);
      TDSCH(I) = change in the exchange of surface water with groundwater
                 from historical conditions (acre-ft); and
     A,B,C,ZZD = regression coefficients.
```

The loop over regression reaches is continued until all flows have been calculated.

The regression approach used in this model does a good job of implicitly representing a complex water allocation procedure and producing good estimates of river flows. The model also does a reasonably good job of evaluating consequences of most of the proposed water projects. However, as with all models, the regression approach has some limitations. Specifically, the implicit incorporation of water rights and reservoir operating criteria in the regression implies that water management alternatives which include changes in existing water rights or reservoir operations cannot be evaluated with this model. Response to a recent questionnaire indicated PRFF participants felt the model should be able to evaluate such alternatives. However, none of the scenarios submitted to date have included these alternatives.

A surface water model could be built which explicitly accounts for reservoir operating and water allocation rules. This type of model would be much more complex, might or might not give any better predictions of streamflows, but would answer different types of questions concerning future water management. One of the primary decisions the Platte River Forum for the Future must make concerning the workshop model is what types of water management questions are most important to address through the process and what type of surface water model is most appropriate.

Specifying new water projects. Values for several variables must be specified for each new project to be included in a simulation. This information is listed in Table 7 because of potential confusion due to some information being specified by regression reach and other information by PRFF model reach (Figure 1). One limitation of the current model is that only one project can be specified in a particular reach. Scenarios which include both the Twin Valley and Prairie Bend projects are handled by specifying one large project with storages, withdrawals, and the like equal to the sum of the two individual projects.

Water project output variables (lines 140-144). Requested and actual additional diversions for new projects (RADIV(I), AADIV(I)) are stored for later evaluation.

Table 7. Information required for new water projects (IR = regression reach, IM = PRFF model reach, J = north or south of river, IMONTH = month of year).

Information	Model variable
Reach in which project is located	IRES(IM,J) = 1
Withdrawal priority with respect to other projects (1 is first priority and two projects cannot have the same priority)	IPRIOR(IM)
Additional diversions associated with the new project by month (acre-ft)	ADDDIV(IR,IMONTH)
Additional return flows from the new project by month (acre-ft)	ADDRET(IR,IMONTH)
Maximum storage in the project (acre-ft)	STOMAX(IM,J)
Surface acres associated with the new project	SURFAC(IM,J)

Convert flow calculations to model reaches (lines 145-154). This section of code converts river flows calculated for regression reaches into flows for corresponding PRFF model reaches for use by the other submodels.

Compute Annual Discharge (Lines 155-163)

Monthly flows for each reach are summed to give a total annual discharge.

Compute Diversion Indicators for Model Reaches (Lines 164-182)

Diversions for existing appropriations (HDIV(I)), total additional diversions for new projects (TADIV(I)), and total diversions (TDIV(I)) are computed for each model reach based on calculations made earlier by regression reaches.

Compute Storage in New Projects and Available Agricultural Water (Lines 183-213)

The amount of water in storage during a month (STOWAT(I,J)) is computed as the storage at the end of last month, minus use of stored water last month (STOUSE(I,J)), plus additional diversions for the project this month (TADIV(I)). Agricultural use of stored water last month is computed as total surface water irrigation in the reach (AGUSE(I,J)) minus that water provided by existing water rights (HLDIV(I) * AGFAC(I,J,IMONTH)). The amount of water available for agricultural use in the current month (AGWAT(I,J)) is the amount in storage plus diversions during the month (HDIV(I) * AGFAC(I,J,IMONTH)). Diversions for agricultural use in reaches 4 and 5 south of the river occur primarily in reach 3 (AGWAT(3,2)). The model routes this water for agricultural use with the variable AG45(K).

Stream Width at Grand Island (Lines 214-218)

Stream width at Grand Island (SWIDTH) is calculated as a function of flow (cfs) at the bottom of reach 5 (BFLOWC(5)) by linear interpolation from Figure 5. Data points defining Figure 5 are stored in the arrays XCFS and YWIDTH.

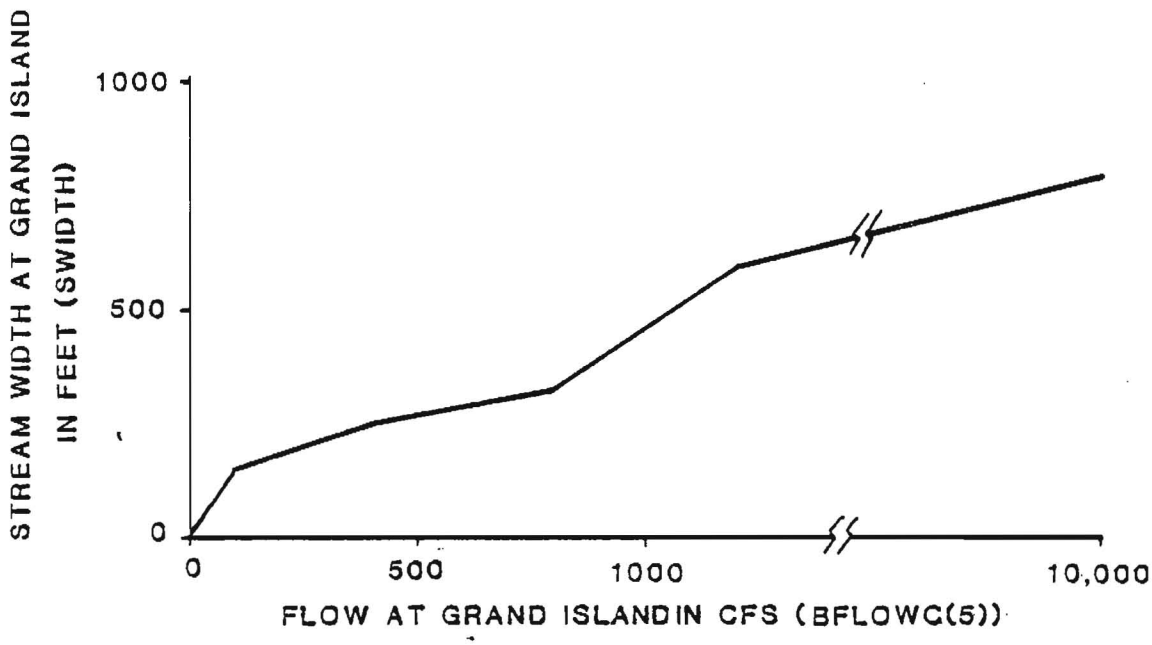


Figure 5. Stream width at Grand Island as a function of flow.

Nitrate Concentrations (Lines 218-234)

Nitrate concentrations in surface water (SNIT(I)) are crudely calculated from the amount of surface water (TFLOWA(I)) and its nitrate concentration (RNO3D1(I)) entering the top of a reach mixing with an amount of water (DSCH(I,K)), if any, entering the river from groundwater and its nitrate concentration (GNIT(I,K)). It was assumed that nitrate concentrations entering the model system at Julesburg and Keystone (RNO3IC(K)) would not change over the course of the model run. The formulation also assumes that surface water nitrate concentrations within Nebraska would change primarily as a result of groundwater input, not as a result of changes in agricultural runoff. This assumption should be re-evaluated.

Consecutive No-Flow Days at Grand Island (Lines 235-241)

When monthly flow at Grand Island is less than 6,440 acre-ft in July or less than 10,110 acre-ft in August, then there is a no-flow event of two or more days (NOFLOW(K) = 1). These general rules were derived during the workshop by examining historical Grand Island gauge data.

Number of Days With Flow Greater than 3,800 cfs at Overton (Lines 242-248)

The number of days in a year with flow at Overton greater than 3,800 cfs is calculated from a regression equation developed during the workshop:

```
SCOUR  =  1.603 * ((TFLOW(4) / 1.0E6) ** 4.3)
```

where

```
SCOUR  =  number of days with flow > 3,800 cfs;
TFLOW(4)  =  annual flow at Overton (acre-ft); and
1.603, 4.3  =  regression coefficients.
```

This variable is used by the Wildlife/Recreation submodel to calculate scouring of vegetation on sand bars.

Maximum Daily Flow at Grand Island (Lines 249-252)

The maximum daily flow at Grand Island (FLOMAX) is computed from a regression developed during the workshop from Grand Island gauge data:

```
FLOMAX = ((BFLOWA(5) / 1.0E-3) * 0.054) + 1.46
```

where

```
FLOMAX = maximum daily flow (cfs);
BFLOWA(5) = monthly flow at Grand Island (acre-ft);
1.0E-3 = a conversion factor to thousands of acre-ft; and
0.054, 1.46 = regression coefficients.
```

Acres Flooded (Lines 253-260)

Maximum daily flow in each reach (QMAX(I)) is calculated from a regression developed during the workshop:

$$QMAX(I) = (TFLOWC(I) * 1.5) + 535$$

where

QMAX(I) = maximum daily flow (cfs);
TFLOWC(I) = monthly flow (cfs); and
1.5, 535 = regression coefficients.

The maximum daily flow is multiplied by a factor to give urban acres flooded and agricultural acres flooded. The factors (0.024 for urban, 1.52 for agricultural) were crudely estimated from contour maps during the workshop.

AGRICULTURE SUBMODEL

The following submodel description is organized according to the sequence of calculations illustrated in Figure 6. The sequence is executed iteratively for all spatial subunits along the Platte as depicted in Figure 1. The submodel is not currently quantified for the spatial subunits corresponding to out-of-basin projects (areas 9, 10, 11 of Figure 1). Land is classified, and associated variables are subscripted, on four dimensions:

1. Adjacent river reach or project area, subscript IR (e.g., Overton to Grand Island, Big Blue project area);

2. Direction from river, subscript ID (e.g., North or South);

3. Crop type, subscript IC (e.g., corn, soybeans); and

4. Water-use type, subscript IW (e.g., surface-water irrigated, dryland, subirrigated).

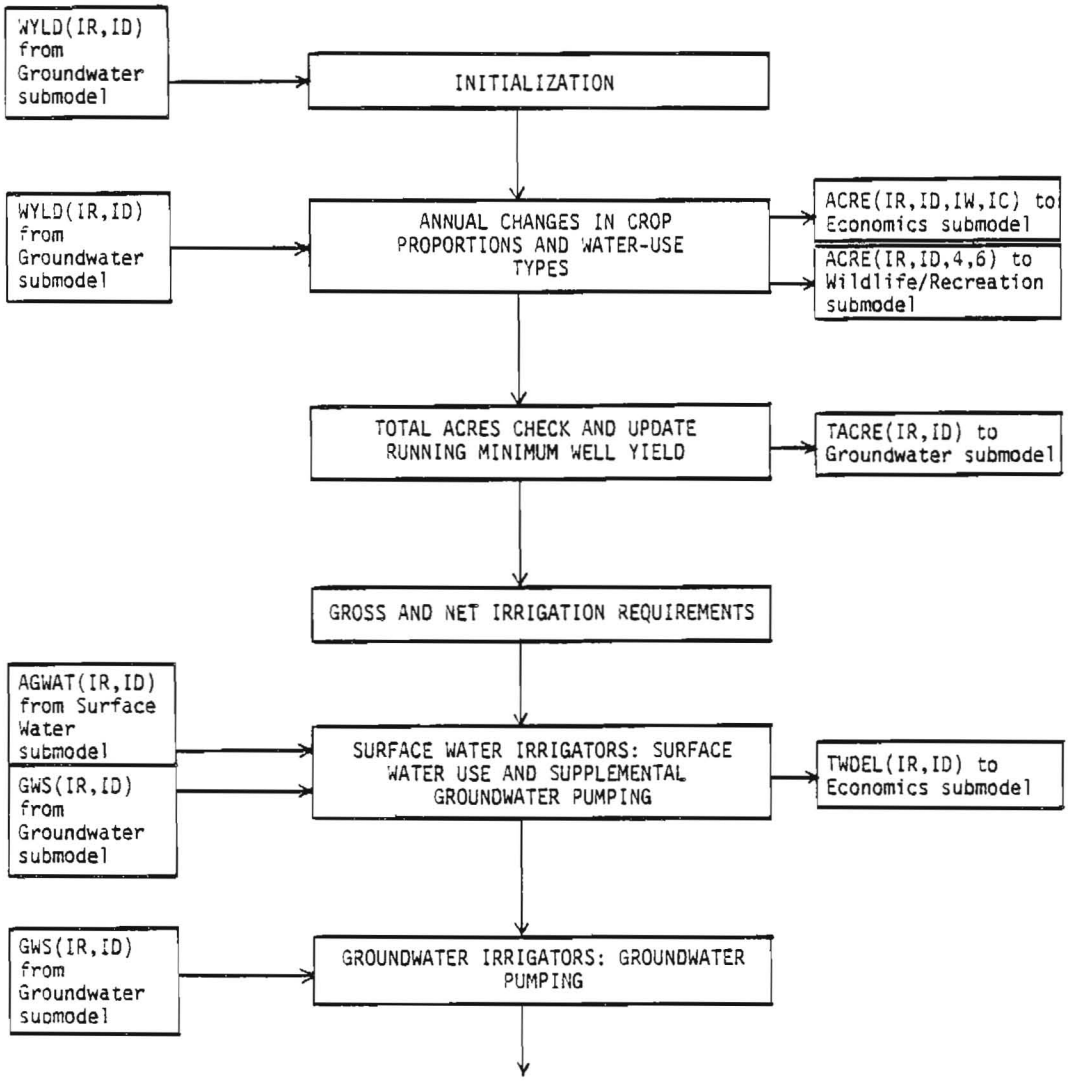


Figure 6. General structure of the Agriculture submodel.

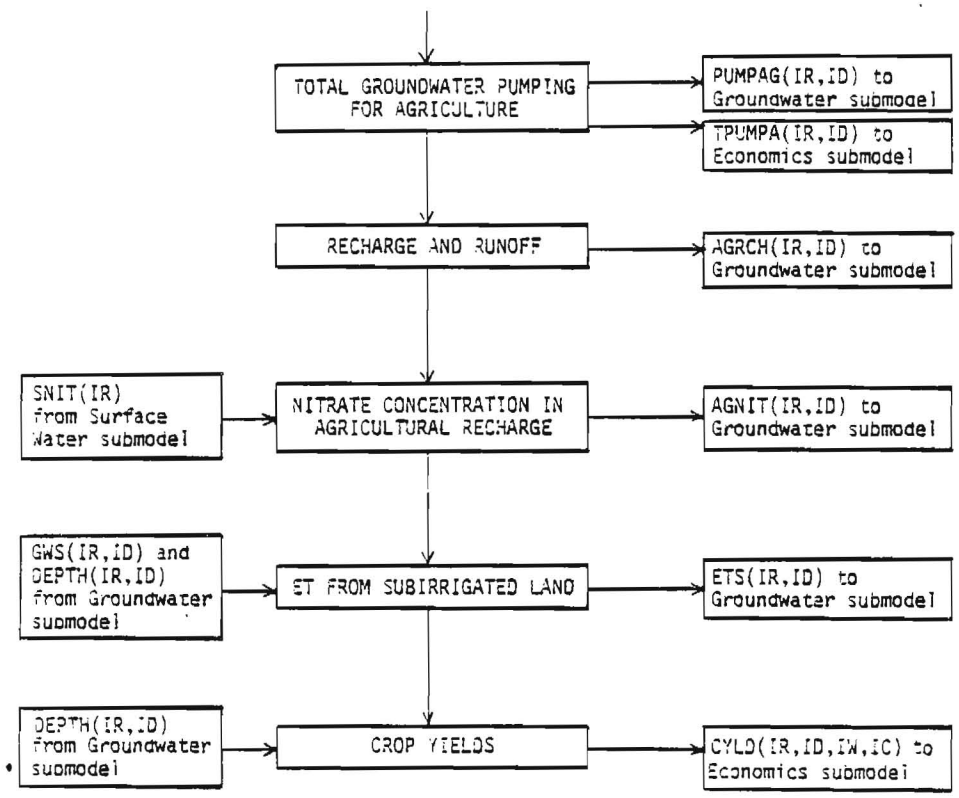


Figure 6. (concluded)

The class types and associated subscripts are listed in file AG.DEF of Appendix C. The subscript IMONTH designates the current month (IMONTH = 1 = January). Unless otherwise noted, these are the subscript definitions used throughout the Agriculture submodel description. Parenthetically noted line numbers in the Agriculture submodel description refer to lines in file AG.S of Appendix C.

Initialization (Lines 9-40)

Minimum well yields (lines 10-19). This section is executed only in the first month of the first year of simulation. The variable WYLDM(IR,ID), annual minimum well yield in gallons per minute (gpm), is used in the first month of each simulation year to modify groundwater-irrigated acreage. At the point of use (lines 73-83), WYLDM(IR,ID) represents minimum well yield for the preceeding year. In order to provide an initial condition for the first month of simulation, WYLDM(IR,ID) is set equal to the current well yield (WYLD(IR,ID), as provided by the initial conditions set in the Groundwater submodel.

Zero annual totals (lines 20-29). These calculations are executed only in the first month of each simulation year. Variables which will be accumulated across months to yield an annual total, TPUMPA(IR,ID) and TWDEL(IR,ID), as well as DDMAX(IR,ID), which represents a maximum monthly value throughout the year, are given a value of 0.0 at the beginning of the first month of each year.

Zero other cumulative variables (lines 30-40). These calculations are executed at the beginning of every month of every year. Cumulative check variables, CCHECK and TACRE(IR,ID), and two variables, AGN(IR,ID) and WNET (IR,ID,IW), which are calculated each month as sums across crop types, are set to 0.0. An integer form of the current year, IYEAR, is converted to a real form, YEAR.

Annual Changes in Crop Proportions and Water-use Types (Lines 41-89)

All of the calculations in this section are executed only in the first month of each simulation year. Crop proportions and water-use acreages are calculated by interpolation between initial (1980) conditions and estimated future (2020) conditions. These values are then modified based on minimum well yields in the preceding year (WYLDM(IR,ID) and any project-specific changes (TCHANG(IR,ID,IW).

Long-term crop changes (lines 48-56). Crop proportions for the water-use types of surface water-irrigated, groundwater-irrigated, and dryland are calculated by linear interpolation between CROP1(IR,IW,IC), representing initial (1980) proportions, and CROP2(IR,IW,IC), representing projected future (2020) proportions. The amount of change in a crop proportion between CROP1 (IR,IW,IC) and CROP2(IR,IW,IC) values is thus proportional to the amount of time between 1980, the start of the simulation, and 2020. Such linear interpolations are performed by the SIMCON function SLP (line 55) described in the SYSTEM MODEL section above. Crop proportions in other water-use types are assumed to remain constant. Crop proportions for 1980 and 2020 (Table 8) were estimated by Agriculture subgroup participants based on personal knowledge, county agricultural statistics, and on results of the High Plains Study (Nebraska Natural Resources Commission 1981).

Long-term water-use changes (lines 58-65). These long-term changes are calculated by linear interpolation in a manner similar to that described above for long-term changes in crop proportions. Values used for initial (1980) and projected (2020) conditions (Table 9) were estimated by Agriculture subgroup participants and drew heavily on results of the High Plains Study (Nebraska Natural Resources Commission 1981).

Table 8. Initial (1980) and projected (2020) crop proportions. Water-use scubscrips (IW) are as follows: 1 = surface water-irrigated, 2 = groundwater-irrigated, and 3 = dryland.

		Year 1980 (Initial) - CROP1(IR,IW,IC)					
		Crop type (IC)					
Reach (IR)	Water-use type (IW)	Alfalfa (1)	Corn (2)	Milo (3)	Soybean (4)	Wheat (5)	Other (6)
1	1	0.14	0.83	0.01	0.00	0.02	0.00
2	1	0.14	0.83	0.01	0.00	0.02	0.00
3	1	0.14	0.83	0.01	0.00	0.02	0.00
4	1	0.14	0.83	0.01	0.00	0.02	0.00
5	1	0.04	0.93	0.01	0.02	0.00	0.00
6	1	0.04	0.93	0.01	0.02	0.00	0.00
7	1	0.02	0.79	0.01	0.18	0.00	0.00
8	1	0.02	0.79	0.01	0.18	0.00	0.00
1	2	0.14	0.83	0.01	0.00	0.02	0.00
2	2	0.14	0.83	0.01	0.00	0.02	0.00
3	2	0.14	0.83	0.01	0.00	0.02	0.00
4	2	0.14	0.83	0.01	0.00	0.02	0.00
5	2	0.04	0.93	0.01	0.02	0.00	0.00
6	2	0.04	0.93	0.01	0.02	0.00	0.00
7	2	0.02	0.79	0.01	0.18	0.00	0.00
8	2	0.02	0.79	0.01	0.18	0.00	0.00
1	3	0.38	0.02	0.03	0.00	0.57	0.00
2	3	0.38	0.02	0.03	0.00	0.57	0.00
3	3	0.38	0.02	0.03	0.00	0.57	0.00
4	3	0.38	0.02	0.03	0.00	0.57	0.00
5	3	0.34	0.11	0.22	0.02	0.31	0.00
6	3	0.34	0.11	0.22	0.02	0.31	0.00
7	3	0.09	0.40	0.10	0.35	0.06	0.00
8	3	0.09	0.40	0.10	0.35	0.06	0.00

Table 8. (concluded)

		Year 2020 - CROP2(IR,IW,IC)					
		Crop type (IC)					
Reach (IR)	Water-use type (IW)	Alfalfa (1)	Corn (2)	Milo (3)	Soybean (4)	Wheat (5)	Other (6)
1	1	0.15	0.60	0.10	0.05	0.05	0.05
2	1	0.15	0.60	0.10	0.05	0.05	0.05
3	1	0.15	0.60	0.10	0.05	0.05	0.05
4	1	0.15	0.60	0.10	0.05	0.05	0.05
5	1	0.05	0.65	0.10	0.20	0.00	0.00
6	1	0.05	0.65	0.10	0.20	0.00	0.00
7	1	0.02	0.60	0.08	0.30	0.00	0.00
8	1	0.02	0.60	0.08	0.30	0.00	0.00
1	2	0.15	0.60	0.10	0.05	0.05	0.05
2	2	0.15	0.60	0.10	0.05	0.05	0.05
3	2	0.15	0.60	0.10	0.05	0.05	0.05
4	2	0.15	0.60	0.10	0.05	0.05	0.05
5	2	0.05	0.65	0.10	0.20	0.00	0.00
6	2	0.05	0.65	0.10	0.20	0.00	0.00
7	2	0.02	0.60	0.08	0.30	0.00	0.00
8	2	0.02	0.60	0.08	0.30	0.00	0.00
1	3	0.30	0.05	0.10	0.05	0.50	0.00
2	3	0.30	0.05	0.10	0.05	0.50	0.00
3	3	0.30	0.05	0.10	0.05	0.50	0.00
4	3	0.30	0.05	0.10	0.05	0.50	0.00
5	3	0.30	0.05	0.30	0.10	0.25	0.00
6	3	0.30	0.05	0.30	0.10	0.25	0.00
7	3	0.05	0.20	0.30	0.40	0.05	0.00
8	3	0.05	0.20	0.30	0.40	0.05	0.00

Table 9. Initial (1980) and projected (2020) acres (in units of thousands of acres) in various water-use types. Direction subscripts (ID) are as follows: 1 = north, 2 = south.

			Thousands of acres by water-use types (IW)					
	Reach (IR)	Direction (ID)	Surface water-irrigated (1)	Groundwater-irrigated (2)	Dryland (3)	Subirrigated (4)	Pasture (5)	Other (6)
1980	1	1	0	55	144	0	123	40
	1	2	10	124	123	6	125	5
	2	1	0	0	31	15	1,081	5
	2	2	40	3	90	0	50	0
	3	1	1	5	12	2	410	0
	3	2	0	38	21	10	160	5
	4	1	45	195	109	25	346	0
	4	2	15	78	48	17	230	15
	5	1	15	385	72	23	187	48
	5	2	100	144	35	15	58	8
	6	1	0	175	15	20	60	30
	6	2	0	52	18	10	46	12
	7	1	0	152	237	19	46	20
	7	2	0	55	90	10	30	11
	8	1	0	67	39	10	0	12
	8	2	0	93	833	0	28	141
2020	1	1	0	110	144	0	68	40
	1	2	10	199	123	6	50	5
	2	1	0	55	31	15	1,026	5
	2	2	40	6	90	0	47	0
	3	1	1	20	12	2	395	0
	3	2	0	76	21	10	122	5
	4	1	45	390	109	25	151	0
	4	2	15	156	48	17	152	15
	5	1	15	553	72	23	19	48
	5	2	100	196	35	15	6	8
	6	1	0	229	15	20	6	30
	6	2	0	73	18	10	25	12
	7	1	0	193	237	19	5	20
	7	2	0	82	90	10	3	11
	8	1	0	67	39	10	0	12
	8	2	0	118	833	0	3	141

Project-specific water-use changes (lines 67-71). Specific changes in water-use types, such as those associated with a new development (e.g., dryland to surface-irrigated or groundwater-irrigated to surface water-irrigated), are represented as combinations of positive and negative entries in the matrix TCHANG(IR,ID,IW). These changes are in addition to any long-term projected shifts. The elements of TCHANG(IR,ID,IW), TYPE1(IR,ID,IW), and TYPE2(IR,ID,IW) are in thousands of acres, which are then converted to acres in the variable TYPE(IR,ID,IW) (line 69). The variable CCHECK is a summation of the elements of TCHANG(IR,ID,IW), checking to see that simulated water-use changes conserve the total number of acres.

Dry-well water-use changes (lines 73-83). The extent of groundwater irrigation is assumed to be limited by well yields; lower well yields are associated with a smaller number of groundwater-irrigated acres. This is incorporated in the model as relationships between the fraction of the potential groundwater-irrigated acreage in each spatial subunit which is realized (GWL(IR,ID)) and the minimum well yield (WYLDM(IR,ID)) for the previous year in that spatial subunit. These relationships were estimated (best guess) by subgroup participants (Figure 7). Data defining Figure 7 are stored in the arrays XG1 and YG1 for IR = 6 and ID = 2, and XG and YG for all other spatial subunits. The relationships are adjusted by multiplying the minimum well yields by a calibration coefficient (WFAC(IR,ID)). The coefficient is used to insure that initial conditions of minimum well yield and groundwater-irrigated acres are consistent. After GWL(IR,ID) is calculated (lines 77-78), the fraction is used to reduce groundwater-irrigated acreage and to increase dryland acreage by the appropriate amount (lines 79-83).

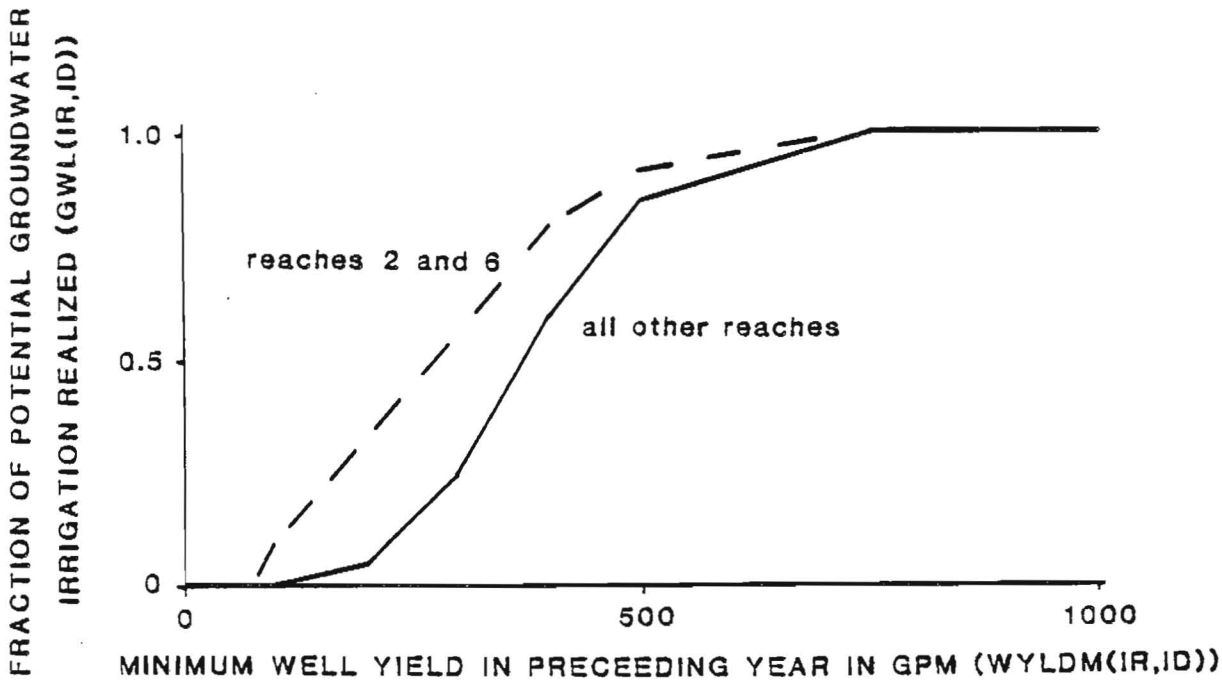


Figure 7. Fraction of potential groundwater irrigation realized as a function of minimum well yield.

Update and total (lines 84-89). Following the use of WYLDM(IR,ID) in the preceding section, WYLDM is set equal to current well yield, WYLD(IR,ID), as provided by the Groundwater submodel (line 82). The running minimum value of WYLDM(IR,ID) will be updated throughout the rest of the current year, in order to be used in the first month of the following year. In the first month the minimum value is set equal to the first month's value. Acreages (ACRE(IR, ID,IW,IC)) of each water-use type (IW) and crop type (IC) for each spatial subunit (IR,ID) are then calculated (lines 86-89) by multiplying acres in each water-use type (TYPE(IR,ID,IW)) by the respective crop proportions (CROP(IR,ID, IW,IC)).

Total Acres Check and Update Running Minimum Well Yield (Lines 98-106)

These calculations are executed every month of every year. Minimum well yield for the current year is updated based on the current month's value of WYLD(IR,ID) provided by the Groundwater submodel (lines 98-99). A check on conservation of acres is performed by recalculating the total number of acres in each spatial subunit (TACRE(IR,ID)) as the sum of all the water-use and crop types within that spatial subunit (lines 103-106).

Net and Gross Field Irrigation Requirements (Lines 108-122)

Net field irrigation requirements are calculated by multiplying the number of acres in each crop times the annual net irrigation requirement for each crop (in inches), dividing by 12.0 to convert to acre-feet, and finally multiplying by a decimal fraction representing the proportion of the annual requirement that occurs in a particular month (lines 115-116). The values are accumulated across crops to produce a total value (WNET(IR,ID,IW)) for each irrigation type in each spatial subunit. Values for crop water requirements (RNET(IR,IC)) and the seasonal distribution of these annual requirements (SEAS(IMONTH)) were estimated by subgroup participants (best guesses). These values are given in Tables 10 and 11, respectively.

Table 10. Net crop water requirement (RNET(IR,IC)) in inches per year.

Reach (IR)	Crop type (IC)					
	Alfalfa (1)	Corn (2)	Milo (3)	Soybean (4)	Wheat (5)	Other (6)
1	17.0	13.5	12.2	13.3	9.9	17.0
2	17.0	13.5	12.2	13.3	9.9	17.0
3	17.0	13.5	12.2	13.3	9.9	17.0
4	13.6	10.9	10.1	11.2	8.2	13.6
5	12.9	10.4	9.6	10.7	7.8	12.9
6	12.9	10.4	9.6	10.7	7.8	12.9
7	12.9	10.4	9.6	10.7	7.8	12.9
8	12.9	10.4	9.6	10.7	7.8	12.9

Table 11. Seasonal distribution of net crop water requirement (SEAS(IMONTH)).

Fraction of annual requirement (SEAS(IMONTH))					
Jan	Feb	March	April	May	June
0.0	0.0	0.0	0.0	0.15	0.35
July	Aug	Sept	Oct	Nov	Dec
0.35	0.15	0.0	0.0	0.0	0.0

Gross irrigation requirements at the field (WGS(IR,ID,IW)) are then calculated by dividing the net requirements (WNET(IR,ID,IW)) by field application efficiencies (EF(IW)) (line 121). The application efficiencies were estimated as 0.60 for surface water irrigation and 0.70 for groundwater irrigation.

Surface Water Irrigators: Surface Water Use and Supplemental Groundwater Pumping (Lines 124-134)

The volume of surface water needed for surface water irrigation (WDIV(IR, ID,1)) is calculated by dividing the gross field irrigation requirement for surface water irrigation in a particular spatial subunit (WGS(IR,ID,1)) by a delivery efficiency (ED(1)). The delivery efficiency (ED(1)) was estimated as 0.80. The volume of surface water used (AGUSE(IR,ID)) is calculated as the minimum of the amount needed (WDIV(IR,ID,1)) and the amount available (AGWAT(IR,ID)) as provided by the Surface Water submodel. Surface water delivered to fields (WDEL(IR,ID)) is then calculated by multiplying AGUSE(IR,ID) by the delivery efficiency (ED(1)). WDEL(IR,ID) is accumulated throughout each year in the variable TWDEL(IR,ID)). If available surface water is not sufficient to meet demand (WDEL(IR,ID) less than WGS(IR,ID,1)), the deficit is met by supplemental pumping of available groundwater (GAVAL). Available groundwater is calculated as the volume of the groundwater reservoir (GWS(IR,ID)) provided by the Groundwater submodel times an availability coefficient (GA) which is arbitrarily set to 0.75 in order to keep pumping from depleting the entire reservoir in one month. After a check to see that supplemental pumping is not greater than available groundwater, the volume of supplemental pumping required (SPUMP(IR,ID)) is subtracted from the groundwater reservoir (GWS(IR,ID)).

Groundwater Irrigators: Groundwater Pumping (Lines 136-140)

Water available for groundwater pumping (GAVAL) is calculated by multiplying the availability factor (GA) by the volume of storage (GWS(IR,ID)) as updated by the subtraction of supplemental pumping. Groundwater pumping by groundwater irrigators (GPUMP(IR,ID)) is the minimum of water required at the

field (WGS(IR,ID,2)) and available groundwater (GAVAL). The reservoir volume (GWS(IR,ID)) is then updated by subtracting the pumped volume (GPUMP(IR,ID)).

Total Groundwater Pumping for Agriculture (Lines 142-144)

Total groundwater pumping for agriculture in each month (PUMPAG(IR,ID)) is the sum of supplemental pumping by surface water irrigators (SPUMP(IR,ID)) and pumping by groundwater irrigators (GPUMP(IR,ID)). PUMPAG(IR,ID) is accumulated throughout the year as the variable TPUMPA(IR,ID).

Recharge and Runoff (Lines 146-192)

Explicit calculations of groundwater recharge (or deep percolation) and runoff are made for three water-use types: surface water irrigation, groundwater irrigation, and dryland farming (IW = 1, 2, and 3, respectively). Recharge and runoff from other water-use types are assumed to be implicit in the calculations of the Surface Water and Groundwater submodels.

Dryland (lines 147-153). Groundwater recharge for dryland (IW = 3) is calculated as follows:

```
DPERC(IR,ID,3) = FPERCD(IMONTH) * RAIN(IR,IMONTH) * (1.0 / 12.0)
                 * TYPE(IR,ID,3)
```

where

DPERC(IR,ID,IW) = deep percolation or groundwater recharge (acre-ft);
FPERCD(IMONTH) = fraction of precipitation which is deep percolation from dryland (decimal fraction);
RAIN(IR,IMONTH) = precipitation (inches); and
TYPE(IR,ID,IW) = land (acres).

The values for FPERCD(IMONTH) and RAIN(IR,IMONTH), presented in Tables 12 and 13, were estimated by Agriculture subgroup participants.

Table 12. Fraction of precipitation which is groundwater recharge. FPERCD(IMONTH) is applied to dryland (IW = 3); FPERC(IMONTH) is applied to irrigated land (IW = 1 and 2).

	Jan	Feb	March	April	May	June
Dryland (FPERCD(IMONTH))	0.0	0.0	0.0	0.1	0.0	0.0
Irrigated (FPERC(IMONTH))	0.0	0.0	0.0	0.1	0.0	0.0
	July	Aug	Sept	Oct	Nov	Dec
Dryland (FPERCD(IMONTH))	0.0	0.0	0.0	0.1	0.1	0.0
Irrigated (FPERC(IMONTH))	0.0	0.0	0.0	0.1	0.1	0.0

Table 13. Precipitation in inches (RAIN(IR,IMONTH)).

	Reach (IR)							
Month	1	2	3	4	5	6	7	8
Jan	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.75
Feb	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00
March	1.00	1.00	1.00	1.25	1.25	1.50	1.50	1.75
April	1.75	1.75	2.00	2.00	2.75	2.50	2.50	2.75
May	3.25	3.25	3.25	3.25	3.50	3.75	3.75	4.00
June	3.50	3.50	4.00	4.50	4.75	4.75	5.00	5.25
July	2.75	2.75	2.75	3.00	3.00	3.25	3.50	3.00
Aug	2.00	2.00	2.25	2.25	2.50	3.00	3.25	3.50
Sept	1.75	1.75	2.00	2.25	2.50	3.00	3.00	3.00
Oct	1.00	1.00	1.00	1.00	1.25	1.25	1.50	1.75
Nov	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dec	0.25	0.25	0.25	0.25	0.25	0.50	0.50	0.50

Runoff for dryland (IW = 3) is calculated as follows:

```
RUN(IR,ID,3) = FRUND(IMONTH) * RAIN(IR,IMONTH)
                 * (1.0 / 12.0) * TYPE(IR,ID,3)
```

where

RUN(IR,ID,IW) = runoff (acre-ft);

FRUND(IMONTH) = fraction of precipitation which is dryland runoff (decimal fraction); and

RAIN(IR,IMONTH) and TYPE(IR,ID,IW) are as previously defined.

Values for FRUND(IMONTH), estimated by Agriculture subgroup participants, are given in Table 14.

Table 14. Fraction of precipitation which is runoff from dryland (FRUND(IMONTH)).

Fraction of precipitation which is runoff (FRUND(IMONTH))					
Jan	Feb	March	April	May	June
1.0	1.0	1.0	0.1	0.1	0.1
July	Aug	Sept	Oct	Nov	Dec
0.1	0.1	0.1	0.1	0.1	1.0

Irrigated land: non-irrigation season (lines 154-172). This section deals only with irrigated water-use types (IW = 1 and 2) and is executed only in the months January - May (IMONTH = 1-5) and October - December (IMONTH = 10-12).

Recharge from surface water irrigation (IW = 1) is separated into two components: DPERCF(IR,ID,1) is recharge from the field and DPERCT(IR,ID,1) is associated with delivery losses. For these months, DPERCT(IR,ID,1) is set equal to zero. DPERCF(IR,ID,1) is calculated as follows:

```
DPERCF(IR,ID,1) = FPERC(IMONTH) * RAIN(IR,IMONTH) * (1.0 / 12.0)
                  * TYPE(IR,ID,1)
```

where

DPERCF(IR,ID,IW) = deep percolation or recharge from surface water-irrigated fields (acre-ft);

FPERC(IMONTH) = fraction of precipitation which is deep percolation (decimal fraction); and

RAIN(IR,IMONTH) and TYPE(IR,ID,IW) are as previously described.

Values for FPERC(IMONTH), estimated by Agriculture subgroup participants, are given in Table 12. Total recharge associated with surface water irrigation (DPERC(IR,ID,1)) is the sum of the field (DPERCF(IR,ID,1)) and transport (DPERCT(IR,ID,1)) components. Runoff from surface irrigated fields is calculated as one-tenth of precipitation:

```
RUN(IR,ID,1) = 0.1 * RAIN(IR,IMONTH) * (1.0 / 12.0) * TYPE (IR,ID,1)
```

where

RUN(IR,ID,IW) = runoff (acre-ft); and

RAIN(IR,ID,IW) is as previously described.

Recharge from groundwater-irrigated land (DPERC(IR,ID,2)) is calculated by the same algorithm used for field percolation from surface water-irrigated land (DPERCF(IR,ID,1)). The only differences are substitution of DPERC(IR,ID, 2) for DPERCF(IR,ID,1) and change in the water-use subscript (IW = 2 for IW = 1). Likewise, runoff from groundwater-irrigated land (RUN(IR,ID,2)) is calculated in the same manner as runoff from surface water-irrigated land, altering the water-use subscripts to represent groundwater irrigation.

Irrigated land: irrigation season (lines 173-187). The transport component of recharge associated with surface water irrigation (DPERCT(IR,ID,1)) is calculated as a percolation efficiency for applied water (EPER = 0.9) times the volume of water lost in transport (AGUSE(IR,ID) - WDEL(IR,ID)). The field component associated with surface water irrigation (DPERCF(IR,ID,1)) is calculated as the water applied to the field in excess of crop requirements

(SPUMP(IR,ID) + WDEL(IR,ID) - WNET(IR,ID,1)) times the percolation efficiency of applied water (EPER = 0.9), times an additional reduction applied only to surface water irrigation (EPER1 = 0.9). Total recharge from surface water irrigation (DPERC(IR,ID,1)) is then obtained by summing the two components (DPERCF(IR,ID,1) + DPERCT(IR,ID,1)). Runoff from surface water-irrigated land is calculated as one-tenth of applied water in excess of crop requirements (SPUMP(IR,ID) + WDEL(IR,ID) - WNET(IR,ID,1).

Recharge from groundwater irrigation is calculated as water applied in excess of crop requirements (GPUMPIR(ID) - WNET(IR,ID,2)) times the percolation efficiency of applied water (EPER = 0.9). Runoff from groundwater-irrigated land in irrigation season is assumed to be 0.0.

Totals (lines 188-192). Total groundwater recharge from agriculture (AGRCH(IR,ID)) and total runoff from agriculture (RETAG(IR,ID)) are calculated as sums of recharge (DPERC(IR,ID,IW)) and runoff (RUN(IR,ID,IW)) from the irrigated (IW = 1 and 2) and dryland (IW = 3) water-use types. No explicit calculation is made for recharge or runoff from other water-use types (IW = 4, 5, and 6). Nominal values for these types are implicit in the Surface Water and Groundwater submodels; furthermore, these values are assumed to be relatively small and constant over the period being simulated.

Nitrate Concentration in Agricultural Recharge (Lines 193-209)

The total loading of nitrate from field leaching (AGN(IR,ID)) is calculated by summing the following across water-use and crop types: a crop-specific loading (lb-N per inch of percolating water) estimated by Agriculture subgroup participants (RLOAD(IW,IC)) with values given in Table 15, times the fraction of each water-use type in each crop type (CROP(IR,ID,IW,IC)), times the total volume of percolating water from fields of each water-use type (DPERCF(IR,ID,1) for surface water-irrigated and DPERC(IR,ID,IW) for groundwater-irrigated and dryland). Nitrate loading from transport losses (TGN(IR,ID)) is calculated from the transport component of surface water-irrigated percolation (DPERCT(IR, ID,2)) and the nitrate concentration of surface water (SNIT(IR)) provided by the Surface Water submodel.

Table 15. Crop-specific nitrate loadings (RLOAD(IW,IC)). All values are in pounds of N as NO_3 per acre-inch of water percolating to groundwater.

Water-use type (IW)	Crop type (IC)					
	Alfalfa (1)	Corn (2)	Milo (3)	Soybeans (4)	Wheat (5)	Other (6)
Surface water-irrigated (1)	0.1	7.5	4.5	0.1	1.0	0.0
Groundwater-irrigated (2)	0.1	7.5	4.5	0.1	1.0	0.0
Dryland (3)	0.1	4.5	3.8	0.1	1.0	0.0

Average concentration (AGNIT(IR,ID)) is then calculated by a dimensional conversion factor (CON) times the total loading (AGN(IR,ID) + TGN(IR,ID)) divided by the total volume of percolating water (AGRCH(IR,ID)). Because agricultural contribution to groundwater nitrate is a controversial topic, several potential weaknesses of these calculations need to be stressed. First, the crop-specific loadings of nitrogen per acre-inch of percolating water (Table 15) are critical parameters in the calculation. There was some disagreement in the Agriculture subgroup over these values and they need to be better supported by experimental data. Second, estimating the percolating volume for each crop by multiplying total volume of percolating water for each water-use type by crop proportions in each water-use type may not be accurate if application efficiencies and crop water-use efficiencies differ strongly among crops. Finally, loadings and percolating volumes from water-use types other than irrigated and dryland cropland may need to be explicitly calculated in order to accurately represent the total effect on groundwater nitrate concentrations.

Evapotranspiration from Subirrigated Land (Lines 210-224)

The current value of depth to groundwater (DEPTH(IR,ID)) is compared to the initial depth to groundwater (DEPI(IR,ID)) in order to calculate a difference (DD(IR,ID)) for the current month. This value is used in the relationship (Figure 8) developed by Agriculture subgroup participants to calculate a multiplicative reduction (RED) in evapotranspiration from subirrigated land for the current month. Data defining Figure 8 are stored in the arrays XSUB and YSUB. The maximum value of this increase in depth to groundwater (DDMAX(IR,ID)) during the growing season (IMONTH = 5-9) is also updated for later use in calculating yield reductions. Evapotranspiration from subirrigated land is then calculated as follows:

```
ETS(IR,ID) = SEAS(IMONTH) * RED * (ACRE(IR,ID,4,1) *
                ALET + ACRE(IR,ID,4,6) * HNET)
```

where

ETS(IR,ID) = evapotranspiration from subirrigated land (acre-ft);

SEAS(IMONTH) = monthly distribution of annual total evapotranspiration (decimal fraction) (see Table 11);

ACRE(IR,ID,IW,IC) = land (acres);

ALET = annual potential evapotranspiration from alfalfa (ft);

HNET = annual potential evapotranspiration from native hay (ft); and

RED = multiplicative reduction in evapotranspiration due to lowered groundwater (decimal fraction) (see Figure 8).

Evapotranspiration from subirrigated land (ETS(IR,ID)) is then subtracted from available groundwater in a manner similar to that previously described for groundwater pumping (SPUMP(IR,ID) and GPUMP(IR,ID)).

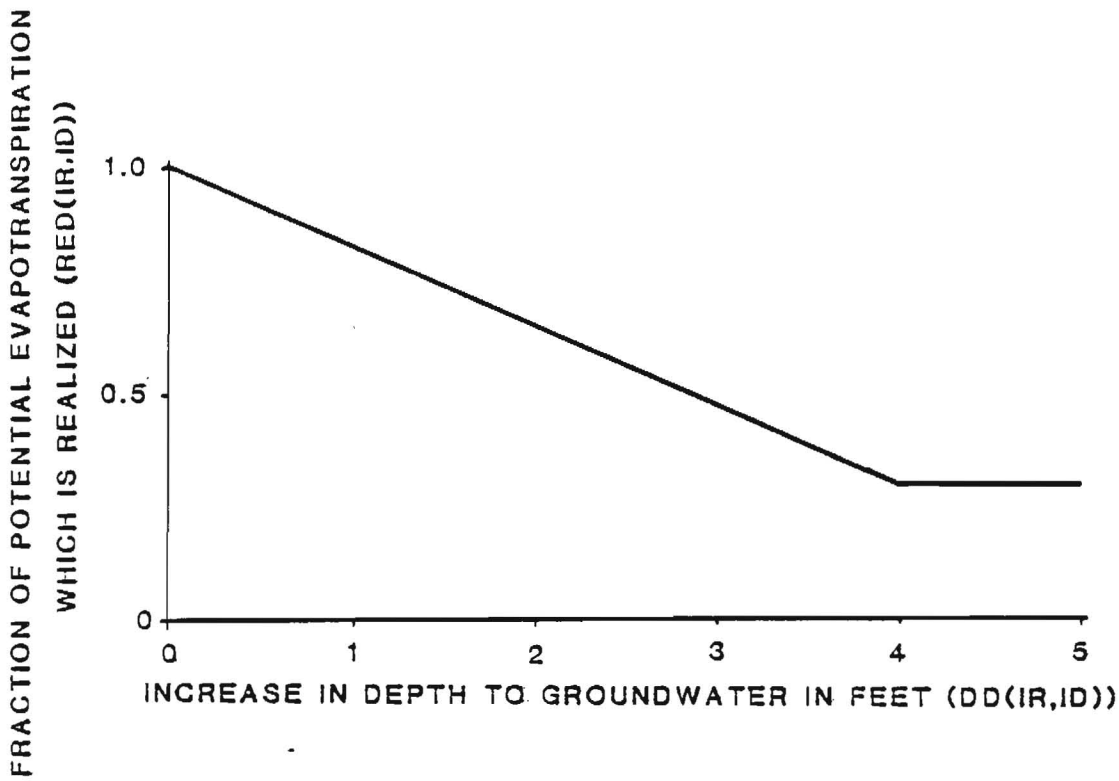


Figure 8. Multiplicative reduction in evapotranspiration from subirrigated land as a function of increase in depth to groundwater.

Crop Yields (Lines 225-238)

These calculations are executed only in the last month (IMONTH = 12) of each year.

Long-term yield changes (lines 227-233). Current crop yields (CYLD(IR,ID, IW,IC)) are calculated by linear interpolation between initial (1980) crop yields (YIELD1(IW,IC)) and projected year 2020 yields (YIELD2(IW,IC)) in a manner similar to that described previously for long-term changes in crop proportions and water-use types. Values for YIELD1(IW,IC) and YIELD2(IW,IC) (Table 16) were estimated by Agriculture subgroup participants using personal knowledge, current agricultural statistics, and the High Plains Study results (Nebraska Natural Resource Commission 1981). A multiplicative yield reduction for subirrigated land (YRED(IR,ID)) is calculated based on the maximum increase in depth to groundwater during the growing season (DDMAX(IR,ID)) using a

relationship estimated by Agriculture subgroup participants (Figure 9). Data defining Figure 9 are stored in the arrays XSUB and YSUB. This yield reduction (YRED(IR,ID)) is then applied to decrease yields from subirrigated land.

With the exception of the reduction applied to subirrigated lands described above, the crop yield calculations assume irrigated land receives full irrigation and that there is no annual climatic variation affecting yields.

Table 16. Initial (1980), YIELD1(IW,IC), and projected (2020), YIELD2(IW,IC), crop yields.

Water-use type (IW)	Cover type (IC)				
	Alfalfa (tons/ac) (1)	Corn (bu/ac) (2)	Milo (bu/ac) (3)	Soybeans (bu/ac) (4)	Wheat (bu/ac) (5)
1980					
Surface water-irrigated (1)	4.3	129.0	94.0	46.0	52.0
Groundwater-irrigated (2)	4.3	129.0	94.0	46.0	52.0
Dryland (3)	2.7	51.0	59.0	37.0	35.0
Subirrigated (4)	4.3	-	-	-	-
2020					
Surface water-irrigated (1)	6.5	180.0	150.0	60.0	81.0
Groundwater-irrigated (2)	6.5	180.0	150.0	60.0	81.0
Dryland (3)	3.6	64.0	88.0	48.0	55.0
Subirrigated (4)	6.5	-	-	-	-

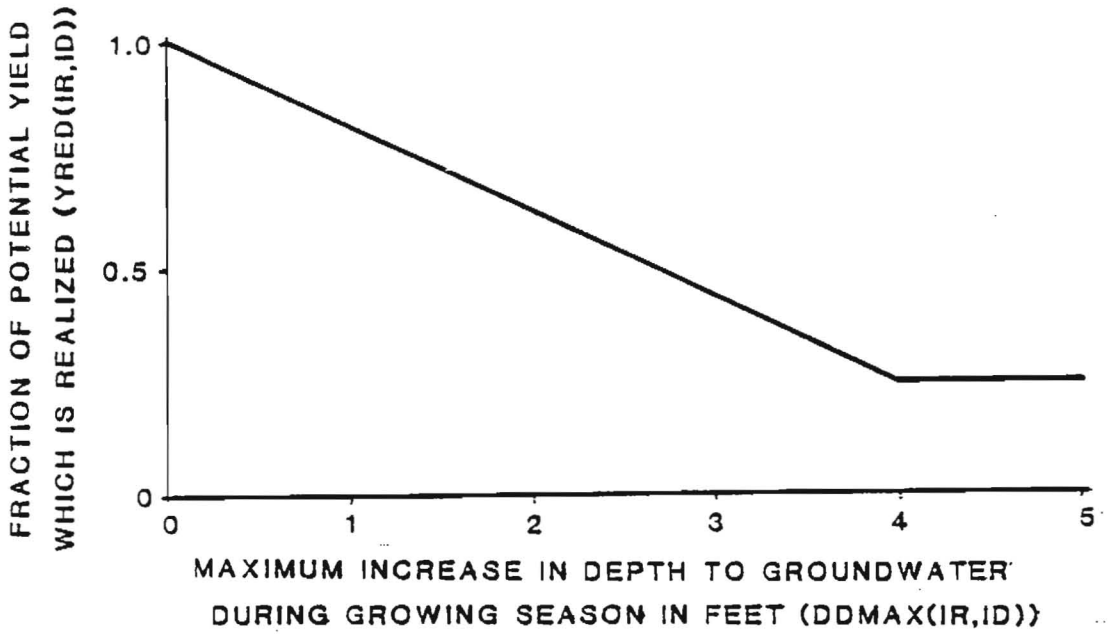


Figure 9. Multiplicative reduction in yield for subirrigated crops as a function of the maximum increase in depth to groundwater during the growing season.

MUNICIPAL/INDUSTRIAL SUBMODEL

The general structure of the Municipal/Industrial submodel is diagrammed in Figure 10. Line number notations in the following narrative description refer to the FORTRAN code file MIND.S in Appendix D. Associated computer files and variable definitions are also listed in Appendix D. Unless otherwise noted, subscript I refers to river reach, subscript J denotes direction from the river, and subscript K represents hydroelectric versus thermal power plants.

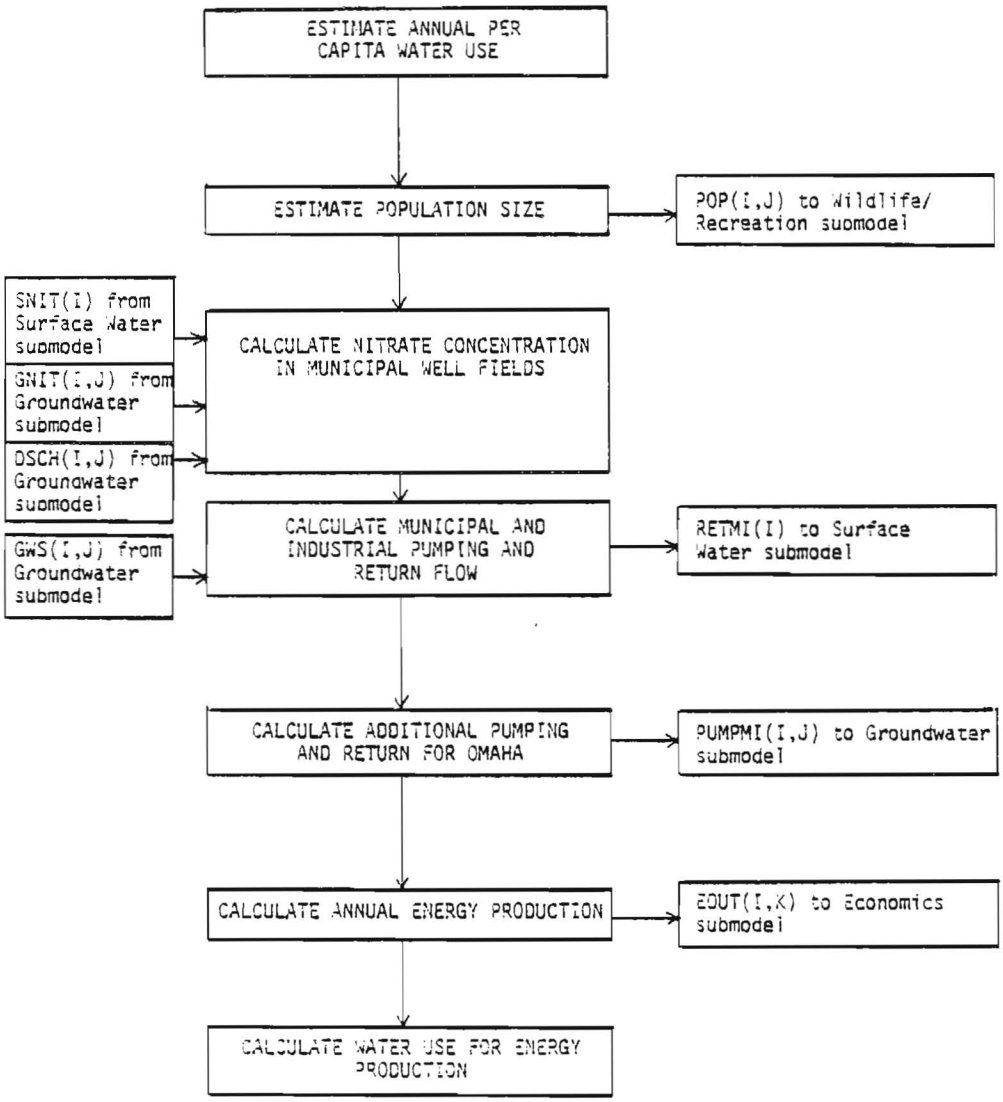


Figure 10. General structure of the Municipal/Industrial submodel.

Compute Municipal/Industrial Pumping and Well-Field Water Quality (Lines 5-27)

Average annual per capita water use (lines 9-12). The average annual per capita water use (PCWU(I)) is computed based on approximate current use (400 gallons/day) and an assumed rate of increase (DPCWU(I)) of 2% per year. This per capita use rate needs to be refined to be made more specific, perhaps using individual municipalities to determine current use and projected growth.

Population size (lines 15-18). Current populations and projected growth rates (DROP(I)) (Table 17) are used to make new population (POP(I,J)) estimates each year. These population estimates need to be checked for accuracy and more realistic projections of growth determined.

Table 17. Relocation and construction crew estimates associated with proposed water projects.

Project	No. of families relocated	Construction crews (no. of individuals)	Duration of construction	Towns impacted
Twin Valley	20	100	3-10 yrs.	Kearney, Wood River, Grand Island
Prairie Bend	6	100	3-10 yrs.	Kearney, Wood River, Grand Island
Little Blue	1	100	3-10 yrs.	Hastings, Artell, Mendin, Campbell, Funk
Enders	0	20	3-10 yrs.	Ogallala, Grant, Imperial
Twin Platte	N/A	N/A	3-10 yrs.	N/A
Plum Creek	4	100	3-10 yrs.	Lexington

Water quality (lines 19-24). The nitrate concentration in municipal well fields (XNIT(I,J)) is the only water quality variable considered by the submodel. Information on the average surface water concentrations of nitrate (SNIT(I)) and the groundwater concentrations of nitrate (GNIT(I,J)) for the entire reach is available from the water submodels. A crude estimate of the nitrate concentrations is made by taking a weighted average of these two concentrations. The relative contributions of the surface water (PNIT(I,J)) and the groundwater concentrations (1. - PNIT(I,J)) to a municipal well field nitrate concentration are assumed to depend on the amount of groundwater recharge (DSCH(I,J)) in a given reach. The relative contribution from surface water is calculated as:

PNIT(I,J) = 1. - (DSCH(I,J) / ZDMAX(I,J))

where

PNIT(I,J) = relative contribution of surface water to well field nitrate concentrations;

DSCH(I,J) = amount of water moving between the surface water and groundwater (acre-ft) where DSCH < 0 indicates groundwater recharge from the river; and

ZDMAX(I,J) = the hypothesized maximum value of DSCH(I,J).

In the model, PNIT(I,J) is constrained to the range 0.10 to 0.90.

The equation for estimating nitrate concentrations is:

XNIT(I,J) = (SNIT(I) * PNIT(I,J)) + (GNIT(I,J) * (1. - PNIT(I,J)))

where

XNIT(I,J) = municipal well field nitrate concentration (ppm);

SNIT(I) = surface water nitrate concentration (ppm);

GNIT(I,J) = groundwater nitrate concentration (ppm); and

PNIT(I,J) = proportional contribution of surface water nitrate to well field nitrate concentrations.

This nitrate calculation is overly simplistic and should be refined if well field nitrate concentrations are deemed to be an important indicator for the PRFF. It may also be desirable to add other water quality variables, such as dissolved oxygen, iron, manganese, total dissolved solids, hardness, and organics. Some of these may be especially important if proposed projects result in expanded agricultural land use or changes in agricultural practices which might eventually affect municipal water supplies. Also, a much finer spatial resolution is probably needed to make realistic predictions of water quality in municipal well fields.

Municipal and industrial pumping and return flow (lines 25-30). In each reach, the monthly municipal and industrial pumping of groundwater is calculated as:

PUMPMI(I,J) = POP(I,J) * PCWU(I) * TPROP(IMONTH) * UPOP(I,J)

where

PUMPMI(I,J) = amount of water pumped for municipal and industrial use (acre-ft);
POP(I,J) = human population;
PCWU(I) = average annual per capita water use (acre-ft);
TPROP(IMONTH) = fraction of annual water use for the current month; and
UPOP(I,J) = fraction of the population residing in municipal areas.

The assumed monthly pattern of water use is shown in Table 18. The amount of water pumped, which cannot exceed the amount in storage, is subtracted from groundwater storage (GWS(I,J)). Municipal and industrial return flows to the Platte River are assumed to be a fraction of the amount pumped. Variation in monthly return flows is in part due to variation in pumping as demand increases and partly due to seasonal factors (RFPROP(IMONTH)) (Table 19). Differences in return flow proportion by reaches (DPROP(I,J)) are also considered.

Table 18. Proportion of average annual per capita water use realized in each month (TPROP(IMONTH)).

Fraction realized					
Jan	Feb	March	April	May	June
0.50	0.75	0.75	1.00	1.25	1.75
July	Aug	Sept	Oct	Nov	Dec
1.75	1.25	1.00	0.75	0.75	0.50

Table 19. Proportion of monthly municipal/industrial groundwater withdrawals that eventually return to the river (RFPROP(IMONTH)).

Proportion returning					
Jan	Feb	March	April	May	June
0.50	0.50	0.60	0.70	0.75	0.85
July	Aug	Sept	Oct	Nov	Dec
0.85	0.75	0.70	0.60	0.50	0.50

Omaha Municipal and Industrial Water Demand (Lines 32-39)

The demand for municipal and industrial water for Omaha (XS) is considered as a special case. Demand is predicted using an SLP function based on the projection diagrammed in Figure 11. Data points defining Figure 11 are stored in the arrays ATIME and YTIME. This additional amount of water pumped is added to the amount previously calculated for reach 8 and return flows are calculated as described above.

Electric Energy Production and Water Use (Lines 40-54)

Annual energy production (lines 45-47). The annual energy production (EOUT(I,K)) for facilities on the Platte River is assumed, in the model, to remain constant, except for production at Sutherland which is assumed to increase at a rate (DEOUT(1,2)) of 2% per year. Production estimates used in the model are based on 1970 data from the Platte Level B Study (Table 20). These estimates should be updated and a realistic scenario for future growth in energy production determined.

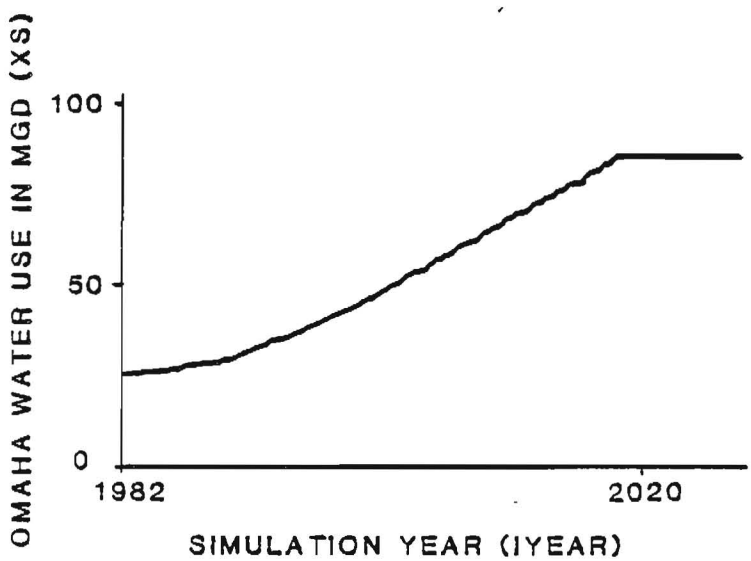


Figure 11. Average annual water use projections for the city of Omaha water system until the year 2020.

Table 20. Energy production and water use.

HYDROELECTRIC

Plant	Reach	Capacity (MW)	Annual production (MWH)	Withdrawals (cfs)	Use (cfs)
Kingsley	2	50.0	N/A	0	0
North Platte	3	26.1	147,463	711	0
Johnston 1	4	18.0	86,846	1,382	0
Johnston 2	4	18.0	116,462	1,102	0
Jeffrey	4	18.0	123,150	1,394	0
Kearney	5	1.5	620	60	0
Total		131.6	474,541	4,649	0

THERMAL

Plant	Reach	Capacity (MW)	Production (MWH)	Withdrawals (acre-ft/yr)	Use (acre-ft/yr)
Sutherland	1	1,300.0	5,124,600	N/A	9,434
Canady	4	108.8	638,000	95,600	640
Grand Island	6				
Pine Street		17.5	27,900	11,300	80
Burdock		39.5	139,200	24,400	160
Burbick		14.8	1,500	N/A	N/A
Platte		100.0	N/A	N/A	N/A
Schuyler		8.0	9,400	1,500	0
Hallam-Sheldon		228.6	1,008,500	151,000	1,580
		1,817.2	6,949,100	283,800	11,894

Energy production water use (lines 48-54). The primary consumptive use of water in energy production is for cooling in thermal plants. It is assumed in the model that hydroelectric plants do not have any consumptive use. The consumptive use of water for cooling (PX) is calculated by multiplying the estimated monthly production by the amount of water consumed per megawatt-hour (EOUTW(I,K)). The model currently assumes that 600 gallons of water are consumed in the production of one megawatt-hour. Annual energy production (EOUT(I,K)) is converted to monthly production by multiplying by the proportion generated in a given month (EOUTM(IMONTH)) (Table 21). The water consumption needs for a reach are partitioned to the north or south side of the river using EPL(I,J) and are added to the appropriate municipal and industrial pumping (PUMPMI(I,J)) calculated earlier. A small return flow from power plant cooling (PX * EOUTR(I,K)) is added to the appropriate return flows (RETMI(I)).

Flood Damage and Relocation Costs

In conceptualizing the Municipal/Industrial submodel, several potentially important factors were discussed which could not be adequately included in the current model. The likelihood and effects of flooding in urban and rural areas need to be further evaluated. If floods are likely to cause major damage and if proposed water projects might significantly reduce economic loss, then additional model refinement to include these factors should be done.

The construction of proposed water projects could bring about significant costs to some municipalities as displaced individuals relocate and as construction workers move into the area. Most towns could probably absorb these relcoation costs with no need for additional infrastructures. However, some towns, such as Artell, Mendin, Campbell, Funk, and Lexington, may require additional educational and municipal facilities. A much better understanding of other socio-economic impacts of potential projects must be developed.

Table 21. Proportion of annual energy production generated each month (EOUTM(IMONTH)).

Proportion generated					
Jan	Feb	March	April	May	June
0.06	0.06	0.06	0.06	0.08	0.11
July	Aug	Sept	Oct	Nov	Dec
0.13	0.13	0.11	0.08	0.06	0.06

WILDLIFE/RECREATION SUBMODEL

The following discussion of the Wildlife/Recreation submodel is organized around the computational sequence illustrated in Figure 12. Line numbers in parentheses refer to the file WR.S (Appendix E). Throughout the discussion, subscript IR denotes a river reach (Figure 1), IA refers to direction from the river, IM denotes the simulation month, IT denotes a riparian habitat type (sand bar, meadow, shrubs, trees), IML denotes an age class within the meadow type, and ISL denotes an age class within the shrub type. Additional information on subscript values can be found in the file WR.DEF (Appendix E), which also contains definitions of submodel variables.

Throughout this section, reference is made to the "relative" status of variables (e.g., relative crane habitat, relative recreation use-days). Relative should always be interpreted as the value of the variable during the current simulation year divided by the value of the variable at the beginning of the simulation (1982 conditions).

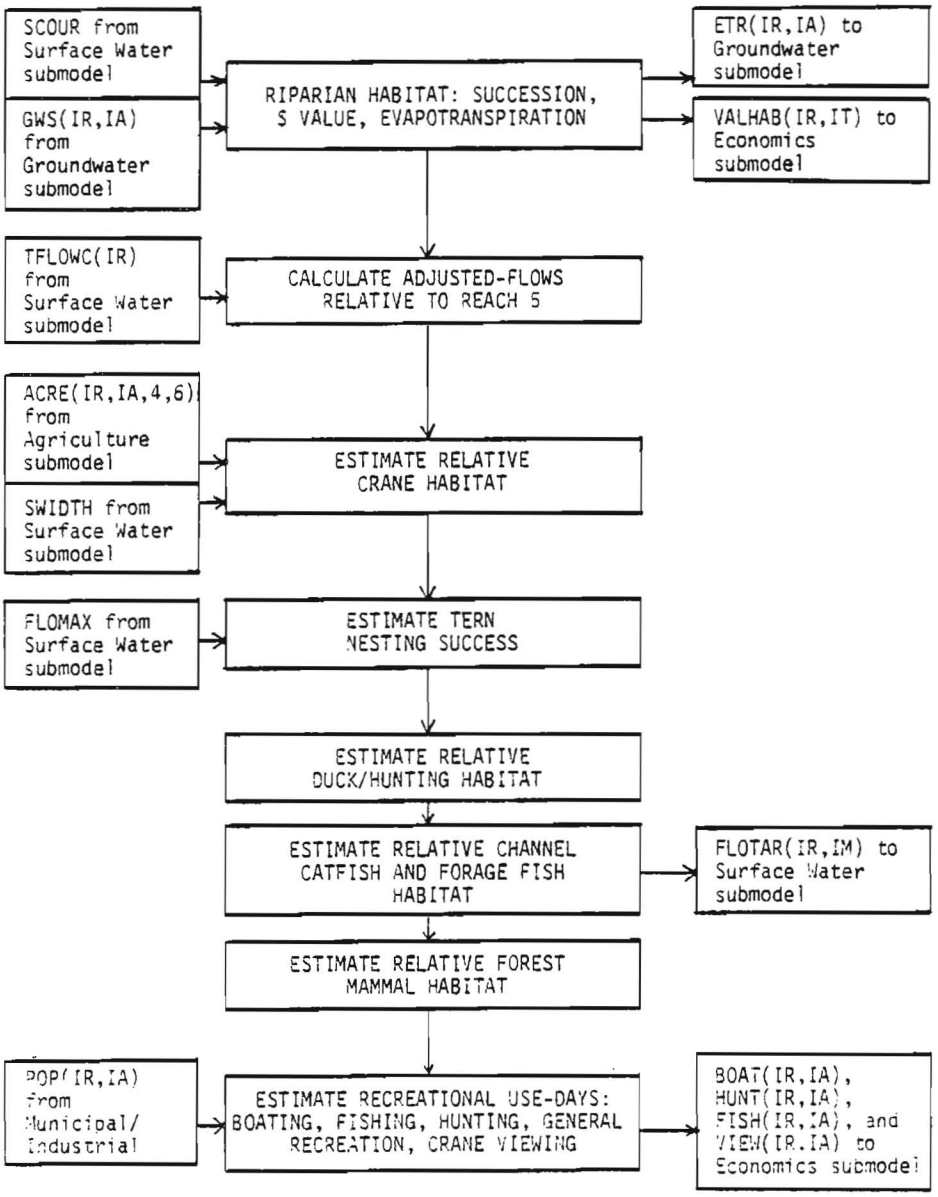


Figure 12. General structure of the Wildlife/Recreation submodel.

Riparian Vegetation (Lines 44-171)

Calculations contained in this section are executed annually except for evapotranspiration, which is computed monthly.

Riparian Succession (Lines 49-122)

Riparian vegetation in each reach consists of four types--sand bar (SAND(IR)), meadow (GRASS(IR)), shrubs (SHRUB(IR)), and trees (TREE(IR)). Initial acreages for each type are shown in Table 22. Meadow is assumed to have three age classes (GLAG(IR,IML)) and shrubs five age classes (SHLAG(IR, ISL)); that is, meadow succeeds to shrubs in 3 years, while shrubs succeed to trees in 5 years. Sand bars are converted to wet meadow at a rate (DSAND(IR)) determined by the number of scouring flows (Figure 13), which is calculated by the Surface Water submodel as the number of times annually the daily flow is greater than or equal to 3800 cfs (SCOUR). The SLP function (line 60) interpolates linearly between the points shown in Figure 13 using SCOUR as the independent variable. Data values defining Figure 13 are contained in the arrays XMED and YMED. Multiplication of this rate times the number of sand bar acres (SAND(IR)) then yields the number of acres in the first shrub age class (GLAG(IR,1)) (line 70).

Two strategies representing habitat manipulation by humans are available to the user: (1) convert enough first-year shrubs (SHLAG(IR,1)) or trees (TREE(IR)) to sand bar to offset the acres succeeding from sand bar to first-year meadow; or (2) convert a specified acreage of first-year shrubs and/or trees to sand bar.

Table 22. Initial acreages of the four riparian habitat types.

Habitat type (variable name)	Reach (subscript IR) 1	2	3	4	5	6	7	8
Sand bar (SAND(IR))	12,040	5,124	266	2,912	11,256	95,761	10,000	11,648
Wet meadow[a] (GRASS(IR))	7,224	6,832	266	2,912	5,628	6,384	2,520	2,912
Shrub[b] (SHRUB(IR))	9,632	6,832	1,596	4,368	5,628	4,788	5,040	5,824
Tree (TREE(IR))	19,264	15,372	8,512	18,928	15,008	11,172	7,560	8,736

[a]Evenly divided among the three meadow age classes (GLAG(IR,IML)).

[b]Evenly divided among the five shrub age classes (SHLAG(IR,ISL)).

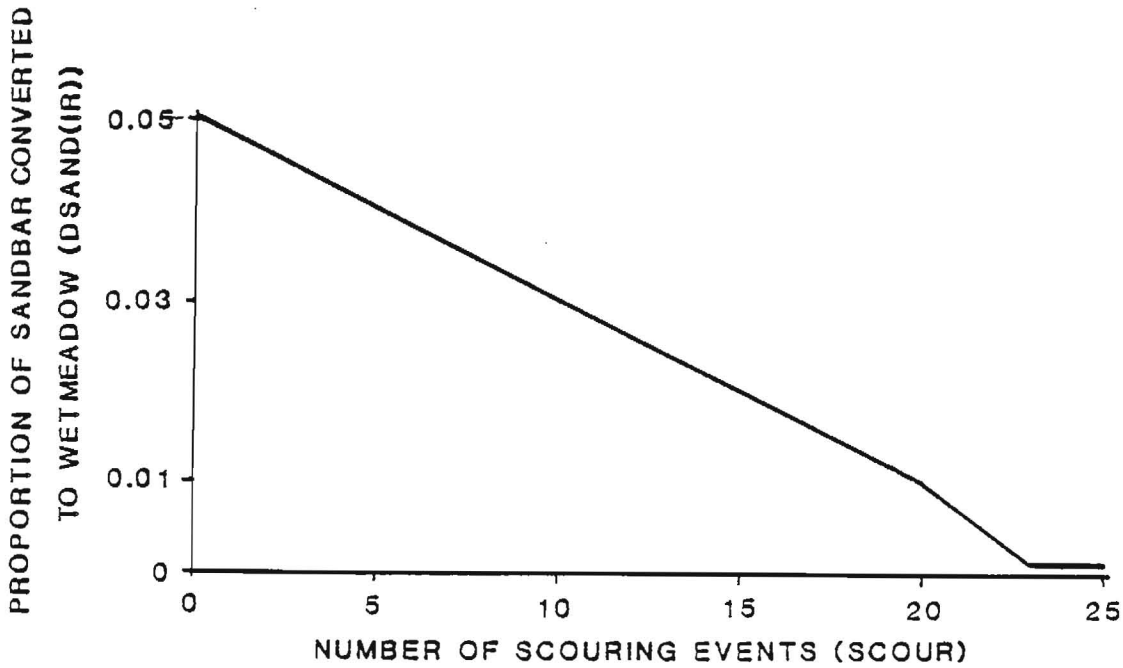


Figure 13. Rate of conversion of sand bar to wet meadow as a function of the annual number of scouring events.

To implement strategy 1, the user first decides whether the sand bar losses are to be replaced from shrubs or trees. Then the appropriate switch must be set to a value of 1 each year the strategy is to remain in effect (and reset to 0 when nominal model operation is desired). If sand bar losses are to be replaced from shrubs the switch is ISHMNT (line 85). If trees are to be the source of sand bar replacement, the switch is ITRMNT (line 93). Note that in both of these cases the switch activates the strategy in all reaches. This should be changed to a reach-specific application as a submodel refinement. The acreage converted from either shrubs (SHMNT(IR)) or trees (TRMNT(IR)) is calculated as DSAND(IR) * SAND(IR) (lines 91 and 99).

The second strategy, return of user-defined acreages from first-year shrubs and/or trees to sand bar, is implemented by specifying the desired acreages in the variables SHRIP(IR) and TRRIP(IR), respectively. These acreages are subtracted from the appropriate type (lines 117-121) and added to sand bar (line 122). Note that the submodel currently does not protect against the user attempting to remove more acres than are present.

Riparian Habitat Value (Lines 124-131)

The dollar value of each of the riparian habitat types (VALHAB(IR,IT)) is obtained by multiplying the acreage in each type (SAND(IR), GRASS(IR), SHRUB(IR), TREE(IR)) times an estimated 1982 selling price for each type (DOLAC(IT)). Estimated 1982 selling prices are shown in Table 23.

Riparian Habitat Totals (Lines 133-142)

Total acreages of the riparian habitat types are found by summing the individual reach contributions.

Table 23. Estimated 1982 selling prices (DOLAC(IT)) for the four riparian habitat types.

Habitat type (IT)	Price ($/acre)
Sand bar (1)	300
Wet meadow (2)	1,250
Shrubs (3)	300
Trees (4)	300

Evapotranspiration by Riparian Vegetation (Lines 144-171)

Annual evapotranspiration (ET) by each of the riparian habitat types (ETSDR, ETMDR, ETSHR, ETTRR) and a monthly distribution pattern (ETDIST(IMONTH)) were estimated by workshop participants (Tables 24 and 25).

Table 24. Annual evapotranspiration by the riparian habitat types.

Habitat type (variable name)	Evapotranspiration rate (acre-ft/acre/year)
Sandbar (ETSDR)	2
Wet meadow (ETMDR)	2
Shrubs (ETSHR)	3
Trees (ETTRR)	3

Table 25. Monthly distribution of annual evapotranspiration (ETDIST(IMONTH)).

Month	Proportion	Month	Proportion
January	0.0	July	0.3
February	0.0	August	0.1
March	0.0	September	0.05
April	0.1	October	0.0
May	0.2	November	0.0
June	0.25	December	0.0

Monthly ET for each habitat type in each reach (ETSD(IR), ETMD(IR), ETSH(IR), ETTR(IR)) is calculated by multiplying the annual total times the monthly proportion (ETDIST(IMONTH)) times the number of acres in the type (lines 151-154). Total ET for the reach (TETR(IR)) is then the sum of the values for the four habitat types (line 155). ET north and south of the river (ETR(IR,IA)) is obtained by dividing the reach total by two (line 160). This value is then checked (line 164) to see that it does not exceed the amount of groundwater present (GWS(IR,IA)) and subtracted from the groundwater supply (line 168).

Flow Conversions (Lines 172-189)

During the first workshop, subgroup participants developed flow/habitat relationships for reach 5 (Figure 1) for ducks, channel catfish, and forage fish. However, time constraints prevented them from developing similar explicit relationships for other river reaches. A temporary solution for this problem was achieved in the following way. Participants estimated the average

flow in each reach as a proportion of the flow in reach 5 (ADJF(IR)) (Table 26). These factors are used (line 178) to compute an adjusted or surrogate flow for each reach:

AFLOW(IR) = TFLOWC(IR) / ADJF(IR)

where

AFLOW(IR) = adjusted or surrogate flow (cfs);

TFLOWC(IR) = flow calculated by the Surface Water submodel (cfs); and

ADJF(IR) = the relationship or flow in reach IR to flow in reach 5 (Table 26).

The adjusted flows (AFLOW(IR)) are then used with the flow/habitat relationships developed for reach 5 to estimate habitat in the other reaches (see below).

Table 26. Relative magnitude of flows in each reach compared to the flow in reach 5 (ADJF(IR)).

Reach	Flow relative to reach 5	Reach	Flow relative to reach 5
1	0.5	5	1.0
2	2.0	6	1.0
3	0.5	7	3.0
4	1.0	8	4.0

One management option available is to operate the model system attempting to satisfy flow requests for wildlife needs (see Surface Water submodel description). These flow requests are specified as reach- and month-specific targets (TARFLO(IR,IM)) in cfs. For use by the Surface Water submodel, these are first converted (line 182) to acre-ft/month (FLOTAR(IR,IM)) and then the monthly subscript is dropped (line 186).

Crane Habitat (Lines 190-230)

Crane feeding habitat (lines 198-210). The amount of crane feeding habitat is estimated as the acreage of subirrigated native hay (ACRE(IR,IA,4,6) from the Agriculture submodel). This assumes that: (1) subirrigated native hay provides the majority of the wet meadows used by cranes for feeding; and (2) most of the subirrigated native hay lies within 3.5 miles of the river (the assumed maximum distance from the river that cranes range to feed). The total acreage of subirrigated native hay in each reach (CRFR(IR)) is obtained by summing the contribution on each side of the river (ACRE(IR,IA, 4,6)) from the Agriculture submodel (line 201). The relative amount of crane feeding habitat (CRFEED(IR)) is then calculated (line 206) by dividing the amount in the current model year (CRFR(IR)) by the amount at the start of the model run (CRFS(IR)). Crane habitat is calculated only for the migration periods (February-May, October-November) (lines 208-210).

Crane roosting habitat (Lines 213-223). Relative crane roosting habitat (ROOST(IR)) is estimated as a function of either: (1) the river width (SWIDTH) calculated by the Surface Water submodel; or (2) a user-specified river width (VWIDTH(IR)). The latter option represents vegetation manipulation to improve crane roosting habitat. The submodel first takes the maximum of SWIDTH and VWIDTH(IR) (line 218) and then uses the result (RWIDTH) as the independent variable in a linear interpolation (line 223) between the points in Figure 14 to determine relative crane roosting habitat. Data defining Figure 14 are stored in the arrays XCR and YCR.

Overall crane habitat (line 227). The overall relative value of crane habitat in each simulation year is the minimum of the relative feeding and roosting habitats.

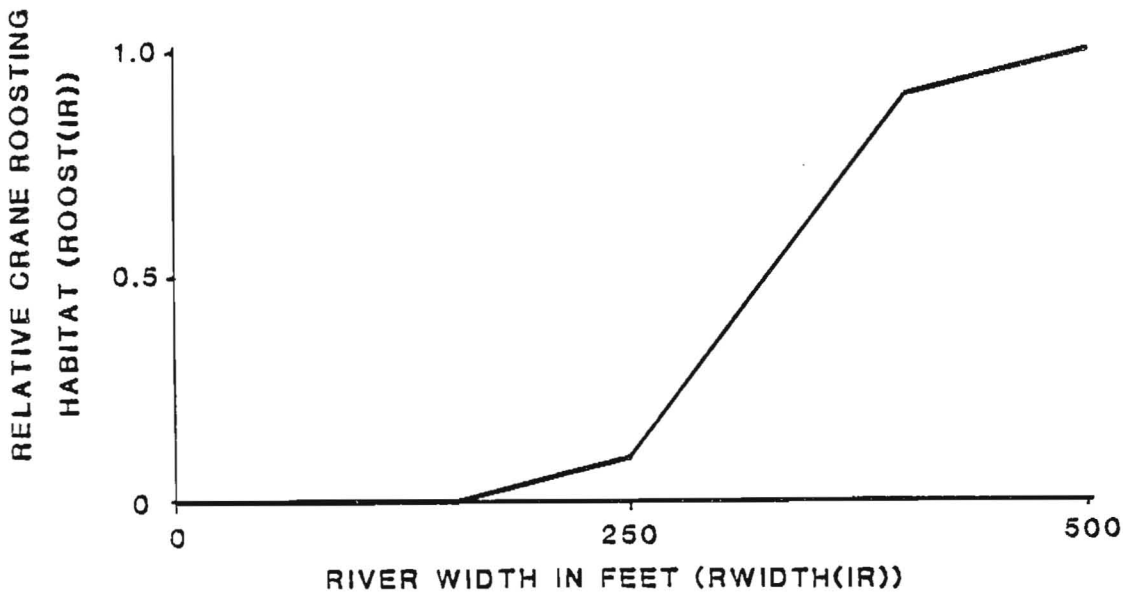


Figure 14. Relative crane roosting habitat as a function of river width.

Least Tern Nesting Success (Lines 231-259)

June, July, and August are assumed to be the months critical to tern nesting success. Scouting for nest sites occurs in June. Nesting itself begins in July and is completed in August. If flows are too high during June, there is no available nesting habitat (line 243). Once the terns have established nests, flows greater than those observed at the time of nest site selection (FLO1) are assumed to drown out the nests (line 251):

```
IF(FLOMAX.GT.FLO1) TERN(IR) = 0.
```

where

FLOMAX = maximum daily flow during July or August (cfs);
FLO1 = maximum daily flow during June (cfs); and
TERN(IR) = tern nesting success (%).

Duck Migration/Hunting Habitat (Lines 260-281)

Relative duck migration/hunting habitat (DHABM(IR)) is calculated for both the northward (February-April) and southward (October-November) migration periods (lines 268-272). The relative amount of habitat is calculated (line 278) by linear interpolation from Figure 15 using the adjusted flow as the independent variable. Data defining Figure 15 are stored in the arrays XDM and YDM.

Fish Habitat (Lines 282-347)

Calculations in this section are made during the appropriate months as described below.

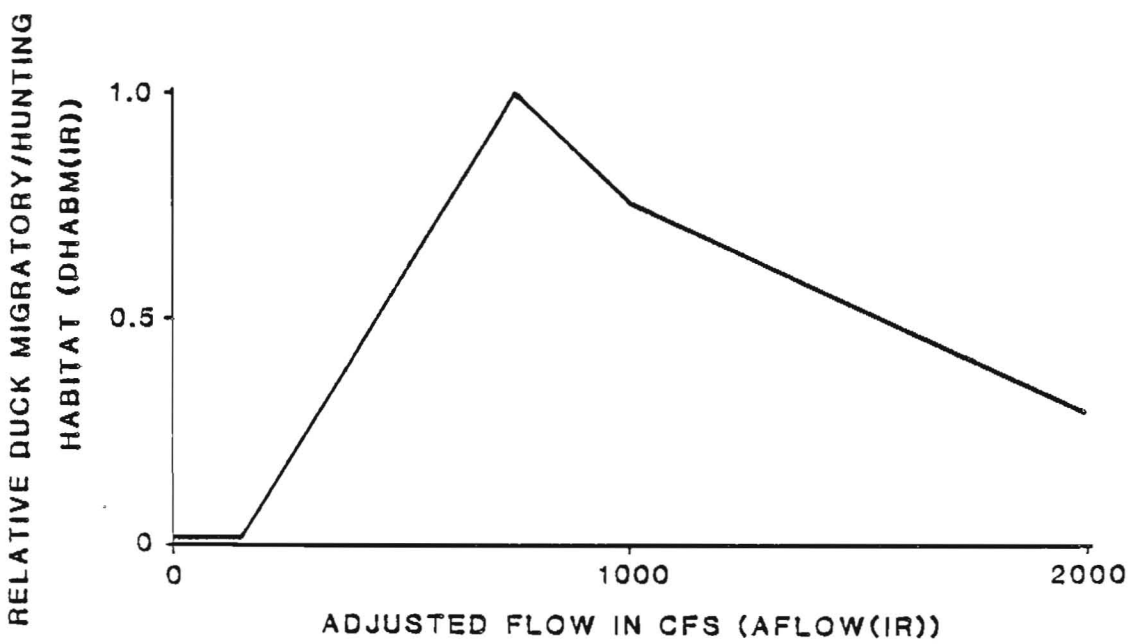


Figure 15. Relative duck migration/hunting habitat as a function of flow.

Channel catfish habitat (Lines 286-307). Three periods of the year were selected by subgroup participants to represent habitat requirements (CCAT(IR)) of three critical life stages of channel catfish: (1) overwintering habitat--January through May (lines 292-293) and October through December (lines 294-295); (2) spawning--June (lines 299-300); and (3) rearing or production--July through September (lines 305-306). The relative amount of each of the three types of habitat is calculated by linear interpolation from Figures 16-18. Data defining these figures are stored in the arrays XCCW and YCCW, XCCS and YCCS, and XCCP and YCCP, respectively. In each case, the adjusted flow (AFLOW(IR)) is used as the independent variable.

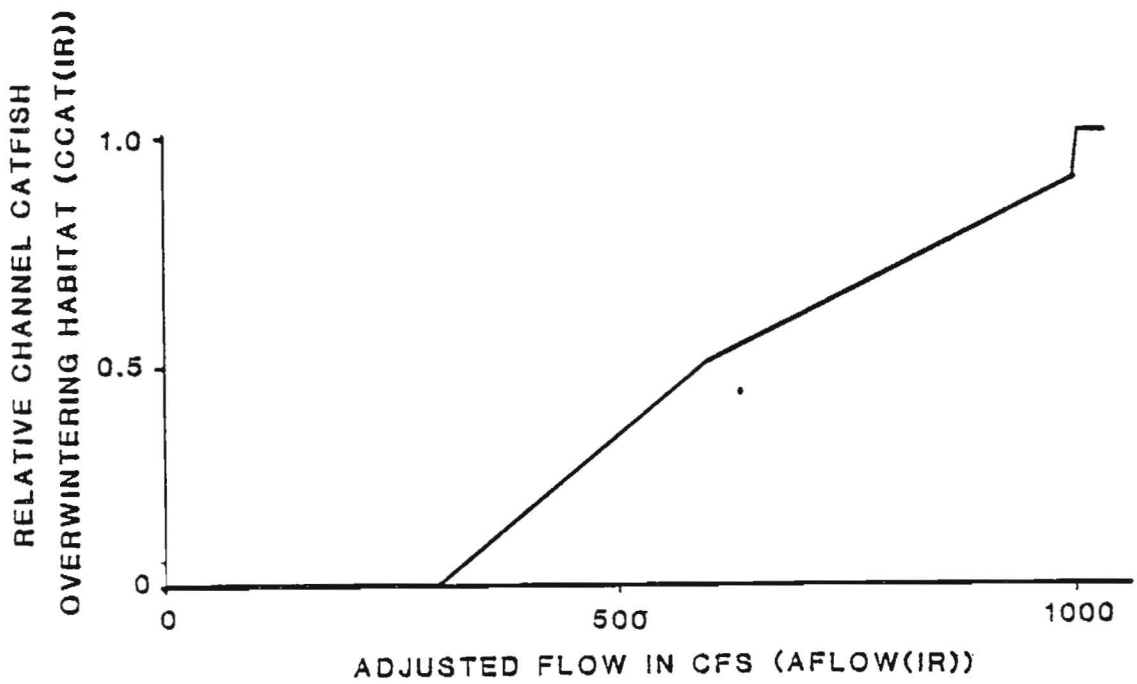


Figure 16. Relative channel catfish overwintering habitat as a function of flow.

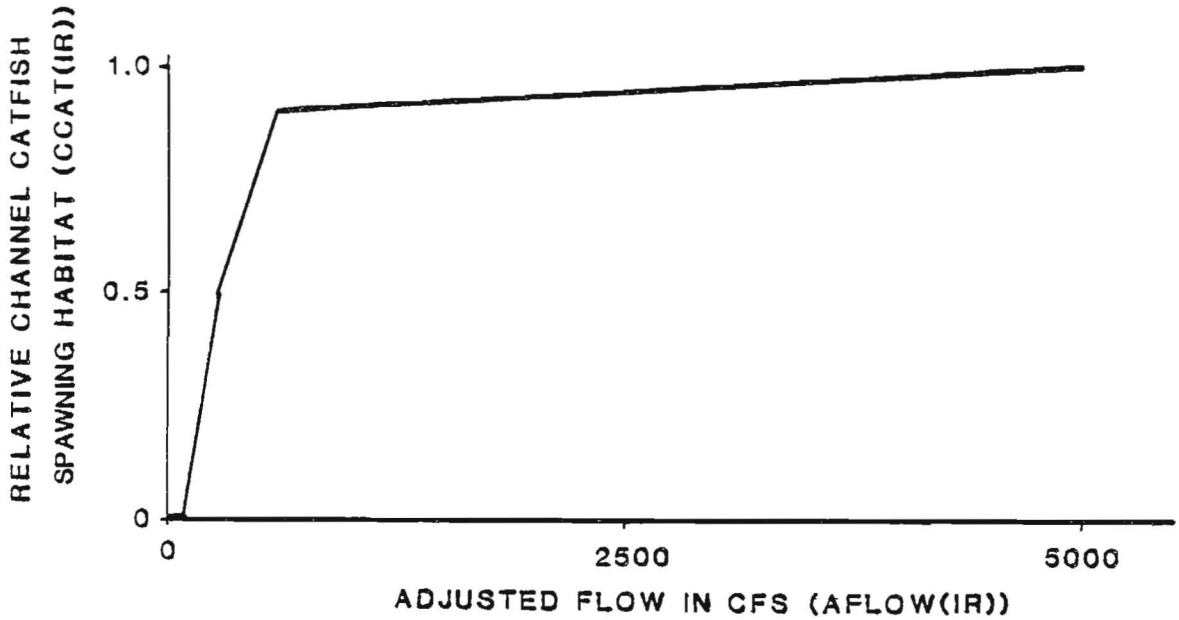


Figure 17. Relative channel catfish spawning habitat as a function of flow.

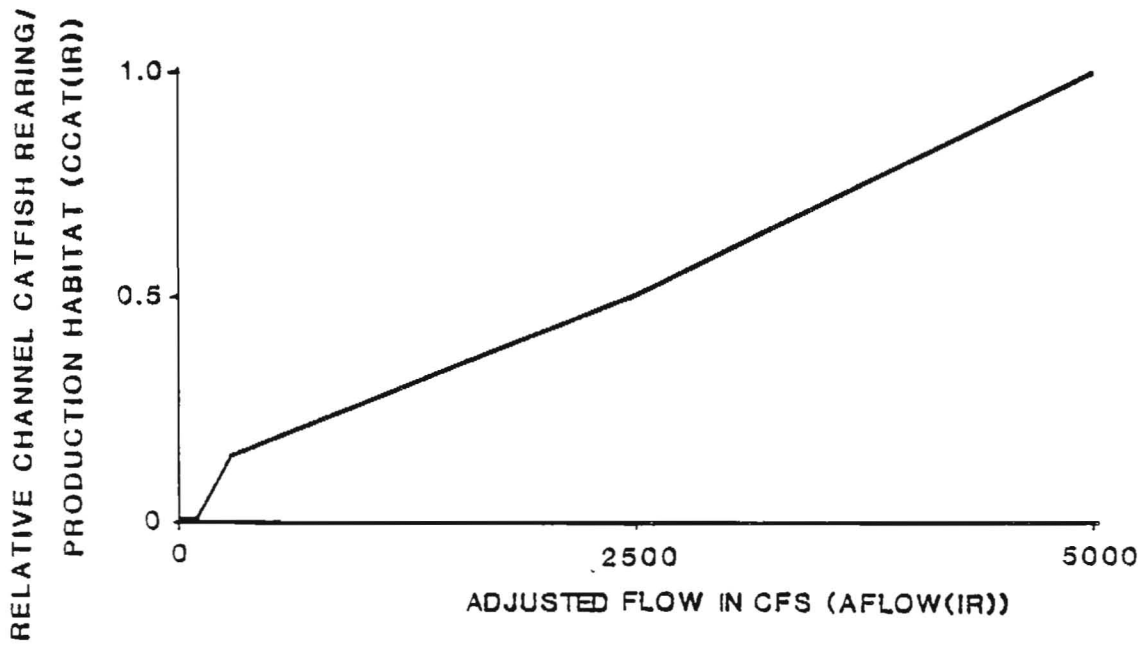


Figure 18. Relative channel catfish rearing/production habitat as a function of flow.

Forage Fish (Cyprinid Minnow) Habitat (Lines 309-331)

An approach similar to that taken for channel catfish was used to estimate relative forage fish habitat (CMINN(IR)). The three critical life stages are: (1) overwintering--January through April (lines 315-316) and October through December (lines 317-318); (2) spawning--May (lines 322-323); and (3) rearing or production (lines 328-329). The relative amount of each of the three types of habitat is calculated by linear interpolation from Figures 19-21. Data defining these figures are stored in the arrays XCMW and YCMW, XCMS and YCMS, and XCMP and YCMP, respectively. In each case, the adjusted flow (AFLOW(IR)) is used as the independent variable.

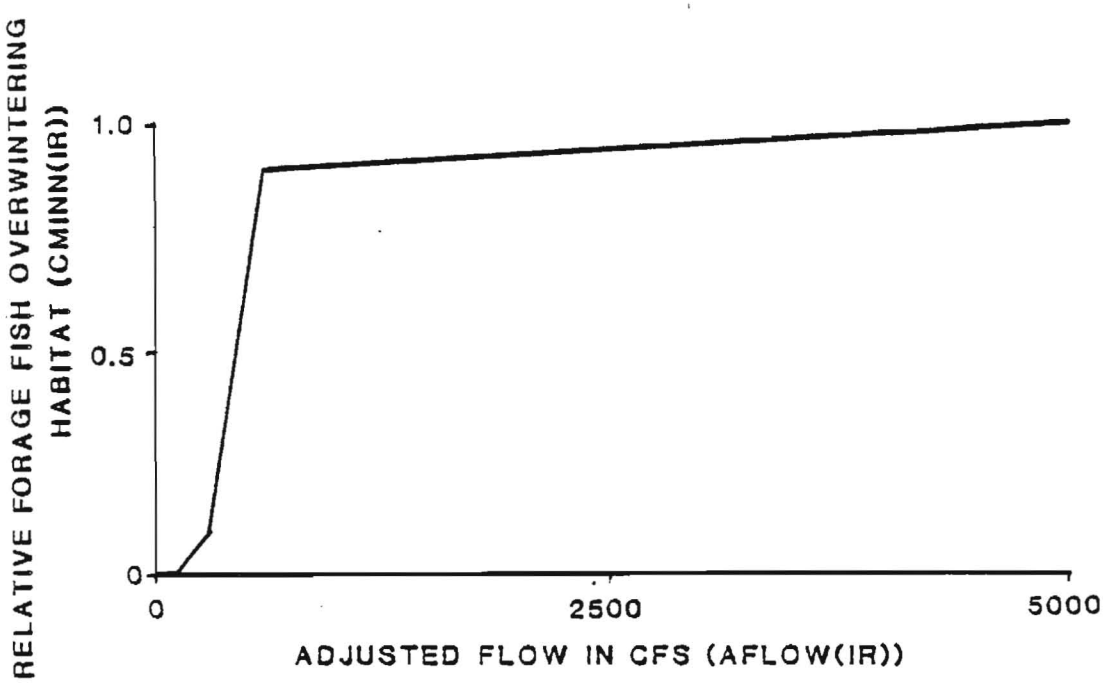


Figure 19. Relative forage fish overwintering habitat as a function of flow.

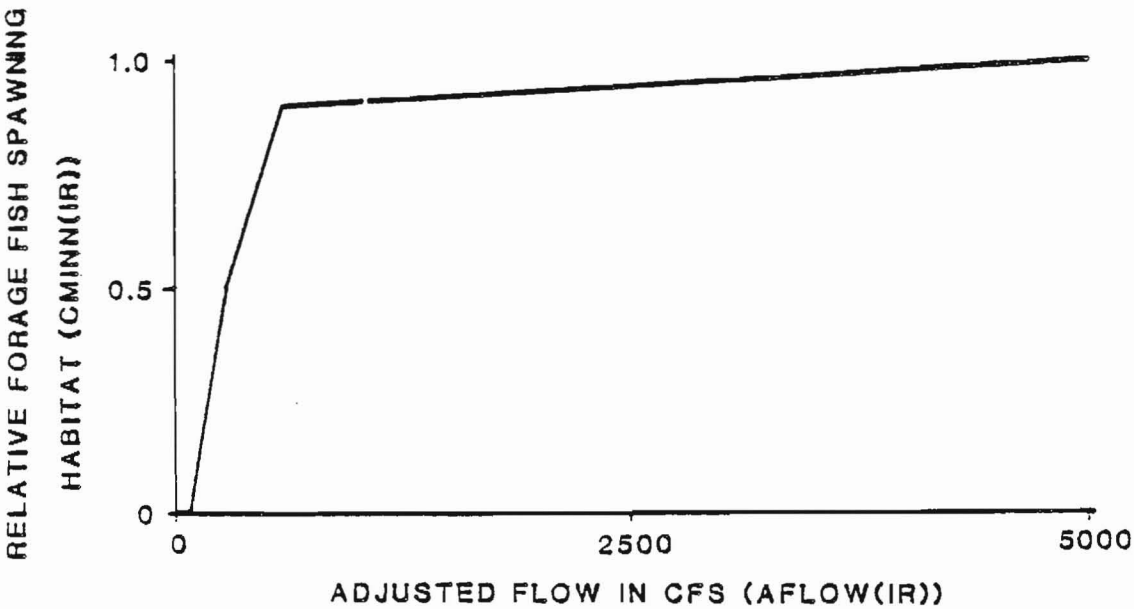


Figure 20. Relative forage fish spawning habitat as a function of flow.

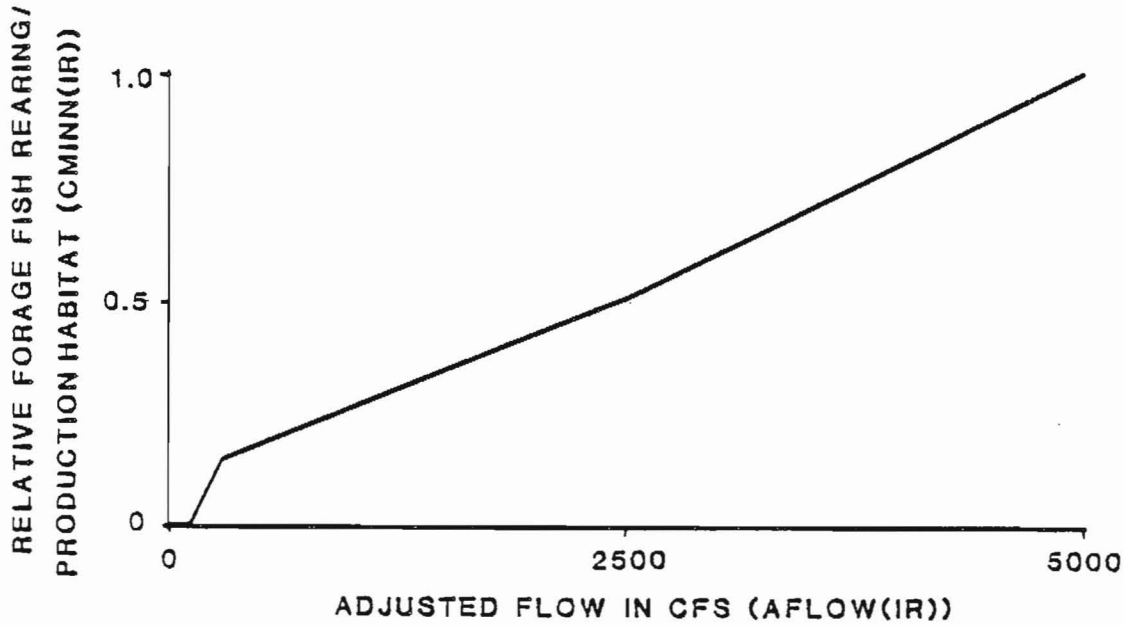


Figure 21. Relative forage fish rearing/production habitat as a function of flow.

Forest Wildlife Habitat (Lines 332-347)

Relative forest habitat (FORSP(IR)) is estimated once annually (line 336) as the total acreage of shrubs (SHRUB(IR)) and trees (TREE(IR)) divided by the amount present at the start of the simulation (FORS(IR)). Current (1982) values for FORS(IR) estimated by workshop participants are shown in Table 27.

Table 27. Initial acreages of shrubs (all age classes) and trees (FORS(IR)).

Reach	Acres	Reach	Acres
1	30,341	5	21,762
2	23,570	6	17,237
3	10,161	7	13,104
4	23,878	8	15,142

Recreational Use-Days (Lines 348-443)

Recreational use-days are calculated once annually (line 336).

Relative human population (lines 354-380). The initial human population for each reach (POPS(IR)) is obtained by summing the contribution from each side of the river (POP(IR,IA)) in the first month of the simulation (line 359). The population in January of each simulation year (POPI(IR)) is obtained in the same way (line 364). The relative population in each reach (POPM(IR)) is then POPI(IR) / POPS(IR) (line 369). The sum (line 374) of these relative reach populations (SPOPM) is used to determine the average (over all reaches) change from initial conditions (DVIEW) (line 380). DVIEW is used only in the calculation of the number of crane viewers and is an attempt to reflect the relatively high mobility of that type of recreationist.

Recreational use-days without project effects (lines 383-395). Four recreation categories are represented in the model: boating, fishing, hunting, and general nonconsumptive activities (e.g., picnicking, swimming, bird watching). Initial estimates of numbers of recreational use-days in each of these categories were provided by subgroup participants based on Nebraska Department of Fish and Game records (Table 28). In the absence of any development projects, the number of use-days in each of these classes (HUNTR(IR), FISHR(IR), BOATR(IR), VIEWR(IR)) is simply the initial value (Table 28) times the relative population (lines 392-395). This assumes that the ratio of recreationists to total population remains constant and that the distribution of recreationists among the categories remains constant.

Table 28. Estimated initial (1982) numbers of recreational use-days for boating, fishing, hunting, and general nonconsumptive activities.

	Category (variable name)			
Reach	Boating (BOATS(IR))	Fishing (FISH(IR))	Hunting (HUNT(IR))	General (VIEW(IR))
1	134,400	106,828	19,793	417,000
2	276,897	284,000	59,100	278,000
3	16,030	16,000	11,790	108,000
4	58,296	140,080	41,894	216,000
5	6,170	75,844	84,215	54,000
6	4,960	36,924	37,069	54,000
7	22,400	138,640	59,471	81,000
8	13,647	116,000	48,054	27,000
Total	532,800	914,316	361,386	1,235,000

Recreational use-days added by new projects (lines 397-404). If a new water project is implemented during a model run, the user may attribute increased recreational use as a project effect (BOATP(IR,IA), FISHP(IR,IA), HUNTP(IR,IA), and VIEWP(IR,IA)). Parameters available for user manipulation are:

SURFAC(IR,IA)	=	added surface water (acres);
HACRE(IR,IA)	=	added land available for hunting (acres);
BPAC	=	boaters/acre of surface water;
FPAC	=	fishermen/acre of surface water;
HPAC	=	hunters/acre of available land; and
VPAC	=	general recreationists/acre of land available for hunting.

The number of recreational use-days generated by a new project is calculated as the product of added number of acres and recreationists/acre (lines 401-404).

Recreational use-days north and south of the river including project effects (lines 406-412). To provide data required by the Economics submodel, recreational use-days for each category and reach are divided equally between areas north and south of the river (BOAT(IR,IA)), FISH(IR,IA), HUNT(IR,IA), VIEW(IR,IA)). Use-days attributable to projects are area-specific and are added to the appropriate value (lines 409-412).

Update initial recreational use-days by category and reach (lines 414-419). If a water project generates additional recreational use-days in any or all of the use categories, the new use is assumed to affect the original base of use-days (BOATS(IR)), FISHS(IR), HUNTS(IR), VIEWS(IR)). Therefore, project generated use-days (BOATP(IR,IA), FISHP(IR,IA), HUNTP(IR,IA), VIEWP(IR,IA)) are added to the initial estimates (lines 416-419).

Total Use-Days By Reach and Category (Lines 421-426)

Total recreational use-days for the four use categories is the sum of the relative use-days as a function of population change plus the use-days added by water projects (lines 423-426).

Crane Viewing Use-Days (Lines 429-434)

Crane viewing use-days (CVIEW) differs from the four recreational use categories discussed above by taking into account relative changes in crane habitat. CVIEW is estimated once annually and only for reach five. As discussed earlier, the relative population index used for this activity (DVIEW) attempts to capture the non-local characteristic of people engaged in viewing cranes. Crane viewing use-days are estimated (line 434) by:

CVIEW = CVIEWS * DVIEW * CRANE(5)

where

CVIEW = relative number of crane viewing use days;
CVIEWS = initial number of crane viewing use-days (estimated to be 20,000); and
DVIEW and CRANE(5) are as defined above.

Total Recreational Use-Days (Lines 436-442)

The total number of recreational use-days in all reaches (VISIT) is obtained simply by summing the individual reach contributions (lines 438-439 and 442).

GROUNDWATER SUBMODEL

The following submodel description is organized according to the sequence of calculations illustrated in Figure 22. Line references pertain to line numbers in the FORTRAN file GROUND.S (Appendix F). Unless otherwise noted, subscripts used in the discussion are as follows: I denotes a river reach or project area (Figure 1), J denotes direction from the river, and K refers to the simulation month. Additional information concerning these subscripts, along with definitions of other variables used in the submodel, can be found in the listing of the file GROUND.DEF (Appendix F). FORTRAN COMMON statements and data used in the submodel are listed in the files GROUND.C and GROUND.D, respectively (Appendix F). Aquifer characteristics and initial conditions used in the submodel are shown in Tables 29 and 30.

Initialization (Lines 1-7)

The submodel begins by storing the number of the current simulation month (IMONTH) in the variable K. Loops over river reach or project area (line 5) and direction (line 6) are begun, and values for RUNOFF(I,J) are set to zero.

Set Base Values for Calculating Changes in Pumping and Recharge (Lines 8-19)

In determining changes in groundwater levels, the Groundwater submodel considers six pumping and recharge factors: recharge from water storage facilities (STRCH(I,J)) from the Surface Water submodel; evapotranspiration by subirrigated lands (ETS(I,J)), groundwater pumping for irrigation (PUMPAG(I,J)), and agricultural (including water delivery system) recharge (AGRCH(I,J)) from the Agriculture submodel; municipal/industrial pumping (PUMPMI(I,J)) from the Municipal/Industrial submodel; and evapotranspiration by riparian vegetation (ETR(I,J)) from the Wildlife/Recreation submodel.

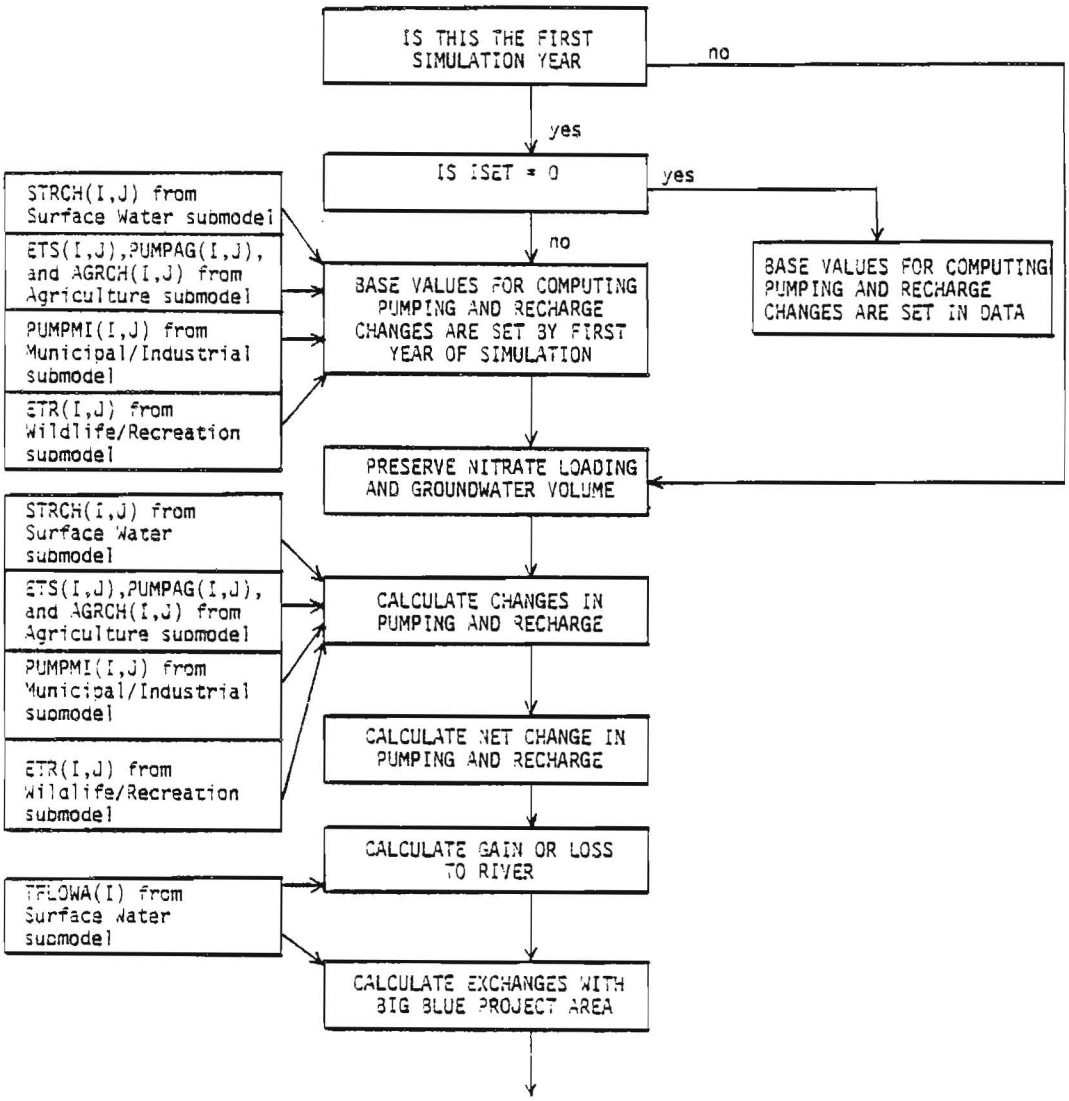


Figure 22. General structure of the Groundwater submodel.

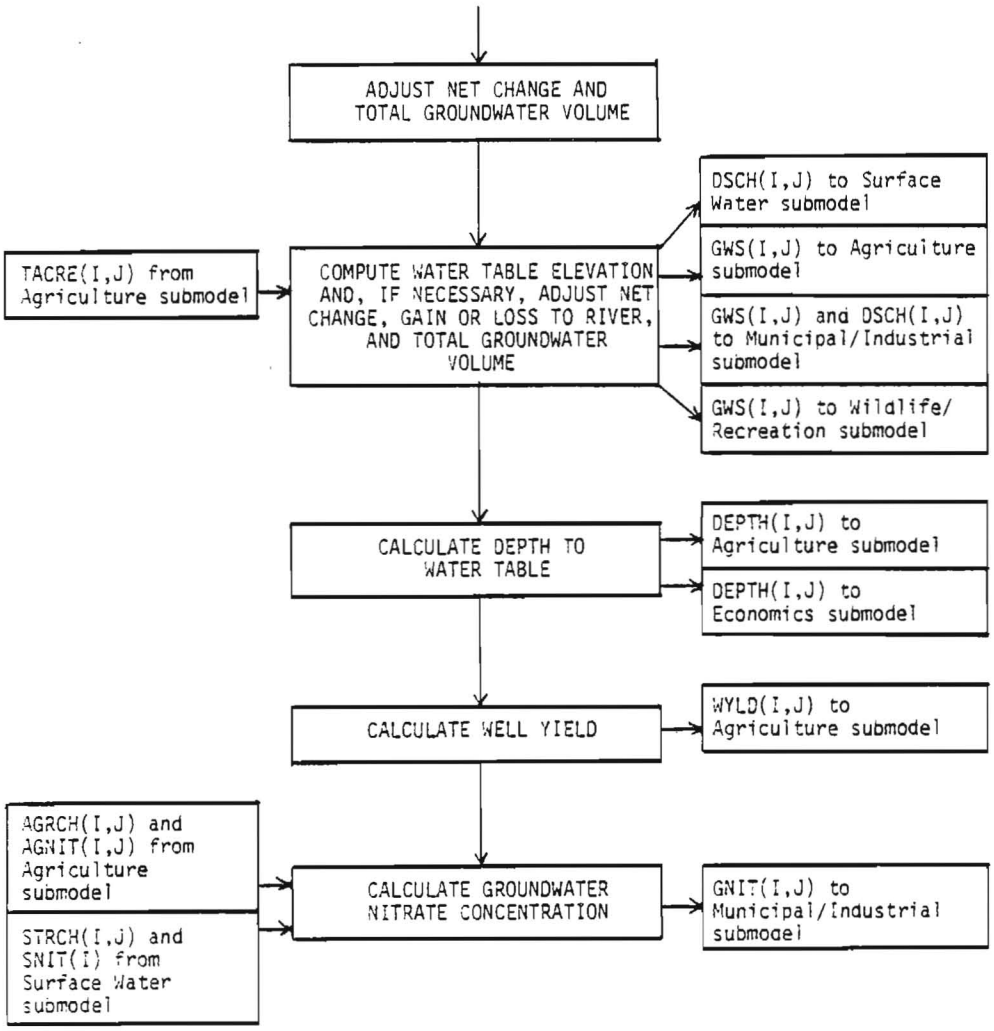


Figure 22. (concluded).

Table 29. Aquifer characteristics used in the Groundwater submodel. Units and variable names are in parentheses.

Reach	Direction	Surface elevation (ft above sea level) (SURFEL(I,J))	Elevation of base of aquifer (ft above sea level) (AQEL(I,J))	Permeability (gpd/ft) (PERM(I,J))	Storage coefficient (inches of water/ inch of soil) (STC(I,J))	Discharge coefficient (dimensionless) (DC(I,J))
1	North	3,360	3,100	250	0.25	0.019
1	South	3,170	2,850	400	0.25	0.010
2	North	3,430	2,875	200	0.25	0.001
2	South	3,325	3,100	250	0.25	0.070
3	North	2,975	2,300	200	0.25	0.002
3	South	2,850	2,300	200	0.25	0.006
4	North	2,590	2,100	275	0.25	0.001
4	South	2,590	2,150	375	0.25	0.004
5	North	2,085	1,850	250	0.25	0.001
5	South	2,175	1,950	750	0.25	0.008
6	North	1,663	1,550	500	0.25	0.003
6	South	1,640	1,450	675	0.25	0.055
7	North	1,485	1,300	325	0.25	0.001
7	South	1,465	1,275	500	0.25	0.004
8	North	1,220	1,100	1,000	0.25	0.055
8	South	1,241	1,100	1,000	0.25	0.001
Big Blue project area		1,655	1,375	750	0.25	0.001

Table 30. Initial conditions used in the Groundwater submodel. Units and variable names are in parentheses.

Reach	Direction	Water table elevation (ft above sea level) (WTELIN(I,J))	Depth to groundwater (ft) (DEPTH(I,J))	Groundwater in storage (million acre-ft) (GWSIN(I,J))	Well yield (gpm) (WYLD(I,J))	Groundwater nitrogen concentration (ppm) (GNIT(I,J))
1	North	3,300	60	18.10	1,000	1
1	South	3,100	70	24.56	1,000	1
2	North	3,375	55	141.50	1,000	1
2	South	3,300	25	9.15	1,000	1
3	North	2,900	75	64.50	1,000	2
3	South	2,800	50	29.25	1,000	2
4	North	2,550	40	81.00	1,000	3
4	South	2,550	40	40.30	1,000	2
5	North	2,050	35	7.30	1,000	6
5	South	2,150	25	18.00	1,000	3
6	North	1,650	13	7.50	1,000	12
6	South	1,600	40	5.18	1,000	5
7	North	1,450	35	17.78	1,000	13
7	South	1,425	40	7.35	1,000	6
8	North	1,200	20	3.20	1,000	3
8	South	1,200	41	27.38	1,000	3
Big Blue project area		1,575	80	90.00	1,000	2

The regression approach used in the Surface Water submodel implicitly incorporates historic levels for these factors, as well as historic exchanges between groundwater and the Platte River; that is, all of these processes were occurring during the period of record (1954-1979) from which data were used to develop the regression coefficients. In projecting future conditions, the Groundwater submodel therefore uses only changes from "historic" pumping and recharge levels to calculate additional changes in groundwater in storage. "Historic" or base levels for the pumping and recharge factors can be set in two ways, depending on the value of the variable ISET. If ISET = 0 (line 12), base values for pumping and recharge are assumed to be set in the data file GROUND.D. If ISET ≠ 0, values of the pumping and recharge factors for each month of the first simulation year are preserved as the base condition.

Preserve Nitrate Loadings (Lines 20-23)

At the start of each month, the total loading of nitrate (TNIT) is calculated (line 22) by multiplying the groundwater volume (GWS(I,J)) in acre-ft times the groundwater nitrate concentration (GNIT(I,J)) in ppm (or mg/l) times a constant (1.23345) to convert to kilograms. Similarly, the volume of water in storage (TWAT) is preserved (line 23) as the groundwater volume in acre-ft times a constant (1233450.) to convert to liters.

Changes in Pumping and Recharge Factors (Lines 24-30)

Changes in evapotranspiration by riparian vegetation (CETR(I,J)), evapotranspiration by subirrigated lands (CETS(I,J)), municipal/industrial pumping (CMIP(I,J)), agricultural pumping (CAGP(I,J)), agricultural recharge (CAGRCH(I,J)), and recharge from storage facilities (CSTRCH(I,J)) for the current month are calculated as the difference between the values for these factors in the current month (computed by the other submodels) and the base or "historic" values.

Net Change in Pumping and Recharge (Lines 31-34)

The cumulative (since the start of the simulation) net change in pumping and recharge (DELTA(I,J)) is calculated by adding the net change from the previous iteration to current changes in recharge and subtracting current changes in pumping.

Gain or Loss to the River (Lines 35-45)

If DELTA(I,J) is positive (i.e., additional recharge exceeds additional pumping), movement of water is assumed to be from groundwater to the river. If DELTA(I,J) is negative (i.e., additional pumping exceeds additional recharge), movement of water is assumed to be from the river to groundwater. In either case, the volume of water moving (DSCH(I,J)) is calculated (line 36) as the net change (DELTA(I,J)) times a discharge coefficient (DC(I,J)). Discharge coefficients (Table 29), which reflect the surface area, storage coefficient, and transmissivity of the aquifer, were determined by workshop participants based on the method of Glover (1963).

If movement of water is into the river, the value of DSCH(I,J) is checked to be sure that it is not larger than the amount of groundwater in storage (line 38). If movement of water is from the river to groundwater, checks are made to be sure that the value of DSCH(I,J) does not exceed river flow. For spatial subunits north of the river, DSCH(I,J) is simply compared to river flow (TFLOWA(I)) (line 41). For spatial subunits south of the river, DSCH(I,J) is compared to river flow less any movement of water to spatial subunits north of the river (lines 42-44).

Big Blue Project Area Exchanges (Lines 46-51)

River reach 6 is also considered to contribute water to the Big Blue project area, which, in the present form of the model, is identified by the subscripts I = 11 and J = 1. Contributions to the Big Blue area are handled in the same manner as any other, with the exception that discharges to reaches

6 North and 6 South are subtracted from the flow in reach 6 (line 49) before checking to see that the discharge to the Big Blue area does not exceed the water available (line 50).

Update Net Change and Groundwater Volume (Lines 53-55)

Recall that a positive value of DELTA(I,J) means that water moves from groundwater to the river. When this occurs, the value of DELTA(I,J) is reduced by the amount of that movement (line 54). Conversely, if the value of DELTA(I,J) is negative, water moves from the river to groundwater. In that event, the value of DSCH(I,J) is negative (line 36) and subtracting the negative value (line 54) adds water to DELTA(I,J). A new value for the amount of groundwater in storage (GWS(I,J)) is then calculated (line 55) by adding the cumulative net change (DELTA(I,J)) to the initial volume of groundwater in storage (GWSIN(I,J)) (Table 30). Again, DELTA(I,J) can be either positive or negative.

Water Table Elevation (Lines 56-65)

A new value for water table elevation is calculated as (line 57):

WTEL(I,J) = WTELIN(I,J) + DELTA(I,J) / TACRE(I,J) / STC(I,J)

where

WTEL(I,J) = new water table elevation (ft above sea level);
WTELIN(I,J) = initial water table elevation (ft above sea level);
DELTA(I,J) = net change in pumping, recharge, and exchanges with the river (acre-ft); and
STC(I,J) = storage coefficient of the aquifer (inches of water/inch of soil).

The new water table elevation is then checked to see that it is not higher than the surface elevation (SURFEL(I,J)) of the spatial subunit (line 59). If it is, excess water is stored in the variable RUNOFF(I,J) (line 60) and the water table elevation is set equal to the surface elevation (line 61). The

value of RUNOFF(I,J) is then subtracted from the cumulative net change (line 62), added to the exchange with the river (line 63), and subtracted from the volume of groundwater in storage (line 64).

Depth to Water Table (Lines 66-67)

Depth to the water table is calculated simply as the surface elevation minus the water table elevation.

Well Yield (Lines 68-70)

Well yield is calculated from an empirical relationship suggested by workshop participants. The saturated thickness in feet (THIK(I,J)) is first computed (line 69) as the difference between the water table elevation and the elevation of the base of the aquifer (AQEL(I,J)) (Table 30). Well yield is then calculated as:

WYLD(I,J) = THIK(I,J) * PERM(I,J) / WC

where

WYLD(I,J) = well yield (gpm);
THIK(I,J) = saturated thickness (ft);
PERM(I,J) = permeability of the aquifer (gpd/ft^2); and
WC = an empirical constant (100).

Nitrogen Mass Balance (Lines 71-87).

The total amount of nitrogen in storage (TNIT) is reduced by a rate representing denitrification (CNIT, presently set at 1.).

Withdrawals from groundwater are assumed not to influence the nitrate concentration. Therefore, only additions are considered in calculating a new concentration. The nitrate loading from agriculture is calculated as the agricultural recharge (AGRCH(I,J)) in acre-ft, times the nitrate concentration

in agricultural recharge (AGNIT(I,J)) in mg/l, times a constant to convert to kilograms (1.23345) and added to the nitrate loading (TNIT) from the previous iteration (line 75). Similarly, the volume of water remaining from the previous iteration (TWAT) is incremented by the amount of agricultural recharge (AGRCH(I,J)) and storage recharge (STRCH(I,J)) times a constant (123345.) to convert to liters (lines 76-77). If movement of water is from the river to groundwater, TNIT and TWAT are also incremented by that volume of water and its associated nitrate concentration (SNIT(I)) (lines 78-81). Note that the absolute value of DSCH(I,J) is used since movement of water from the river to groundwater implies that DSCH(I,J) is negative. If the volume of water (TWAT) is zero, then the new nitrate concentration (GNIT(I,J)) is set to zero (lines 83-85). Otherwise, the new concentration is calculated as the loading divided by the water volume times a constant (1×10^6) to convert to mg/l (or ppm).

ECONOMICS SUBMODEL

The general structure of the Economics submodel is diagrammed in Figure 23. Line number notations in the following narrative description refer to the FORTRAN code file ECON.S in Appendix G. Variable definitions, data, and common files are also listed in Appendix G. Unless otherwise noted, the subscript I refers to particular reaches of the river, J refers to the direction (North or South) from the river, IC denotes a crop type, IS refers to a riparian habitat type, and IW denotes a water-use type.

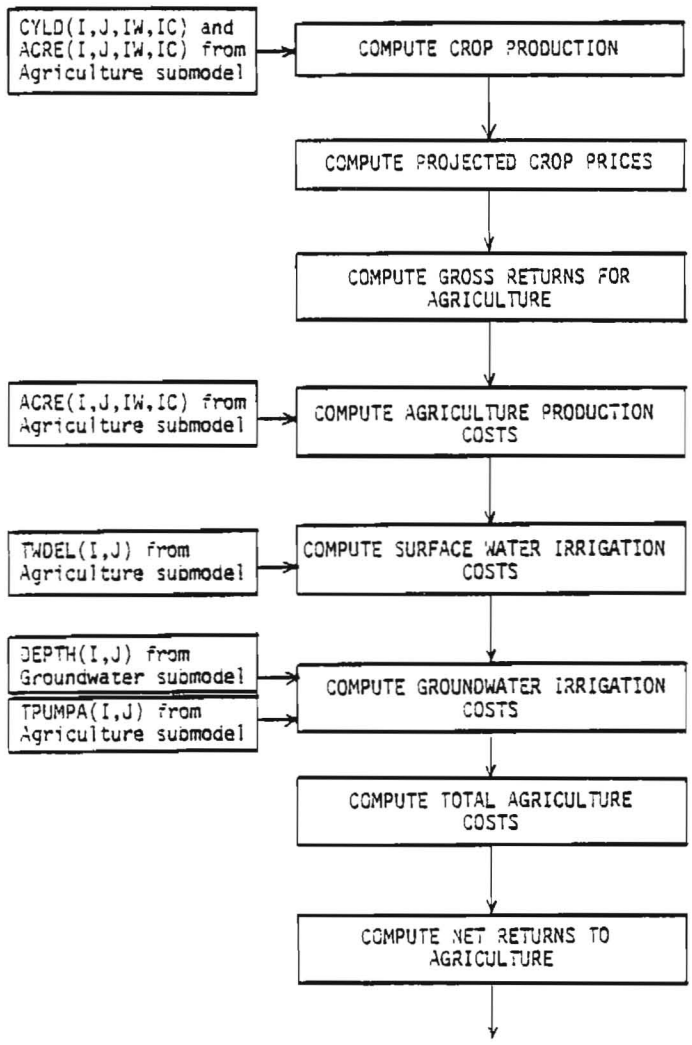


Figure 23. General structure of the Economics submodel.

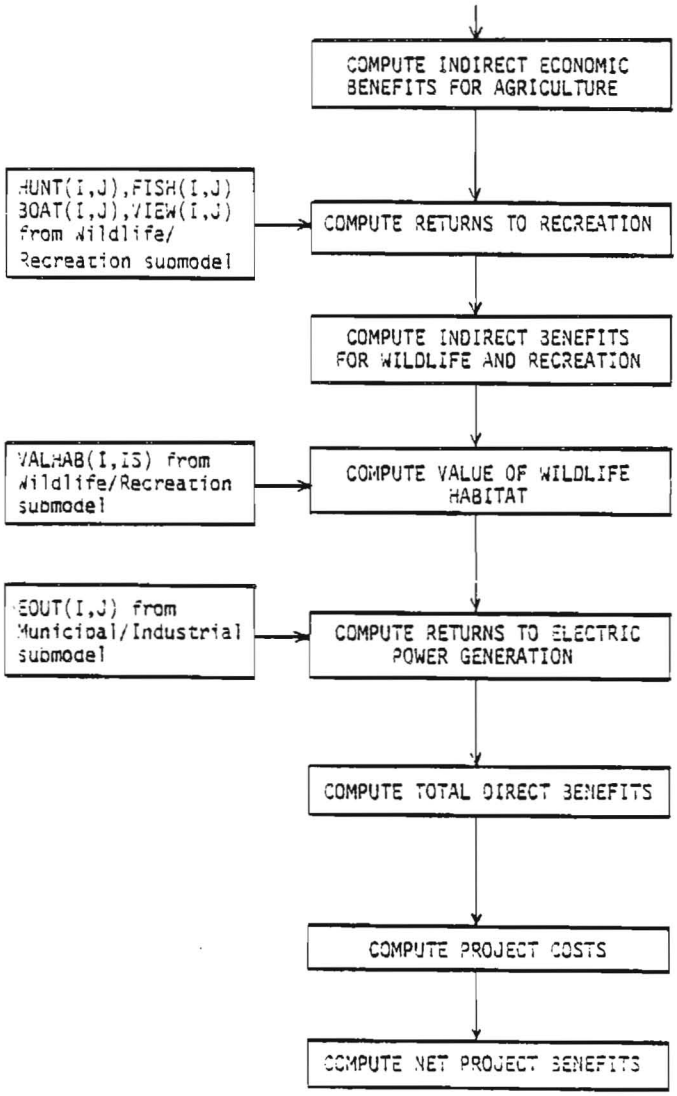


Figure 23. (concluded).

Initialization (Lines 7-28)

The first section of code initializes variables used by the Economics submodel. TYEAR is set equal to the number of the current simulation year (IYEAR) (line 7). The price per megawatt-hour of electricity (PRWATT) is set equal to a base price ($98.80/megawatt-hour) plus an increase of $0.06 annually. Crop prices ($/bushel or $/ton) for alfalfa (PRCROP(1)), corn (PRCROP(2)), milo (PRCROP(3)), soybeans (PRCROP(4)), and wheat (PRCROP(5)) are determined by linear interpolation from Figure 24 (Nebraska Natural Resources Commission 1981) (lines 9-13). TYEAR is the independent variable in each case. ZTIME is the X-array used in all five SLP functions. The Y-arrays are ALTIME, COTIME, XMTIME, SOTIME, and WHTIME, respectively. A variety of variables are set to zero and major loops are begun (lines 14-28).

Agricultural Costs and Returns (Lines 29-48)

Developments being considered in the Platte River study are primarily related to crop irrigation needs, and the most obvious economic implications of development alternatives are in the agriculture sector. Net returns to agriculture are equal to gross returns minus total costs. Gross returns are the product of agricultural crop production and crop prices, and total costs are the sum of field production costs and other irrigation costs.

Crop production (lines 29-30). Yields per acre (CYLD(I,J,IW,IC)) and the number of acres of each crop grown in each spatial subunit for any simulated year (ACRE(I,J,IW,IC)) are provided by the Agriculture submodel. Total production of each crop for each spatial subunit and time period (CPROD(I,J,IC)) is the product of yields per acre and acres in production.

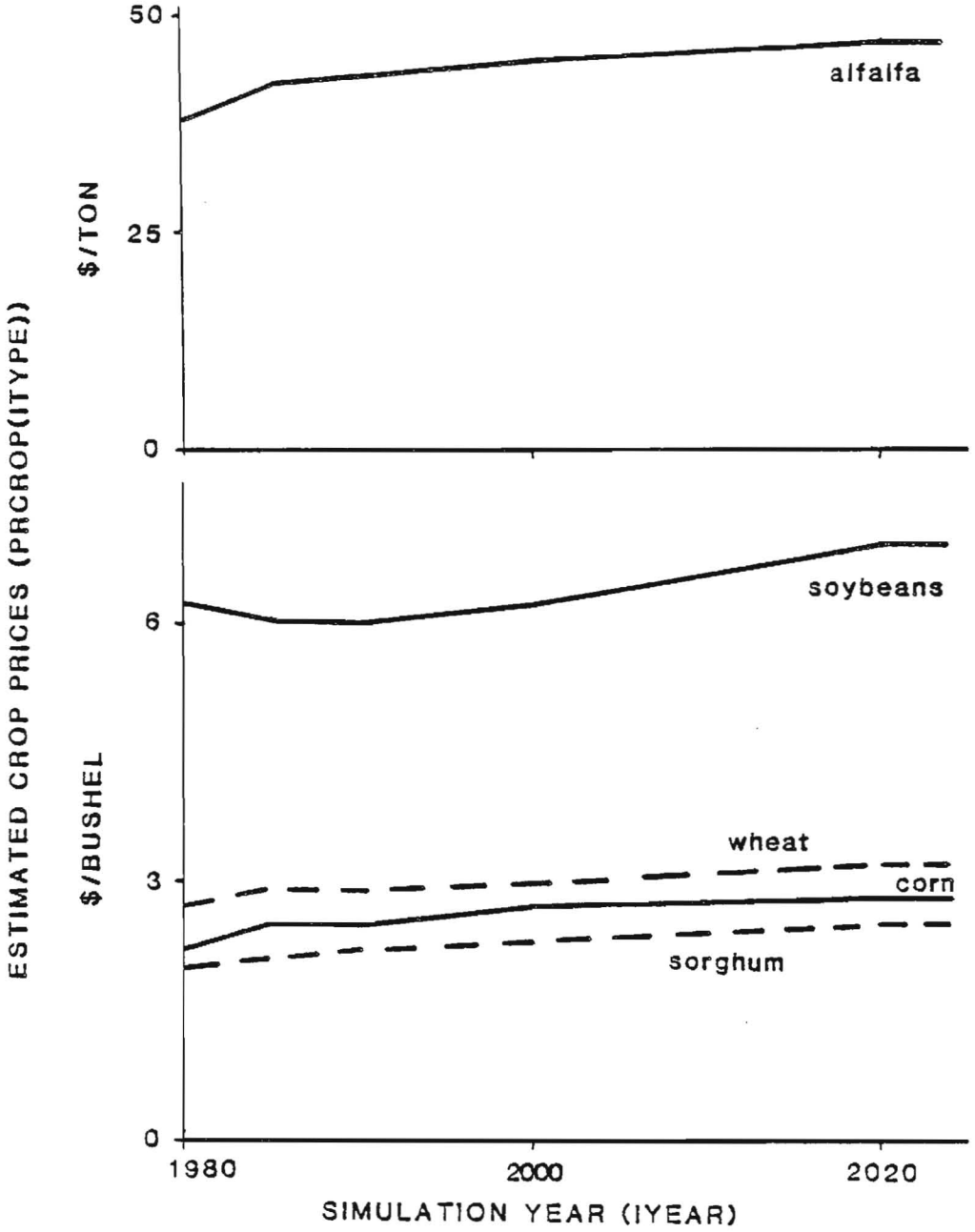


Figure 24. Trends in crop prices. Relationships are based on data from the High Plains Study (Nebraska Natural Resources Commission 1981).

Field production costs (lines 32-34). Field production costs (exclusive of water delivery costs) depend on both crop type and water-use type. For example, corn production is more costly than alfalfa, and it is less costly to produce alfalfa on subirrigated land than on surface-irrigated land (Table 31). Field production costs (COSTPR(I,J,IW,IC)) are computed by multiplying the field production cost/acre (PRPR(IW,IC)) times the number of acres. These are summed over water-use types and crops to obtain the total agricultural field production costs for each spatial subunit (TCOSTP(I,J)).

Gross returns (line 36). Crop production is multiplied by crop price and summed across all five crops to produce gross returns to agriculture for each spatial subunit (AGGBEN(I,J)).

Table 31. Field production costs ($/acre) for each crop grown in each water-use type.

Crop type (IC)	Water-use type (IW)			
	Surface water-irrigated (1)	Groundwater-irrigated (2)	Dryland (3)	Sub-irrigated (4)
Alfalfa (1)	121	121	8	117
Corn (2)	208	208	117	N/A
Milo (3)	127	127	103	N/A
Soybeans (4)	79	79	69	N/A
Wheat (5)	73	73	77	N/A
Native hay (6)	0	0	0	0

Water delivery costs (lines 38-44). In addition to the field production costs, other costs are incurred in delivering water to the field. In the case of surface irrigation, the additional cost for each spatial subunit (COSTSW(I,J)) is calculated as the volume of water delivered (TWDEL(I,J)) times a price per unit volume (PRSW(I,J)) (lines 40-41). The amount of water delivered to each spatial subunit is provided by the Agriculture submodel, and the price per acre foot is assumed to be $15.00 for all spatial subunits. This price can be changed in the model, and could be used to reflect differences in the cost of delivering surface water to different spatial subunits.

Where groundwater is used, pumping costs are a function of the depth to groundwater (from the Groundwater submodel) and the amount of groundwater pumped (from the Agriculture submodel), as well as the average fixed cost per acre-ft of water used and the variable cost of pumping water per foot of lift (lines 38-39):

```
COSTPU(I,J) = (DAFL(I,J) * DEPTH(I,J) + FPUMP) * TPUMPA(I,J)
```

where

```
COSTPU(I,J) = total cost of pumping ($);
DAFL(I,J)   = variable cost of pumping ($/acre-ft/ft of lift);
DEPTH(I,J)  = depth to groundwater (ft);
FPUMP       = fixed cost of groundwater irrigation ($/acre-ft); and
TPUMPA(I,J) = groundwater used for irrigation (acre-ft).
```

Total costs (lines 42-44). Field production costs for all crops, surface irrigation costs, and groundwater irrigation costs are summed by spatial subunit to produce total agricultural costs for each spatial subunit (TCOSTA(I,J)).

Net returns lines 45-46). Net returns to agriculture in each spatial subunit (AGNBEN(I,J)) are calculated by subtracting total costs from total gross returns.

Indirect benefits (lines 47-48). In addition to direct benefits, indirect benefits can accrue as a result of increased economic activity generated by a development project. These indirect benefits to agriculture (AGMBEN(I,J)) are estimated by applying a multiplier (AMULT, currently set at 2.55) to gross returns.

Recreation Benefits (Lines 49-55)

Proposed projects could affect recreation through changes in wildlife habitat and other resource characteristics. Recreational use-days for four activities (hunting (HUNT(I,J)), fishing (FISH(I,J)), boating (BOAT(I,J)), and crane viewing (VIEW(I,J)) are provided by the Wildlife/Recreation submodel. Direct benefits to recreation in each spatial subunit (RECBEN(I,J)) are a product of recreational use-days and a price per use-day (PRHUNT, PRFISH, PRBOAT, and PRVIEW, respectively), currently set at $3.00 for each activity. Indirect benefits (REMBEN(I,J)) are the product of direct benefits and a multiplier (RMULT, currently set at 2.7).

Total Benefits (Lines 57-68)

Total direct net returns to agriculture (TANBEN), total direct and indirect gross returns to agriculture (TAMBEN), total direct benefits to recreation (TRCBEN), total direct and indirect benefits to recreation (TRMBEN), total returns to electric power generation (THYBEN), and total direct gross returns to agriculture (TAGBEN) are obtained by summing across all spatial subunits. Returns to electric power generation are calculated as the product of the amount of power generated in megawatt-hours (from the Municipal/Industrial submodel) and the price per megawatt-hour. WATTHR is obtained by summing EOUT(I,J). Note that the subscript J in EOUT(I,J) refers to hydroelectric (J = 1) and thermal (J = 2) plants.

If returns to electric power generation are to be comparable with net returns to agriculture, the price per megawatt-hour should represent a net

price, after power production costs have been removed. It is assumed, however, that the price currently used in the model is a total price, and that returns to electric power generation are therefore gross returns.

Wildlife Habitat Values (Lines 71-79)

The Wildlife/Recreation submodel provides an estimate of the dollar value (VALHAB(I,IS)) for each of four wildlife habitat types (sand bar, meadow, shrub, and tree). These values are simply summed to obtain the value for each reach (TVHAB(I)) and for the total study area (TVH).

Project Costs (Line 81)

Project costs include the construction, engineering, contingency, legal, and administrative costs of each project. These costs are amortized over the life of the project by using the following formula:

```
COSTK = CAPINV * (RINT * (1 + RINT) ** AMYR) / ((1 + RINT) ** AMYR-1)
```

where

COSTK = annual cost of capital ($);
RINT = real rate of interest (assumed 5%); and
AMYR = number of amoritization years (assumed 50).

These amortized costs should be added to annual operation, maintenance, and replacement charges to provide an estimate of total annual project costs. Some of these costs were very crudely estimated by participants at the workshop, but have not yet been activated in the simulation model (the CAPINV variable is currently set at zero, as are operation, maintenance and replacement costs). These costs have not yet been used because of uncertainty about what is included in the costs of some projects and lack of a clear cut method to relate projects to spatial subunits.

Project Costs and Benefits (Lines 83-87)

Total project costs are subtracted from the sum of net benefits from agriculture, wildlife/recreation, and electric power generation to provide an estimate of the net direct benefit (TB(1)) each project would have on the total study are (line 85). An estimate of the impact of projects on gross regional product (TB(2)) is made by adding the direct and indirect (multiplier times revenue) values for agriculture and recreation to the direct revenues from electric power production (line 86).

Employment benefits (line 87). Benefits to people from various projects can be measured in terms of jobs as well as dollars. Employment in agriculture (EMPLOY) is calculated by assuming each million dollars of gross revenue in agriculture represents 12 jobs. Hence, the variable RJOBS in line 87 of the code is set at 12.

REFERENCES

Glover, R. E. 1963. Return flows from an irrigated strip. Appendix A7, in Symposium on transient groundwater hydraulics. Civil Engineering Section, Colorado State University, Ft. Collins, CO.

Nebraska Natural Resources Commission. 1981. Summary of the Nebraska research for the six state high plains Ogallala Aquifer study. Nebraska Natural Resources Commission, Lincoln, NE.

U.S. Fish and Wildlife Service. 1975. Platte River Basin, Nebraska - level B study. Final draft technical paper.

APPENDICES

APPENDIX A. SYSTEM MODEL FILES

```
SYSTEM MODEL VARIABLE DEFINITIONS
=================================

AG=SUBROUTINE CONTAINING THE AGRICULTURE SUBMODEL
   (FILE AG.S)
CMREAD=SUBROUTINE THAT READS THE SIMCON COMMON BLOCK FROM
       THE FILE SPECIFIED IN THE PARAMETER STRING
DFAULT=SUBROUTINE THAT ASSIGNS A LOGICAL I/O UNIT NUMBER
       TO AN MTS FILE
ECON=SUBROUTINE CONTAINING THE ECONOMICS SUBMODEL
     (FILE ECON.S)
GWAT=SUBROUTINE CONTAINING THE GROUNDWATER SUBMODEL
     (FILE GROUND.S)
IMONTH=THE NUMBER OF THE CURRENT SIMULATION MONTH
       (1 = JANUARY, 12 = DECEMBER)
INT=FORTRAN FUNCTION THAT RETURNS THE INTEGER PORTION
    OF A REAL NUMBER
ITIME=THE NUMBER OF THE CURRENT ITERATION
IYEAR=THE NUMBER OF THE CURRENT SIMULATION YEAR
MOD=FORTRAN FUNCTION THAT RETURNS THE REMAINDER RESULTING
    FROM DIVIDING THE FIRST ARGUMENT BY THE SECOND
    ARGUMENT
RIVER=SUBROUTINE CONTAINING THE SURFACE WATER SUBMODEL
      (FILE RIVER.S)
UINIT=SIMCON INITIALIZATION SUBROUTINE.  EXECUTED ONCE
      AT THE START OF EACH SIMULATION
UMODEL=SIMCON SUBROUTINE CONTAINING A USER-DEFINED
       MODEL.  EXECUTED ONCE FOR EACH SIMULATION
       ITERATION
WILD=SUBROUTINE CONTAINING THE WILDLIFE/RECREATION SUBMODEL
```

```
:     31          (FILE WR.S)
:     32     XMIND=SUBROUTINE CONTAINING THE MUNICIPAL/INDUSTRIAL SUBMODEL
:     33          (FILE MIND.S)
```

```
C.....SUBROUTINE TO READ DATA AND COMMON BLOCK.
C.....EXECUTED ONLY ONCE AT START OF EACH
C.....SIMULATION.
      SUBROUTINE UINIT
      CALL DFAULT('1=PLATTE.D ')
      CALL DFAULT('15=RCOEF ')
      CALL DFAULT('16=RDATA ')
      CALL CMREAD('PLATTE.C ')
      RETURN
      END
C.....SUBROUTINE CONTAINING USER-DEFINED MODEL.
C.....EXECUTED ONCE FOR EACH ITERATION.
      SUBROUTINE UMODEL(ITIME)
C.....CONCATENATE COMMON BLOCK
$CONTINUE WITH PLATTE.C RETURN
C.....CALCULATE YEAR AND MONTH (1 THROUGH 12)
      IYEAR=INT((ITIME-1)/12.)+1
      IMONTH=MOD((ITIME-1),12)+1
C.....CALL SUBMODELS IN SEQUENCE
      CALL RIVER(ITIME)
      CALL AG
      CALL XMIND
      CALL WILD(ITIME)
      CALL GWAT
      IF(IMONTH.NE.12) GO TO 1
      CALL ECON
    1 CONTINUE
      RETURN
      END
C.....CONCATENATE CODE FOR SUBMODELS
```

```
:    31    $CONTINUE WITH RIVER.S RETURN
:    32    $CONTINUE WITH AG.S RETURN
:    33    $CONTINUE WITH MIND.S RETURN
:    34    $CONTINUE WITH WR.SOURCE RETURN
:    35    $CONTINUE WITH GROUND.S RETURN
:    36    $CONTINUE WITH ECON.S RETURN
```

```
:      1          COMMON IMONTH,IYEAR
:      2     $CONTINUE WITH RIVER.C RETURN
:      3     $CONTINUE WITH AG.C RETURN
:      4     $CONTINUE WITH MIND.C RETURN
:      5     $CONTINUE WITH WR.COMMON RETURN
:      6     $CONTINUE WITH GROUND.C RETURN
:      7     $CONTINUE WITH ECON.C RETURN
```

```
$CONTINUE WITH RIVER.D RETURN
$CONTINUE WITH AG.D RETURN
$CONTINUE WITH MIND.D RETURN
$CONTINUE WITH WR.DATA RETURN
$CONTINUE WITH GROUND.D RETURN
$CONTINUE WITH ECON.D RETURN
SAVE FILE=-S
MACRO PRBEND
S IRES(5,1)=1
S STOMAX(5,1)=352000.
S SURFAC(5,1)=7000.
S STRCH(5,1)=2000.
S IPRIOR(5)=1
S ADDDIV(7,1...8)=29500. 13900. 4600. 2200. 1800. 200. 0. 0.
S ADDDIV(7,9...12)=16100. 43100. 47000. 51600.
S ADDRET(8,1...6)=1530. 1120. 1070. 350. 510. 1530.
S ADDRET(8,7...12)=2350. 6880. 5110. 5670. 2240. 1790.
S ADDRET(9,1...6)=8560. 6860. 6770. 5970. 5800. 5580.
S ADDRET(9,7...12)=6730. 8090. 9010. 10800. 10140. 9500.
S TCHANG(5,1,1)=68.6
S TCHANG(5,1,2)=-56.
S TCHANG(5,1,3)=-12.6

MACRO SELLWAT
S ADDDIV(2,ALL)=25000.
S ADDRET(2,ALL)=0.0

MACRO BIG MAC
S ISFT=1
S IREL(ALL)=2 1 2
```

```
:    31    S FLOTAR(5,5)=226000.
:    32    S DPCWU(ALL,ALL)=-.0004
:    33    AT 10 'S DPCWU(ALL,ALL)=0.0'
:    34    S WMEAN=.5
:    35    S WSTD=.1
:    36
:    37    MACRO LM
:    38    S IRES(4,2)=1
:    39    S NOAG(4,2)=1
:    40    S STOMAX(4,2)=300000.
:    41    S IPRIOR(4)=1
:    42    S ADDDIV(6,1...5)=25000.
:    43    S ADDDIV(6,6...9)=0.0
:    44    S ADDDIV(6,10...12)=25000.
:    45    S ADDRET(6,ALL)=0.0
:    46    S SURFAC(4,2)=9000.
:    47    S ISFT=1
:    48    S IREL(ALL)=4 2 8
:    49    S ADDDIV(9,1...5)=0.
:    50    S ADDDIV(9,6...9)=50000.
:    51    S AGFAC(6,1)=.5
:    52    S AGFAC(6,2)=.5
:    53    S STRCH(4,2)=2000.
:    54
:    55    MACRO MINTAR
:    56    S FLOTAR(ALL,ALL)=0.
:    57    S FLOTAR(4,1...6)=500. 750. 750. 1100. 1100. 300.
:    58    S FLOTAR(4,7...12)=300. 300. 750. 1100. 1100. 500.
:    59    S FLOTAR(5,1...6)=500. 750. 750. 1100. 1100. 300.
:    60    S FLOTAR(5,7...12)=300. 300. 750. 1100. 1100. 500.
```

```
:    61
:    62    MACRO AVETAR
:    63    S FLOTAR(ALL,ALL)=0.
:    64    S FLOTAR(4,1...6)=500. 500. 1100. 1100. 1100. 500.
:    65    S FLOTAR(4,7...12)=500. 500. 1100. 1100. 1100. 500.
:    66    S FLOTAR(5,1...6)=500. 500. 1100. 1100. 1100. 500.
:    67    S FLOTAR(5,7...12)=500. 500. 1100. 1100. 1100. 500.
:    68
:    69    MACRO PBTV
:    70    S IRES(5,1)=1
:    71    S STOMAX(5,1)=512000.
:    72    S IPRIOR(5)=1
:    73    S ADDDIV(7,1...8)=51920. 24464. 8096. 3872. 3168. 0. 0. 0.
:    74    S ADDDIV(7,9...12)=28336. 75856. 82720. 90816.
:    75    S ADDDIV(8,1...6)=2693. 1971. 1883. 616. 898. 2693.
:    76    S ADDDIV(8,7...12)=4136. 12109. 8994. 9979. 3942. 3150.
:    77    S ADDDIV(9,1...6)=15066. 12074. 11915. 10507. 10208. 9821.
:    78    S ADDDIV(9,7...12)=11845. 14238. 15857. 19008. 17846. 16720.
:    79    S SURFAC(5,1)=12320.
:    80    S TCHANG(5,1,1)=123.6
:    81    S TCHANG(5,1,2)=-111.
:    82    S TCHANG(5,1,3)=-12.6
:    83    S STRCH(5,1)=2000.
:    84
:    85    MACRO TWINPLATTE
:    86    S IRES(1,2)=1
:    87    S STOMAX(1,2)=165000.
:    88    S IPRIOR(1)=1
:    89    S ADDDIV(3,1...5)=30000.
:    90    S ADDDIV(3,10...12)=30000.
```

```
:    91     S ADDRET(3,1...5)=15000.
:    92     S ADDRET(3,10...12)=15000.
:    93     S SURFAC(1,2)=5600.
:    94     S TCHANG(1,2,1)=55.
:    95     S TCHANG(1,2,2)=-55.
:    96     S STRCH(1,2)=2000.
:    97
:    98     MACRO TWINVALLEY
:    99     S IRES(5,1)=1
:   100     S STOMAX(5,1)=160000.
:   101     S IPRIOR(5)=1
:   102     S ADDDIV(7,1...8)=23600. 11120. 3680. 1760. 1440. 0. 0. 0.
:   103     S ADDDIV(7,9...12)=12880. 34480. 37600. 41280.
:   104     S ADDDIV(8,1...6)=1224. 896. 856. 280. 408. 1224.
:   105     S ADDDIV(8,7...12)=1880. 5504. 4088. 4536. 1792. 1432.
:   106     S ADDDIV(9,1...6)=4688. 5488. 5416. 4776. 4640. 4464.
:   107     S ADDDIV(9,7...12)=5384. 6472. 7208. 8640. 8122. 7600.
:   108     S SURFAC(5,1)=5600.
:   109     S TCHANG(5,1,1)=55.
:   110     S TCHANG(5,1,2)=-55.
:   111     S STRCH(5,1)=2000.
:   112
:   113     MACRO TAR
:   114     S TARFLO(ALL,ALL)=0.
:   115     S TARFLO(5,1)=400.
:   116     S TARFLO(5,2...5)=1100.
:   117     S TARFLO(5,6...9)=400.
:   118     S TARFLO(5,10)=1100.
:   119     S TARFLO(5,11...12)=400.
:   120
```

```
:   121     MACRO JVI
:   122     S ITRMNT=1
:   123     S ISFT=1
:   124     S ADDDIV(8,1...5)=11250.
:   125     S ADDDIV(8,10...12)=11250.
:   126
:   127     MACRO JVII
:   128     S ITRMNT=1
:   129     S ADDDIV(8,1...5)=11250.
:   130     S ADDDIV(8,10...12)=11250.
:   131     S TCHANG(5,2,1)=-99.5
:   132     S TCHANG(5,2,2)=99.5
:   133     S IPRIOR(4)=1
:   134     S IPRIOR(5)=2
:   135
:   136     MACRO START
:   137     RESET FILE=-S
:   138     AT P=1 DELETE
:   139     AT LIST
:   140
```

APPENDIX B. SURFACE WATER SUBMODEL FILES

```
SURFACE WATER SUBMODEL VARIABLE DEFINITIONS
===========================================

VARIABLES PRECEDED BY AN * ARE CALCULATED BY
     OTHER SUBMODELS

UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:
     I=RIVER REACH
     J=DIRECTION FROM RIVER
     IMONTH OR M=MONTH OF YEAR

  I=1,11 REFERS TO REACHES IN REGRESSION EQUATION
     I=1=KEYSTONE TO SUTHERLAND
     I=2=SUTHERLAND TO NORTH PLATTE
     I=3=JULESBURG TO NORTH PLATTE
     I=4=NORTH PLATTE TO BRADY
     I=5=BRADY TO COZAD
     I=6=COZAD TO OVERTON
     I=7=OVERTON TO ODESSA
     I=8=ODESSA TO GRAND ISLAND
     I=9=GRAND ISLAND TO DUNCAN
     I=10=DUNCAN TO NORTH BEND
     I=11=NORTH BEND TO LOUISVILLE

  I=1,8 REFERS TO REACHES IN THE PRFF SIMCON MODEL
     I=1=JULESBURG TO NORTH PLATTE
     I=2=LEWELLEN TO NORTH PLATTE
     I=3=NORTH PLATTE TO BRADY
     I=4=BRADY TO OVERTON
     I=5=OVERTON TO GRAND ISLAND
```

```
:     31          I=6=GRAND ISLAND TO DUNCAN
:     32          I=7=DUNCAN TO NORTH BEND
:     33          I=8=NORTH BEND TO LOUISVILLE
:     34
:     35          J=1=NORTH OF RIVER
:     36          J=2=SOUTH OF RIVER
:     37
:     38          IMONTH OR M=1...12=JAN...DEC
:     39
:     40     A(I,M)=REGRESSION COEFFICIENT FOR FLOW AT THE TOP OF
:     41            REACH I
:     42     AADIV(I)=ACTUAL ADDITIONAL DIVERSIONS FOR NEW PROJECTS
:     43              (ACRE-FT)--SEE RADIV(I)
:     44     ACFLO(I,K)=URBAN (K=1) AND AGRICULTURAL (K=2) ACRES FLOODED
:     45     ADDDIV(I,IMONTH)=REQUESTED DIVERSION FOR NEW PROJECT IN
:     46                      REACH I (ACRE-FT)
:     47     ADDRET(I,IMONTH)=ADDITIONAL RETURN FLOW FROM NEW
:     48                      PROJECTS (ACRE-FT)
:     49     ADIV(I,IMONTH)=ACTUAL DIVERSION FOR NEW PROJECT (ACRE-FT)
:     50     AGFAC(I,J,IMONTH)=FACTOR FOR PARTITIONING DIVERSIONS TO
:     51                       NORTH AND SOUTH SIDE OF REACH
:     52     * AGUSE(I,J)=AGRICULTURAL USE OF WATER (ACRE-FT) <FROM
:     53              AGRICULTURAL SUBMODEL>
:     54     AGWAT(I,J)=WATER AVAILABLE FOR AGRICULTURAL USE (ACRE-FT)
:     55     AG45(I)=FACTOR FOR PARTITIONING DIVERSION IN MODEL REACH 3
:     56             TO AGRICULTURAL USE IN REACHES 4 AND 5
:     57     B(I,M)=REGRESSION COEFICIENT FOR GAUGED DIVERSIONS
:     58     BFLOWA(I)=FLOW AT THE BOTTOM OF A REACH (ACRE-FT)
:     59     BFLOWC(I)=FLOW AT THE BOTTOM OF A REACH (CFS)
:     60     BREACH(I)=ARRAY TO CONVERT FLOWS AT THE BOTTOM OF A
```

```
:     61                REGRESSION REACH TO FLOWS AT THE BOTTOM OF THE
:     62                CORRESPONDING MODEL REACH
:     63      C(I,M)=REGRESSION COEFFICIENT FOR GAUGED INFLOWS
:     64      DIV(I,IMONTH)=CALCULATED DIVERSION FOR A REACH (ACRE-FT)
:     65      * DSCH(MREACH(I),J)=GAIN OR LOSS TO THE RIVER IN CURRENT
:     66                          MONTH (ACRE-FT). IF DSCH IS NEGATIVE,
:     67                          MOVEMENT IS FROM THE RIVER TO GROUNDWATER.
:     68                          IF POSITIVE, MOVEMENT IS FROM GROUNDWATER
:     69                          TO THE RIVER.
:     70                          <FROM GROUNDWATER SUBMODEL>
:     71      D1(I)=FLOW AT THE TOP OF REACH I (ACRE-FT)
:     72      D2(I)=FLOW AT THE BOTTOM OF REACH I (ACRE-FT)
:     73      FK(M)=AVERAGE FLOW AT KEYSTONE IN MONTH M (ACRE-FT)
:     74      FLOMAX=MAXIMUM DAILY FLOW AT GRAND ISLAND (CFS)
:     75      FLOTAR(MREACH(I),IMONTH)=FLOW TARGET FOR INSTREAM
:     76                               FLOWS (ACRE-FT)
:     77      FLOWJ(IMONTH)=INPUT FLOW AT JULESBURG (ACRE-FT)
:     78      FLOWK(IMONTH)=INPUT FLOW AT KEYSTONE (ACRE-FT)
:     79      FJ(M)=AVERAGE FLOW AT JULESBURG IN MONTH M (ACRE-FT)
:     80      * GNIT(I,J)=NITRATE CONCENTRATION IN GROUNDWATER (PPM)
:     81                <FROM GROUNDWATER SUBMODEL>
:     82      GWNIT1(I)=NITRATE INPUT FROM GROUNDWATER FROM NORTH
:     83                SIDE OF RIVER (PPM*ACRE-FT)
:     84      GWNIT2(I)=NITRATE INPUT FROM GROUNDWATER FROM SOUTH
:     85                SIDE OF RIVER (PPM*ACRE-FT)
:     86      HDIV(I)=DIVERSIONS FOR HISTORICAL (I.E., EXISTING)
:     87               APPROPRIATIONS (ACRE-FT)
:     88      HLDIV(I)=LAST MONTHS DIVERSIONS FOR HISTORICAL
:     89               APPROPRIATIONS (ACRE-FT)
:     90      HRETMI(I,IMONTH)=HISTORICAL M&I RETURN FLOW (ACRE-FT)
```

```
ICOUNT=LOOP COUNTER FOR CALCULATING DECREASES IN
       UPSTREAM DIVERSIONS
INDEX=INDEX OF ALLOCATION PRIORITIES FOR NEW PROJECTS
      IN REVERSE ORDER
IPRIOR(I)=ALLOCATION PRIORITY FOR NEW PROJECT IN REACH I
IRES(I,J)=1 IF A NEW PROJECT IS LOCATED IN REACH I
IREL(K)=LOCATION OF RESERVOIR FOR SATISFYING INSTREAM
        FLOWS. IREL(1)=MODEL REACH, IREL(2)=NORTH OR
        SOUTH OF RIVER, IREL(3)=REGRESSION REACH FOR RELEASE
ISFT=INSTREAM FLOW TARGET SWITCH (1=INSTREAM FLOWS ARE
     CONSIDERED IN THIS MODEL RUN)
MREACH(I)=ARRAY TO CONVERT REGRESSION REACH I TO
          PRFF SIMCON MODEL REACH
NOAG(I,J)=1 IF NO AGRICULTURAL USE OF STORED WATER
          IN REACH I
NOFLOW(K)=1 IF 2 OR MORE CONSECUTIVE NO FLOW DAYS
          AT GRAND ISLAND IN JULY (K=1) AND AUGUST (K=2)
QMAX(I)=MAXIMUM DAILY FLOW (CFS)
RADIV(I)=REQUESTED ADDITIONAL DIVERSION FOR NEW
         PROJECT (ACRE-FT)
RELS=WATER RELEASED TO MEET INSTREAM FLOWS (ACRE-FT)
RELWAT=WATER POTENTIALLY AVAILABLE FOR RELEASE TO
       MEET INSTREAM FLOWS (ACRE-FT)
RET(I,IMONTH)=CALCULATED RETURN FLOWS TO REACH I (ACRE-FT)
* RETMI(MREACH(I))=CURRENT M&I RETURN FLOW (ACRE-FT)
                  <FROM M&I SUBMODEL>
RFAC=FACTOR TO PARTITION ADDITIONAL INPUTS FROM GROUNDWATER
     FROM MODEL REACHES TO REGRESSION REACHES
RI(I,M)=AVERAGE GAUGED INFLOWS TO REACH I IN MONTH M (ACRE-FT)

RNO3D1(I)=NITRATE CONCENTRATIONS AT THE TOP OF REACH I (PPM)
```

```
:   121     RNO3IC(K)=NITRATE CONCENTRATIONS AT JULESBURG (K=1)
:   122               AND KEYSTONE (K=2)
:   123     RO(I,M)=AVERAGE GAUGED OUTFLOWS FROM REACH I IN MONTH M
:   124             (ACRE-FT)
:   125     RTWAT=TOTAL AMOUNT OF WATER FOR CALCULATING NITRATE
:   126           CONCENTRATION (ACRE-FT)
:   127     SCOUR=NUMBER OF DAYS IN YEAR WITH FLOW AT OVERTON>=3800 CFS
:   128     SNIT(I)=NITRATE CONCENTRATION AT THE BOTTOM OF REACH I (PPM)
:   129     STOMAX(I,J)=MAXIMUM STORAGE FOR NEW PROJECT (ACRE-FT)
:   130     SWIDTH=RIVER WIDTH AT GRAND ISLAND (FT)
:   131     STOUSE(I,J)=USE OF WATER STORED IN NEW PROJECT IN REACH I
:   132                 (ACRE-FT)
:   133     STOWAT(I,J)=AMOUNT OF WATER STORED IN NEW PROJECT IN REACH I
:   134                 (ACRE-FT)
:   135     SURFAC(I,J)=SURFACE ACRES FOR PROJECT IN REACH I
:   136     TADIV(I)=ADDITIONAL DIVERSION FOR NEW PROJECT (ACRE-FT)
:   137     TDIF=TEMPORARY VALUE OF ADIV WHEN CALCULATING DECREASES
:   138          IN EXCESS UPSTREAM DIVERSIONS
:   139     TDIV(I)=TOTAL DIVERSIONS IN REACH I (HISTORICAL+NEW PROJECTS)
:   140             (ACRE-FT)
:   141     TDSCH(I)=TOTAL DISCHARGE FROM GROUNDWATER TO SURFACE
:   142              WATER IN MODEL REACH I (ACRE-FT)
:   143     TEXCES=EXCESS UPSTREAM DIVERSIONS (ACRE-FT)
:   144     TFLOW(I)=TOTAL ANNUAL FLOW (ACRE-FT)
:   145     TFLOWA(I)=FLOW AT THE TOP OF REACH I (ACRE-FT)
:   146     TFLOWC(I)=FLOW AT THE TOP OF REACH I (CFS)
:   147     TREACH(I)=ARRAY TO CONVERT FLOWS AT THE TOP OF A
:   148               REGRESSION REACH TO FLOWS AT THE TOP OF THE
:   149               CORRESPONDING MODEL REACH
:   150     T1=DIVERSION DEFICIT IF DIV(I,IMONTH) > WATER AVAILABLE
```

```
151        (D1(I)+RET(I,IMONTH)
152     T2=DIVERSION DEFICIT IF D1(I) < 0.0
153     T3=DIVERSION DEFICIT FOR INSTREAM FLOW TARGETS
154        (IF D1(I) < FLOTAR(MREACH(I,IMONTH))
155     WYRFJ(K)=HISTORIC WATER YEAR FACTOR AT JULESBURG 1950-1979
156     WYRFK(K)=HISTORIC WATER YEAR FACTOR AT KEYSTONE 1950-1979
157     XCFS=X-ARRAY (CFS) FOR SWIDTH SLP-FUNCTION
158     YWIDTH=Y-ARRAY (FT) FOR SWIDTH SLP-FUNCTION
159     ZZD(I,M)=REGRESSION COEFFICIENT-ERROR TERM
```

```
      SUBROUTINE RIVER(ITIME)
C
C*********************************************************
C
C  THIS SUBMODEL CALCULATES MONTHLY FLOWS IN EIGHT
C  REACHES OF THE PLATTE RIVER BASED ON A MULTIPLE
C  REGRESSION APPROACH DEVELOPED BY THE NEBRASKA
C  DEPARTMENT OF WATER RESOURCES TO PREDICT THE
C  EFFECTS OF PROPOSED WATER PROJECTS ON DOWNSTREAM
C  FLOWS.  OTHER FLOW RELATED VARIABLES ARE ALSO
C  CALCULATED.
C
C*********************************************************
C
$CONTINUE WITH PLATTE.C RETURN
C
C*****READ HISTORIC DATA
C.....AND CONVERT TO CORRECT UNITS
C
      CALL REWIND(15)
      CALL REWIND(16)
      IF(ITIME.NE.1) GO TO 10
C.....READ REGRESSION COEFFICIENTS
      READ(15,220)((A(I,M),B(I,M),C(I,M),ZZD(I,M)
     1,M=1,12),I=1,11)
C.....READ AVG. MONTHLY FLOW-KEYSTONE
      READ(16,230)(FK(M),M=1,12)
C.....READ AVG. MONTHLY FLOW-JULESBURG
      READ(16,230)(FJ(M),M=1,12)
C.....READ AVG. GUAGED INPUTS AND OUTPUTS
```

```
      READ(16,240)((RI(I,M),RO(I,M),M=1,12),I=1,11)
   10 CONTINUE
C.....MODIFY AVG. MONTHLY FLOWS, INPUTS, AND
C......OUTPUTS BY HISTORIC WATER YEAR FACTOR--1950-1979
      FLOWJ(IMONTH)=FJ(IMONTH)*WYRFJ(MOD(IYEAR,30))
      FLOWK(IMONTH)=FK(IMONTH)*WYRFK(MOD(IYEAR,30))
C
      DO 20 I=1,11
        DIV(I,IMONTH)=RO(I,IMONTH)*WYRFK(MOD(IYEAR,30))
        RET(I,IMONTH)=RI(I,IMONTH)*WYRFK(MOD(IYEAR,30))
   20 CONTINUE
C
C*****APPLY REGRESSION EQUATIONS
C
      ICOUNT=0
C
      DO 25 I=1,11
        ADIV(I,IMONTH)=ADDDIV(I,IMONTH)
   25 CONTINUE
C
C.....LOOP OVER REGRESSION RIVER REACHES
C
   30 DO 100 I=1,11
C.....SET FLOW AT TOP OF REACH
        IF(I.EQ.1) D1(1)=FLOWK(IMONTH)
        IF(I.NE.1) D1(I)=D2(I-1)
        IF(I.EQ.3) D1(3)=FLOWJ(IMONTH)
        IF(I.EQ.4) D1(4)=D2(2)
C.....CHECK FOR DIVERSION DEFICIT (THE WAY THIS IS DONE IN
C......THIS VERSION OF THE MODEL SHOULD BE CHECKED!!)
```

```
      T1=0.0
      T2=0.0
      T3=0.0
C.....IS FLOW + OTHER INFLOWS < HISTORICAL DIVERSIONS?
C......(SHOULD OTHER INFLOWS INCLUDE THE GAIN TERM?)
      IF((D1(I)+RET(I,IMONTH)).LT.DIV(I,IMONTH))
     1 T1=DIV(I,IMONTH)-(D1(I)+RET(I,IMONTH))
      IF(D1(I).LT.0.0)
     1 T2=ABS(D1(I))
C.....IF APPROPRIATE FOR THIS RUN (ISFT=1), IS
C......FLOW < INSTREAM FLOW TARGET?
      IF(D1(I).LT.FLOTAR(MREACH(I),IMONTH).
     1 AND.ISFT.EQ.1)T3=FLOTAR(MREACH(I)
     2 ,IMONTH)-D1(I)
C.....DETERMINE EXCESS UPSTREAM DIVERSIONS FOR NEW PROJECTS
      TEXCES=AMAX1(T1,T2,T3)
      IF(TEXCES.EQ.0.0) GO TO 80
      IF(I.LE.ICOUNT) GO TO 80
C.....DECREASE UPSTREAM DIVERSIONS FOR NEW PROJECTS
C......IN REVERSE ORDER (OF ALLOCATION PRIORITY) TO
C......ELIMINATE DOWNSTREAM DIVERSION DEFICITS
      ICOUNT=I
C
      DO 60 J=1,11
        INDEX=12-J
C
        DO 50 K=1,I
          IF(IPRIOR(K).NE.INDEX) GO TO 50
          TDIF=ADIV(K,IMONTH)-TEXCES
          IF(TDIF.LT.0.0) GO TO 40
```

```
      TEXCES=0.0
      ADIV(K,IMONTH)=TDIF
      GO TO 70
40    TEXCES=TEXCES-ADIV(K,IMONTH)
      ADIV(K,IMONTH)=0.0
50  CONTINUE
C
60  CONTINUE
C
70  GO TO 30
80  IF(D1(I).LT.0.0)D1(I)=0.0
    IF(D1(I).LT.0.0)D2(I-1)=0.0
    IF((DIV(I,IMONTH)+ADIV(I,IMONTH)).GT.(D1(I)+
  1   RET(I,IMONTH))) ADIV(I,IMONTH)=D1(I)+
  2   RET(I,IMONTH)-DIV(I,IMONTH)
    IF(ADIV(I,IMONTH).LT.0.0)ADIV(I,IMONTH)=0.0
C.....IF APPROPRIATE FOR THIS RUN, RELEASE STORED WATER
C......TO MEET INSTREAM FLOW TARGET
    IF(D1(I).GE.FLOTAR(MREACH(I),IMONTH).OR.
  1     ISFT.EQ.0) GO TO 90
    RELWAT=STOWAT(IREL(1),IREL(2))
    IF(IREL(1).EQ.2) RELWAT=1.6E6
    RELS=AMIN1((FLOTAR(MREACH(I),IMONTH)-D1(I)),RELWAT)
    D1(IREL(3))=D1(IREL(3))+RELS
    STOWAT(IREL(1),IREL(2))=STOWAT(IREL(1),IREL(2))-RELS
C.....MODIFY FLOWS FOR ADDITIONAL GROUNDWATER
C......INFLUENCE, DIVERSIONS, OR RETURNS OVER
C......HISTORICAL CONDITIONS
C.....GROUNDWATER
90  RFAC=0.5
```

```
      IF(I.GE.9.OR.I.EQ.3.OR.I.EQ.4)
     1 RFAC=1.0
      TDSCH(I)=DSCH(MREACH(I),1)+DSCH(MREACH(I),2)
      TDSCH(I)=TDSCH(I)*RFAC
C.....NEW PROJECTS
      RET(I,IMONTH)=RET(I,IMONTH)+ADDRET(I,IMONTH)
      DIV(I,IMONTH)=DIV(I,IMONTH)+ADIV(I,IMONTH)
C.....ADDITIONAL M&I RETURN
      IF(IYEAR.EQ.1)HRETMI(I,IMONTH)=
     1 RFAC*RETMI(MREACH(I))
      RET(I,IMONTH)=RET(I,IMONTH)+(RFAC*
     1 (RETMI(MREACH(I))-HRETMI(I,IMONTH)))
      IF(RET(I,IMONTH).LT.0.0) RET(I,IMONTH)=0.0
C
C.....REGRESSION  EQUATION
C
      D2(I)=A(I,IMONTH)*D1(I)+C(I,IMONTH)*DIV(I,IMONTH)
     1 +B(I,IMONTH)*RET(I,IMONTH)+ZZD(I,IMONTH)+TDSCH(I)
      IF(D2(I).LT.0.) D2(I)=0.0
C
C.....REQUESTED AND ACTUAL ADDITIONAL DIVERSIONS
      RADIV(I)=ADDDIV(I,IMONTH)
      AADIV(I)=ADIV(I,IMONTH)
  100 CONTINUE
C
C.....CONVERT FLOWS FROM REGRESSION REACHES TO SIMCON
C......MODEL REACHES AND TO CFS
C
      DO 110 I=1,8
      TFLOWA(I)=D1(TREACH(I))
```

```
151              BFLOWA(I)=D2(BREACH(I))
152              TFLOWC(I)=TFLOWA(I)*0.0168
153              BFLOWC(I)=BFLOWA(I)*0.0168
154        110 CONTINUE
155      C
156      C*****ANNUAL DISCHARGE (AC.FT.) FOR PLATTE RIVER REACHES
157      C
158            DO 120 I=1,8
159              IF(IMONTH.EQ.1) TF(I)=0.0
160      C       IF(IMONTH.EQ.1) TFLOW(I)=0.0
161              TF(I)=TF(I)+BFLOWA(I)
162              IF(IMONTH.EQ.12)TFLOW(I)=TF(I)
163        120 CONTINUE
164      C
165      C*****COMPUTE FOR SIMCON MODEL REACHES (FROM REGRESSION
166      C......REACH INFORMATION) THE TOTAL DIVERSIONS,ADDITIONAL
167      C......DIVERSIONS FOR NEW PROJECTS, AND DIVERSIONS FOR
168      C......HISTORICAL(I.E. EXISTING) APPROPRIATIONS
169      C
170            DO 150 I=1,8
171              TADIV(I)=0.
172              TDIV(I)=0.
173      C
174              DO 130 L=1,11
175                IF(MREACH(L).EQ.I) TDIV(I)=
176          1     TDIV(I)+DIV(L,IMONTH)
177                IF(MREACH(L).EQ.I) TADIV(I)=
178          1     TADIV(I)+ADIV(L,IMONTH)
179        130   CONTINUE
180            HDIV(I)=TDIV(I)-TADIV(I)
```

```
C
  150 CONTINUE
C
C*****COMPUTE STORAGE IN NEW RESERVOIRS
C.....AND AVAILABLE AG WATER
C
      DO 170 I=1,8
C
        DO 160 J=1,2
          STOUSE(I,J)=0.0
          AGWAT(I,J)=0.0
          IF(IRES(I,J).NE.1) GO TO 160
          STOUSE(I,J)=AMAX1(0.0,(AGUSE(I,J)-HLDIV(I)*
     1    AGFAC(I,J,IMONTH)))
          STOUSE(I,J)=AMIN1(STOUSE(I,J),STOWAT(I,J))
          IF(NOAG(I,J).EQ.1) STOUSE(I,J)=0.0
          STOWAT(I,J)=STOWAT(I,J)+TADIV(I)-STOUSE(I,J)
          IF(STOWAT(I,J).GT.STOMAX(I,J))
     1    STOWAT(I,J)=STOMAX(I,J)
          IF(STOWAT(I,J).LT.0.0)STOWAT(I,J)=0.0
          AGWAT(I,J)=(HDIV(I)*AGFAC(I,J,IMONTH))+STOWAT(I,J)
          IF(I.EQ.4.AND.J.EQ.2)
     1     AGWAT(4,2)=AGWAT(4,2)+AG45(1)*AGWAT(3,2)
          IF(I.EQ.5.AND.J.EQ.2)
     1    AGWAT(5,2)=AGWAT(5,2)+AG45(2)*AGWAT(3,2)
          IF(I.EQ.5.AND.J.EQ.2)
     1    AGWAT(3,2)=0.0
          IF(NOAG(I,J).EQ.1)
     1      AGWAT(I,J)=HDIV(I)*AGFAC(I,J,IMONTH)
  160   CONTINUE
```

```
      HLDIV(I)=HDIV(I)
C
  170 CONTINUE
C
C*****STREAM WIDTH AT GRAND ISLAND
C
      SWIDTH=SLP(BFLOWC(5),XCFS,YWIDTH,6)
C
C*****NO3 CONCENTRATIONS
C
      DO 180 I=1,8
        IF(I.EQ.1) RNO3D1(I)=RNO3IC(1)
        IF(I.EQ.2) RNO3D1(I)=RNO3IC(2)
        IF(I.GT.2) RNO3D1(I)=SNIT(I-1)
      IF(RNO3D1(I).LE.0.0)RNO3D1(I)=RNO3IC(2)
        GWNIT1(I)=AMAX1((GNIT(I,1)*DSCH(I,1)),0.0)
        GWNIT2(I)=AMAX1((GNIT(I,2)*DSCH(I,2)),0.0)
        RTWAT=TFLOWA(I)+AMAX1(0.0,DSCH(I,1))+
     1  AMAX1(0.0,DSCH(I,2))
        IF(RTWAT.LE.0.0) RTWAT=0.0001
        SNIT(I)=((RNO3D1(I)*TFLOWA(I))+GWNIT1(I)+GWNIT2(I))
     1  /RTWAT
        IF(SNIT(I).GT.20.)SNIT(I)=20.
  180 CONTINUE
C
C*****2 OR MORE CONSECUTIVE NO FLOW DAYS AT GRAND ISLAND
C
  190 IF(IMONTH.EQ.7)NOFLOW(1)=0
      IF(IMONTH.EQ.7.AND.TFLOWA(5).LE.6440.) NOFLOW(1)=1
      IF(IMONTH.EQ.8) NOFLOW(2)=0
```

```
      IF(IMONTH.EQ.8.AND.TFLOWA(5).LE.10110.) NOFLOW(2)=1
C
C*****NUMBER OF DAYS IN YEAR WITH FLOW AT
C.....OVERTON >=3800 CFS
C
      IF(IMONTH.NE.12) GO TO 200
      SCOUR=1.603*((TFLOW(4)/1.0E6)**4.3)
  200 CONTINUE
C
C*****MAX DAILY FLOW AT GRAND ISLAND
C
      FLOMAX=(BFLOWA(5)/1.0E-3)*.054+1.46
C
C*****ACRES FLOODED
C
      DO 210 I=1,8
        QMAX(I)=TFLOWC(I)*1.5+535.
        ACFLO(I,1)=.024*QMAX(I)
        ACFLO(I,2)=1.52*QMAX(I)
  210 CONTINUE
C
      RETURN
  220 FORMAT(F5.3,F6.3,F6.3,F9.2)
  230 FORMAT(F10.2)
  240 FORMAT(2F10.2)
      END
```

```
:    1      COMMON MREACH(11),FLOWK(12),FLOWJ(12),DIV(11,12)
:    2      COMMON RET(11,12),D1(11),D2(11),ISFT
:    3      COMMON TEXCES,ADDDIV(11,12),DIVRED(11,12)
:    4      COMMON TDSCH(11),ADDRET(11,12),TFLOWA(11)
:    5      COMMON BFLOWA(8),TFLOWC(8),BFLOWC(8)
:    6      COMMON TREACH(11),BREACH(11),TFLOW(8)
:    7      COMMON AGFAC(8,2,12),IRES(8,2),STOWAT(8,2)
:    8      COMMON SWIDTH,SNIT(11),FLOMAX,NOFLOW(2)
:    9      COMMON SCOUR,TADIV(8),TDIV(8),STOMAX(8,2)
:   10      COMMON IPRIOR(11),IREL(3),RELWAT,RELS
:   11      COMMON WSTD,WMEAN,FJ(12),FK(12)
:   12      COMMON RI(11,12),RO(11,12)
:   13      COMMON A(11,12),B(11,12),C(11,12),ZZD(11,12)
:   14      COMMON INDEX,T1,T2,T3,RFAC
:   15      COMMON HRETMI(11,12)
:   16      COMMON TF(12),XCFS(6),YWIDTH(6)
:   17      COMMON RNO3D1(8),RNO3IC(2),GWNIT1(8),GWNIT2(8),RTWAT
:   18      COMMON ACFLO(8,2),QMAX(8),SURFAC(11,2)
:   19      COMMON HDIV(11),STOUSE(11,2),HLDIV(11),ADIV(11,12)
:   20      COMMON AG45(2),ISEED,RADIV(11),AADIV(11),NOAG(11,2)
:   21      COMMON WATFAC(2),WYRFJ(30),WYRFK(30)
```

```
:    1    S MREACH(ALL)=2 2 1 3 4 4 5 5 6 7 8
:    2    S TFLOWA(ALL)=0.
:    3    S ISFT=0
:    4    S TREACH(ALL)=3 1 4 5 7 9 10 11
:    5    S BREACH(ALL)=3 2 4 6 8 9 10 11
:    6    S AGFAC(ALL,ALL,ALL)=0.0
:    7    S AGFAC(ALL,1,6)=0. 0. .008 .7 1. 1. 0. 0.
:    8    S AGFAC(ALL,1,7)=0. 0. .008 .7 1. 1. 0. 0.
:    9    S AGFAC(ALL,1,8)=0. 0. .008 .7 1. 1. 0. 0.
:   10    S AGFAC(ALL,1,9)=0. 0. .008 .7 1. 1. 0. 0.
:   11    S AGFAC(ALL,2,6)=1. 1. .5 .3 0. 0. 0. 0.
:   12    S AGFAC(ALL,2,7)=1. 1. .5 .3 0. 0. 0. 0.
:   13    S AGFAC(ALL,2,8)=1. 1. .5 .3 0. 0. 0. 0.
:   14    S AGFAC(ALL,2,9)=1. 1. .5 .3 0. 0. 0. 0.
:   15    S IRES(ALL,ALL)=1
:   16    S STOWAT(ALL,ALL)=0.0
:   17    S STOMAX(ALL,ALL)=0.0
:   18    S XCFS(ALL)=100. 250. 400. 800. 1200. 10000.
:   19    S YWIDTH(ALL)=150. 200. 250. 325. 500. 800.
:   20    S RNO3IC(ALL)=0.6 0.9
:   21    S IPRIOR(ALL)=0
:   22    S DIVRED(ALL,ALL)=0.0
:   23    S WSTD=.3
:   24    S WMEAN=1.0
:   25    S ISEED=35353
:   26    S ADDRET(ALL,ALL)=0.
:   27    S ADDDIV(ALL,ALL)=0.
:   28    S AGWAT(ALL,ALL)=0.
:   29    S SNIT(ALL)=0.9
:   30    S SURFAC(ALL,ALL)=0.0
```

```
:    31    S AG45(ALL)=0.0 1.0
:    32    S HLDIV(ALL)=0.0
:    33    S NDAG(ALL,ALL)=0
:    34    S WYRFK(1...10)=.58 .50 2.04 .83 .77 .70 .88 .48 .35 .77
:    35    S WYRFK(11...20)=.60 .55 .37 .82 .72 .35 .77 .66 1.06 .66
:    36    S WYRFK(21...30)=.90 2.99 1.21 3.90 2.13 .91 1.46 .73 .84 .45
:    37    S WYRFJ(1...10)=.54 .64 .94 .45 .23 .23 .18 1.3 1.85 .72
:    38    S WYRFJ(11...20)=.57 1.65 1.33 .49 .22 1.87 .67 .79 .62 1.7
:    39    S WYRFJ(21...30)=2.42 1.71 .5 3.8 1.03 .81 .40 .34 .22 1.69
```

1	1.059	0.000	0.000	7888.58
2	.967	0.000	0.	7910.36
3	.943	0.	-3.915	10053.98
4	.997	0.	-1.503	9351.73
5	.932	0.	-1.469	14622.41
6	1.026	0.	-2.097	18800.47
7	.956	0.	-1.095	8528.14
8	0.934	0.000	-1.560	23455.66
9	1.028	0.	-1.629	14982.03
10	0.997	0.	-1.054	8295.04
11	1.015	0.	-0.237	8538.23
12	.994	0.	0.	8486.38
13	1.189	0.595	0.	4606.50
14	1.052	0.576	0.	6922.56
15	1.029	1.316	0.	86.06
16	1.062	0.929	-0.917	4094.49
17	0.962	0.814	-0.806	7451.89
18	0.989	0.465	-2.517	18683.96
19	1.033	1.494	-2.436	4563.23
20	1.004	0.525	-1.180	13587.51
21	1.046	0.111	-2.194	23565.37
22	1.049	0.354	-0.292	9493.78
23	1.053	0.482	-0.250	8467.69
24	1.045	0.538	0.	7502.86
25	0.638	0.	-0.737	9363.68
26	1.084	0.	-1.065	9607.44
27	0.934	0.	-0.902	11806.02
28	0.718	0.	-0.796	14507.07
29	0.881	0.	-1.174	19008.35
30	0.794	0.	-0.724	15802.76

: 31	0.619	0.	0.000	7175.13
: 32	0.268	0.	0.068	7926.38
: 33	0.818	0.	-0.343	7146.47
: 34	0.950	0.	-0.904	9266.6
: 35	0.872	0.	-0.851	7649.76
: 36	0.211	0.	-0.166	7671.37
: 37	1.396	0.674	-0.513	-14509.46
: 38	1.156	0.829	-0.756	468.72
: 39	1.357	0.452	-0.379	-14055.44
: 40	1.227	0.565	-0.437	-11881.56
: 41	1.167	0.968	-1.015	13051.33
: 42	1.209	0.934	-1.130	21552.21
: 43	0.861	1.078	-0.829	-12028.78
: 44	0.956	1.071	-0.897	-12582.45
: 45	1.022	0.977	-0.946	2088.96
: 46	1.004	0.956	-0.576	-25091.93
: 47	1.026	0.858	-0.684	-9488.76
: 48	1.076	0.228	-0.186	-12065.24
: 49	1.090	-0.452	0.124	4403.92
: 50	1.186	0.751	-0.640	2600.86
: 51	0.993	1.045	-1.289	9077.09
: 52	1.002	1.061	-1.254	8803.10
: 53	0.973	0.112	-0.730	8652.62
: 54	1.048	0.631	-0.668	1405.33
: 55	1.227	1.673	-1.328	719.28
: 56	0.815	0.897	-0.745	111.34
: 57	0.971	0.833	-0.921	4679.70
: 58	1.054	1.296	-1.213	3948.06
: 59	0.957	1.684	-1.624	5420.74
: 60	0.964	-0.240	0.067	5156.18

:	61	1.071	1.412	0.	-19579.31
:	62	1.125	1.135	0.	-4373.08
:	63	1.043	1.198	0.	-5563.81
:	64	1.057	1.087	0.	5074.88
:	65	0.923	1.139	0.	7274.67
:	66	1.073	1.234	0.	413.95
:	67	1.319	0.956	0.	2933.22
:	68	1.057	0.880	0.	6066.39
:	69	1.128	1.024	0.	105.35
:	70	1.180	0.836	0.	10737.50
:	71	1.361	0.757	0.	14221.15
:	72	1.675	0.829	0.	7423.33
:	73	0.974	0.000	-0.135	496.28
:	74	0.991	0.	-0.215	3507.34
:	75	0.982	0.	-1.233	9875.44
:	76	1.015	0.	-1.095	1661.22
:	77	0.965	1.833	-0.522	-1905.03
:	78	0.912	3.176	-1.573	4226.23
:	79	0.987	2.292	-0.334	-9992.24
:	80	0.962	1.653	-1.145	-1211.23
:	81	0.917	1.928	-0.954	-2612.30
:	82	1.031	0.	-0.703	-5679.23
:	83	0.985	0.	-0.534	-4802.70
:	84	0.944	0.	-0.475	1528.98
:	85	0.971	0.042	0.	-9105.18
:	86	1.055	1.357	0.	-4558.85
:	87	0.814	-2.584	0.	39863.74
:	88	0.975	0.811	0.	9209.86
:	89	0.872	1.697	0.	6718.37
:	90	0.970	2.045	0.	-5373.34

: 91	1.199	0.835	0.	-4958.20
: 92	0.941	0.338	0.	-2838.29
: 93	1.000	0.764	0.	-10088.14
: 94	1.145	1.317	0.	-20300.84
: 95	1.069	0.624	0.	-7339.58
: 96	1.084	0.868	0.	-16955.55
: 97	1.112	0.	0.	-9110.09
: 98	1.250	0.000	0.000	-18528.27
: 99	1.115	0.	0.	7948.46
: 100	1.003	0.	0.	16260.86
: 101	0.896	0.	0.	22016.79
: 102	1.084	0.	0.	5719.76
: 103	1.094	0.	0.	3155.74
: 104	0.850	0.	0.	322.65
: 105	1.015	0.	0.	-5231.71
: 106	0.978	0.	0.	-488.37
: 107	1.196	0.	0.	-10123.79
: 108	1.131	0.	0.	-7573.34
: 109	0.886	0.980	0.	-1012.19
: 110	0.989	1.189	0.	-2264.42
: 111	1.092	1.215	0.	-3724.31
: 112	1.084	1.153	0.	-899.56
: 113	1.137	1.132	0.	627.73
: 114	1.078	1.316	0.000	-6425.14
: 115	1.211	1.181	0.	-1851.32
: 116	1.115	1.167	0.	-432.86
: 117	0.976	1.220	0.	-4914.77
: 118	1.137	1.014	0.	-215.52
: 119	1.084	1.022	0.	-427.18
: 120	0.925	0.967	0.	-100.67

:	121	1.147	0.449	0.	940.42
:	122	1.061	0.863	0.	1948.69
:	123	1.170	0.669	0.	544.15
:	124	0.981	1.346	0.	2864.54
:	125	0.938	1.360	0.	3400.24
:	126	0.935	1.251	0.	7176.24
:	127	0.931	1.282	0.	2715.18
:	128	0.828	1.428	0.	-2044.82
:	129	0.819	1.571	0.	-2687.12
:	130	0.914	1.383	0.	-677.79
:	131	0.997	1.209	0.	-1035.64
:	132	1.115	0.705	0.	-1305.62

:	1	1691.82	
:	2	2337.48	
:	3	9207.27	
:	4	11069.51	
:	5	40081.50	
:	6	54775.05	
:	7	96632.85	
:	8	72960.37	
:	9	27400.30	
:	10	23785.15	
:	11	8301.14	
:	12	2183.96	
:	13	29113.07	
:	14	29672.88	
:	15	29000.01	
:	16	28372.68	
:	17	63652.59	
:	18	68039.78	
:	19	14432.37	
:	20	8022.98	
:	21	8282.97	
:	22	17478.82	
:	23	19917.77	
:	24	20252.87	
:	25	0.00	0.00
:	26	0.00	0.
:	27	0.00	95.68
:	28	0.00	2210.54
:	29	0.00	10306.43
:	30	0.00	13472.44

:	31	0.00	22104.11
:	32	0.00	22407.74
:	33	0.00	13852.08
:	34	0.00	3209.49
:	35	0.00	208.58
:	36	0.00	0.00
:	37	11702.32	0.00
:	38	11030.00	0.
:	39	12335.92	0.
:	40	12070.77	201.76
:	41	13643.02	3176.73
:	42	13095.74	4241.85
:	43	13249.03	7177.54
:	44	14307.09	7042.83
:	45	14538.12	4912.10
:	46	13157.15	1577.42
:	47	11945.09	99.89
:	48	12030.62	0.
:	49	0.	20510.59
:	50	0.	24829.72
:	51	0.	26342.87
:	52	0.	24585.19
:	53	0.	21360.78
:	54	0.	29391.38
:	55	0.	15184.51
:	56	0.	7858.35
:	57	0.	5168.37
:	58	0.	12673.74
:	59	0.	17345.21
:	60	0.	17170.65

:	61	61439.58	74001.77
:	62	59326.15	75303.96
:	63	63554.36	84874.20
:	64	62948.21	83784.33
:	65	98290.87	92800.23
:	66	101447.89	97919.24
:	67	101768.80	121355.54
:	68	97801.30	121499.46
:	69	69116.22	92715.02
:	70	46525.08	78289.48
:	71	47645.34	74124.27
:	72	56844.75	76555.61
:	73	5573.00	5903.36
:	74	4976.61	4973.91
:	75	5247.31	4776.91
:	76	5639.09	6562.91
:	77	7012.76	15665.60
:	78	10083.52	25124.64
:	79	10245.68	63852.76
:	80	16253.56	60861.36
:	81	10171.95	18881.84
:	82	4138.87	5935.65
:	83	3818.66	4374.11
:	84	4273.09	4936.78
:	85	57824.20	0.00
:	86	60441.82	0.
:	87	68442.42	0.
:	88	56700.28	0.
:	89	36941.02	0.
:	90	28800.94	0.

:	91	11608.62	0.
:	92	9658.47	0.
:	93	35569.42	0.
:	94	57257.00	0.
:	95	58600.05	0.
:	96	60102.89	0.
:	97	0.	1425.48
:	98	0.	1396.44
:	99	0.	2494.25
:	100	0.	6612.81
:	101	1903.81	9716.78
:	102	4314.52	11281.35
:	103	3635.54	11163.61
:	104	3488.45	10796.27
:	105	2723.23	10918.13
:	106	0.00	8221.80
:	107	0.00	6476.82
:	108	0.00	2775.91
:	109	1281.16	0.
:	110	1197.54	0.
:	111	2021.55	0.
:	112	5049.12	0.
:	113	7160.88	0.
:	114	8807.08	0.
:	115	6691.59	0.
:	116	6450.80	0.
:	117	8117.71	0.
:	118	6170.02	0.
:	119	5385.20	0.
:	120	2243.07	0.

:	121	0.	0.
:	122	0.	0.
:	123	0.	0.
:	124	0.	0.
:	125	0.	0.
:	126	0.	0.
:	127	0.	0.
:	128	0.	0.
:	129	0.	0.
:	130	0.	0.
:	131	0.	0.
:	132	0.	0.
:	133	113050.94	0.
:	134	140056.30	0.
:	135	208799.04	0.
:	136	161349.84	0.
:	137	149962.07	0.
:	138	155120.13	0.
:	139	86120.41	0.
:	140	79068.93	0.
:	141	93763.83	0.
:	142	118381.96	0.
:	143	127620.73	0.
:	144	112690.59	0.
:	145	41984.45	0.
:	146	78811.40	0.
:	147	158684.50	0.
:	148	128687.52	0.
:	149	134473.62	0.
:	150	197502.22	0.

151	88224.00	0.
152	63012.57	0.
153	50033.77	0.
154	51757.25	0.
155	44170.00	0.
156	39231.79	0.

APPENDIX C. AGRICULTURE SUBMODEL FILES

```
AGRICULTURE SUBMODEL VARIABLE DEFINITIONS
=========== ======== ======== ===========

--VARIABLES PRECEDED BY AN * ARE CALCULATED BY OTHER
     SUBMODELS

--UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:

   IC=CROP TYPE
   ID=DIRECTION FROM RIVER(FOR REACHES ONLY)
   IMONTH=MONTH OF YEAR
   IR=RIVER REACH
   IW=WATER-USE TYPE

  WHERE THE FOLLOWING DEFINE SUBSCRIPT VALUES++NOTE THAT
    ALL POSSIBLE SUBSCRIPT VALUES ARE NOT USED FOR ALL
    VARIABLES.

   IC=1=ALFALFA
   IC=2=CORN
   IC=3=MILO
   IC=4=SOYBEAN
   IC=5=WHEAT
   IC=6=OTHER,ASSUMED TO BE NATIVE HAY

   ID=1=NORTH
   ID=2=SOUTH

   IMONTH=1...12=JAN...DEC
```

```
IR=1=LEWELLEN TO NORTH PLATTE
IR=2=JULESBURG TO NORTH PLATTE
IR=3=NORTH PLATTE TO BRADY
IR=4=BRADY TO OVERTON
IR=5=OVERTON TO GRAND ISLAND
IR=6=GRAND ISLAND TO DUNCAN
IR=7=DUNCAN TO NORTH BEND
IR=8=NORTH BEND TO LOUISVILLE
IR=9=ENDERS PROJECT AREA
IR=10=LITTLE BLUE PROJECT AREA
IR=11=BIG BLUE PROJECT AREA

IW=1=SURFACE WATER-IRRIGATED
IW=2=GROUNDWATER-IRRIGATED
IW=3=DRYLAND CROPLAND
IW=4=SUBIRRIGATED
IW=5=PASTURE
IW=6=OTHER

-----------------------------------------------------------

ACT=TEMPORARY VARIABLE
ACRE(IR,ID,IW,IC)=AREA BY CROP AND WATER-USE TYPE (ACRES)
AGN(IR,ID)=AGRICULTURAL NITRATE LEACHED TO GROUNDWATER
   (LB-N/MONTH)
AGNIT(IR,ID)=NITRATE CONCENTRATION IN TOTAL AGRICULTURAL
   RECHARGE (PPM-N)
AGRCH(IR,ID)=AGRICULTURAL GROUNDWATER RECHARGE
   (ACRE-FT/MONTH)
AGUSE(IR,ID)=SURFACE WATER USED FOR IRRIGATION
```

```
61        (ACRE-FT/MONTH)
62      * AGWAT(IR,ID)=SURFACE WATER AVAILABLE FOR
63        IRRIGATION (ACRE-FT/MONTH) (FROM SURFACE WATER SUBMODEL)
64      ALET=ANNUAL ET YFROM SUBIRRIGATED ALFALFA (ACRE-FT/YEAR)
65      CCHECK=CHECK VARIABLE FOR CONSISTENT VALUES OF
66        TCHANG (ALWAYS 0)
67      CON=MULTIPLICATIVE CONVERSION FROM LB/ACRE-FT TO PPM
68      CROP(IR,ID,IW,IC)=PROPORTION OF LAND IN VARIOUS
69        CROPS  (DECIMAL FRACTION)
70      CROP1(IR,IW,IC)=YEAR 1980, PROPORTION OF LAND IN VARIOUS
71        CROPS  (DECIMAL FRACTION)
72      CROP2(IR,IW,IC)=YEAR 2020, PROJECTED PROPORTION OF LAND
73        IN VARIOUS CROPS (DECIMAL FRACTION)
74      CYLD(IR,ID,IW,IC)=ANNUAL CROP YIELD (BU/AC FOR IC=2,3,4,5
75        AND TONS/AC FOR IC=1,6)
76      D(J)=TEMPORARY VARIABLE
77      DD(IR,ID)=INCREASE IN DEPTH TO GROUNDWATER FROM INITIAL
78        CONDITION (FT)
79      DDMAX(IR,ID)=MAXIMUM VALUE OF DD DURING A GROWING
80        SEASON=IMONTH=5...9 (FT)
81      DEPI(IR,ID)=INITIAL DEPTH TO GROUNDWATER (FT)
82      * DEPTH(IR,ID)=DEPTH TO GROUNDWATER (FT) (FROM GROUNDWATER
83        SUBMODEL)
84      DPERC(IR,ID,IW)=DEEP PERCOLATION, TOTAL (ACRE-FT/MONTH)
85      DPERCF(IR,ID,IW)=DEEP PERCOLATION, FIELD COMPONENT
86        (ACRE-FT/MONTH)
87      DPERCT(IR,ID,IW)=DEEP PERCOLATION, TRANSPORT COMPONENT
88        (ACRE-FT/MONTH)
89      DUM=TEMPORARY VARIABLE
90      ED(IW)=IRRIGATION DELIVERY EFFICIENCY (ACRE-FT DELIVERED/
```

```
      ACRE-FT SENT)
EF(IW)=FIELD IRRIGATION EFFICIENCY (ACRE-FT UTILIZED/
      ACRE-FT APPLIED)
EPER=PERCOLATION EFFICIENCY (DECIMAL FRACION)
EPER1=ADDITIONAL MULTIPLICATIVE REDUCTION IN PERCOLATING
      WATER FROM SURFACE WATER IRRIGATION (DECIMAL FRACION)
ETS(IR,ID)=EVAPOTRANSPIRATION FROM SUBIRRIGATED LAND, IW=4
      (ACRE-FT/MONTH)
FPERC(IMONTH)=FRACTION OF RAIN WHICH IS DEEP PERCOLATION,
      APPLIED TO IW=1,2 (DECIMAL FRACTION)
FPERCO(IR,ID)=FRACTION OF RAIN WHICH IS DEEP PERCOLATION,
      APPLIED TO IW=3 (DECIMAL FRACTION)
FRUND(IMONTH)=FRACTION OF RAIN WHICH IS RUNOFF,APPLIED
      TO IW=3 (DECIMAL FRACTION)
GA=FRACTION OF GROUNDWATER RESERVOIR AVAILABLE FOR
      PUMPING (DECIMAL FRACTION)
GAVAL=AVAILABLE GROUNDWATER, TEMPORARY VARIABLE (ACRE-FT)
GPUMP(IR,ID)=GROUNDWATER PUMPING BY GROUNDWATER
      IRRIGATORS (ACRE-FT/MONTH)
GWL(IR,ID)=FRACTION OF PROJECTED GROUNDWATER-IRRIGATED
      ACREAGE REALIZED DUE TO DEPTH TO GROUNDWATER(DECIMAL
      FRACTION)
* GWS(IR,ID)=VOLUME OF GROUNDWATER RESERVOIR (ACRE-FT) <FROM
      GROUNDWATER SUBMODEL>
HNET=ANNUAL EVAPOTRANSPIRATION FROM SUBIRRIGATED
      NATIVE HAY(ACRE-FT/YEAR)
* IMONTH=CURRENT MONTH(...12=JAN...DEC) <FROM SYSTEM MODEL>
* IYEAR=CURRENT YEAR <FROM SYSTEM MODEL>
PUMPAG(IR,ID)=TOTAL AGRICULTURAL GROUNDWATER PUMPING
      (ACRE-FT/MONTH)
```

```
RAIN(IR,ID)=PRECIPITATION (INCHES/MONTH)
RED=MULTIPLICATIVE REDUCTION IN SUBIRRIGATED ET DUE TO
   DEPTH TO GROUNDWATER, TEMPORARY VARIABLE (DECIMAL
   FRACTION)
RETAG(IR,ID)=AGRICULTURAL RUNOFF (ACRE-FT/MONTH)
RLOAD(IW,IC)=AGRICULTURAL NITRATE LEACHING LOADING (LB-N/
   ACRE-INCH OF PERCOLATING WATER)
RNET(IR,IC)=NET CROP IRRIGATION REQUIREMENT (INCHES/YEAR)
RUN(IR,ID,IW)=RUNOFF FROM AGRICULTURAL LAND (ACRE-FT/MONTH)
SEAS(IMONTH)=MONTHLY DISTRIBUTION OF CROP IRRIGATION
   REQUIREMENT (DECIMAL FRACTION)
* SNIT(IR)=NITRATE CONCENTRATION IN SURFACE WATER (PPM-N)
   (FROM SURFACE WATER SUBMODEL)
SPUMP(IR,ID)=GROUNDWATER PUMPING BY SURFACE WATER-
   IRRIGATORS (ACRE-FT/MONTH)
TACRE(IR,ID)=TOTAL AREA (ACRES)
TCHANG(IR,ID,IW)=SPECIFIC CHANGE IN ACREAGE, USED TO
   REPRESENT SPECIFIC PROJECTS (ACRES*10**3)
TGN(IR,ID)=AGRICULTURAL NITRATE ADDED TO GROUNDWATER FROM
   IRRIGATION DELIVERY LOSSES (LB-N/MONTH)
TPUMPA(IR,ID)=ANNUAL CUMULATIVE TOTAL GROUNDWATER PUMPING
   BY AGRICULTURE, RESET YEARLY (ACRE-FT)
TYPE(IR,ID,IW)=AREA BY WATER-USE TYPE (ACRES)
TYPE1(IR,ID,IW)=YEAR 1980, AREA BY WATER-USE TYPE
   (ACRES*10**3)
TYPE2(IR,ID,IW)=YEAR 2020, PROJECTED  AREA BY WATER-USE TYPE
   (ACRES*10**3)
TWDEL(IR,ID)=ANNUAL CUMULATIVE SURFACE WATER DELIVERED
   TO FIELDS, RESET YEARLY, (ACRE-FT)
WDEL(IR,ID)=SURFACE WATER DELIVERED TO FIELDS (ACRE-FT/MONTH)
```

```
WDIV(IR,ID,IW)=AGRICULTURAL DEMAND FOR SURFACE WATER, BY USE
   (ACRE-FT/MONTH)
WFAC(IR,ID)=CALIBRATION COEFICIENT APPLIED TO WYLDM
   (DECIMAL FRACTION)
WGS(IR,ID,IW)=GROSS IRRIGATION REQUIREMENT AT FIELD
   (ACRE-FT/MONTH)
WNET(IR,ID,IW)=NET CROP IRRIGATION REQUIREMENT AT FIELD
   (ACRE-FT/MONTH)
* WYLD(IR,ID)=WELL YIELD (GAL/MIN) (FROM GROUNDWATER
   SUBMODEL)
WYLDM(IR,ID)=ANNUAL MINIMUM OF WYLD (GAL/MIN)
XG(I)=VALUES OF WYLDM USED TO DEFINE SLP RELATIONSHIP
   BETWEEN WYLDM AND GWL, EXCEPT FOR IR=6 & ID=2
XG1(I)=VALUES OF WYLDM USED TO DEFINE SLP RELATIONSHIP
   BETWEEN WYLDM AND GWL, USED FOR IR=6 & ID=2
XSUB(L)=VALUES OF DD USED TO DEFINE SLP RELATIONSHIP
   BETWEEN DD AND MULTIPLICATIVE ETS REDUCTION
XTIME(K)=VALUES OF YEAR USED TO DEFINE SLP RELATIONSHIP
   BETWEEN YEAR AND CYLD, AND YEAR AND TYPE
YEAR=CURRENT YEAR
YIELD1(IW,IC)=YEAR 1980, ANNUAL CROP YIELDS (SAME
   UNITS AS CYLD)
YIELD2(IW,IC)=YEAR 2020, PROJECTED ANNUAL CROP YIELDS (SAME
   UNITS AS CYLD)
YG(I)=VALUES OF GWL USED TO DEFINE SLP RELATIONSHIP
   BETWEEN WYLDM AND GWL,EXCEPT FOR IR=6 & ID=2
YG1(I)=VALUES OF GWL USED TO DEFINE SLP RELATIONSHIP
   BETWEEN WYLDM AND GWL,USED FOR IR=6 & ID=2
YRED(IR,ID)=MULTIPLICATIVE REDUCTION IN YIELD DUE TO
   DEPTH TO GROUNDWATER, USED FOR IW=4 (DECIMAL FRACTION)
```

```
:   181     YSUB(L)=VALUES OF RED USED TO DEFINE
:   182       RELATIONSHIP BETWEEN DD AND ETS REDUCTION
```

```
C FILE AG.S
C
C.......PRFF AG SUBMODEL..................... ......
C
      SUBROUTINE AG
C COMMON BLOCK
$CONTINUE WITH PLATTE.C RETURN
C
C INITIALIZATION
C==============================
C 1ST MONTH OF 1ST YEAR
C INITIALIZE MINIMUM WELL YIELDS
      IF(IYEAR.NE.1.OR.IMONTH.NE.1) GO TO 379
      DO 378 IR=1,11
      DO 378 ID=1,2
       WYLDM(IR,ID)=WYLD(IR,ID)
  378 CONTINUE
  379 CONTINUE
C
C==============================
C     1ST MONTH OF EACH YEAR
      IF(IMONTH.NE.1) GO TO 91
      DO 92 IR=1,11
      DO 92 ID=1,2
       DDMAX(IR,ID)=0.0
       TPUMPA(IR,ID)=0
       TWDEL(IR,ID)=0
   92 CONTINUE
   91 CONTINUE
C==============================
```

```
C ALL MONTHS OF ALL YEARS
      CCHECK=0.0
      DO 99 IR=1,11
      DO 99 ID=1,2
       AGN(IR,ID)=0.0
       TACRE(IR,ID)=0.0
      DO 99 IW=1,6
       WNET(IR,ID,IW)=0.0
   99 CONTINUE
       YEAR=IYEAR
C ==============================
C ANNUAL CROP AND WATER USE CHANGES
C 1ST MONTH OF ALL YEARS
C
      IF(IMONTH.NE.1) GO TO 299
       DO 298 IR=1,11
       DO 298 ID=1,2
C ANNUAL LONG-TERM CROP CHANGES
C       ON DRYLAND,SURFACE IRR ACRES,GRNDWATER IRR ACRES
C
      DO 201 IW=1,3
      DO 201 IC=1,6
       D(1)=CROP1(IR,IW,IC)
       D(2)=CROP2(IR,IW,IC)
       CROP(IR,ID,IW,IC)=SLP(YEAR,XTIME,D,2)
  201 CONTINUE
C
C ANNUAL CHANGES IN WATER-USE TYPES
C
      DO 203 IW=1,6
```

```
C
C ACRES SLP:LONG-TERM CHANGES
      D(1)=TYPE1(IR,ID,IW)
      D(2)=TYPE2(IR,ID,IW)
      TYPE(IR,ID,IW)=SLP(YEAR,XTIME,D,2)
C
C TCHANG:PROJECT-SPECIFIC CHANGES
     TYPE(IR,ID,IW)=TYPE(IR,ID,IW)+TCHANG(IR,ID,IW)
     TYPE(IR,ID,IW)=TYPE(IR,ID,IW)*1000.
     CCHECK=CCHECK+TCHANG(IR,ID,IW)
  203 CONTINUE
C
C DRY WELL SHIFTS
C FRACTION OF PROJECTED WHICH ARE REALIZED
C
     WYLDM(IR,ID)=WYLDM(IR,ID)*WFAC(IR,ID)
     GWL(IR,ID)=SLP(WYLDM(IR,ID),XG,YG,7)
     GWL(6,2)=SLP(WYLDM(IR,ID),XG1,YG1,7)
C MOVE
     TYPE(IR,ID,3)=TYPE(IR,ID,3)+TYPE(IR,ID,2)*
    1  (1.0-GWL(IR,ID))
     TYPE(IR,ID,2)=TYPE(IR,ID,2)-TYPE(IR,ID,2)*
    1  (1.0-GWL(IR,ID))
C UPDATE AND TOTAL
     WYLDM(IR,ID)=WYLD(IR,ID)
     DO 300 IW=1,6
     DO 300 IC=1,6
     ACRE(IR,ID,IW,IC)=TYPE(IR,ID,IW)*CROP(IR,ID,IW,IC)
  300 CONTINUE
  298 CONTINUE
```

```
  299 CONTINUE
C
C ==============================
C...BIG LOOP...ALL MONTHS OF ALL YEARS
      DO 1000 IR=1,11
      DO 1000 ID=1,2
C
C ANNUAL WELL YIELD MINIMUMS
     WYLDM(IR,ID)=AMIN1(WYLD(IR,ID),WYLDM(IR,ID))
C
C TOTAL ACRES
C
     DO 333 IW=1,6
     DO 333 IC=1,6
       TACRE(IR,ID)=ACRE(IR,ID,IW,IC)+TACRE(IR,ID)
  333 CONTINUE
C
C WATER USE
C
C IRR CROPS
C
C NET IRR
     DO 101 IW=1,2
     DO 102 IC=1,6
      WNET(IR,ID,IW)=WNET(IR,ID,IW)+ACRE(IR,ID,IW,IC)
    1  *RNET(IR,IC)*(1./12.)*SEAS(IMONTH)
  102 CONTINUE
C
C GROSS IRR
C
```

```
      WGS(IR,ID,IW)=WNET(IR,ID,IW)/EF(IW)
  101 CONTINUE
C
C FOR SURFACE WATER IRR ONLY
C DIVERT
C
      WDIV(IR,ID,1)=WGS(IR,ID,1)/ED(1)
      AGUSE(IR,ID)=AMIN1(WDIV(IR,ID,1),AGWAT(IR,ID))
      WDEL(IR,ID)=AGUSE(IR,ID)*ED(1)
      TWDEL(IR,ID)=TWDEL(IR,ID)+WDEL(IR,ID)
      GAVAL=GA*GWS(IR,ID)
      SPUMP(IR,ID)=WGS(IR,ID,1)-WDEL(IR,ID)
      SPUMP(IR,ID)=AMIN1(SPUMP(IR,ID),GAVAL)
      GWS(IR,ID)=GWS(IR,ID)-SPUMP(IR,ID)
C
C GROUND WATER IRR ONLY
C
      GAVAL=GWS(IR,ID)*GA
      GPUMP(IR,ID)=AMIN1(WGS(IR,ID,2),GAVAL)
      GWS(IR,ID)=GWS(IR,ID)-GPUMP(IR,ID)
C
C TOTAL PUMPING
      PUMPAG(IR,ID)=SPUMP(IR,ID)+GPUMP(IR,ID)
      TPUMPA(IR,ID)=TPUMPA(IR,ID)+PUMPAG(IR,ID)
C
C PERCOLATION AND RUNOFF
C DRYLAND
C ALL SEASONS
C
      DPERC(IR,ID,3)=FPERCD(IMONTH)*RAIN(IR,IMONTH)
```

```
     1   *(1./12.)*TYPE(IR,ID,3)
      RUN(IR,ID,3)=FRUND(IMONTH)*RAIN(IR,IMONTH)*
     1    (1./12.)*TYPE(IR,ID,3)
C IRRIGATED LAND
C   NON-IRRIGATION SEASON*****************************
C
      IF (IMONTH.GE.6.AND.IMONTH.LE.9) GO TO 220
C
C    SURFACE WATER IRR
      DPERCF(IR,ID,1)=TYPE(IR,ID,1)*FPERC(IMONTH)
     1    *RAIN(IR,IMONTH)*(1./12.)
      DPERCT(IR,ID)=0.0
      DPERC(IR,ID,1)=DPERCF(IR,ID,1)+DPERCT(IR,ID)
      RUN(IR,ID,1)=.1*RAIN(IR,IMONTH)*(1./12.)*TYPE(IR,ID,1)
C
C      GROUND WATER IRR
C
      DPERC(IR,ID,2)=FPERC(IMONTH)*RAIN(IR,IMONTH)
     1 *TYPE(IR,ID,2)*(1./12.)
      RUN(IR,ID,2)=.1*RAIN(IR,IMONTH)*(1./12.)*TYPE(IR,ID,2)
      GO TO 221
C
C   IRR SEASON*****************************************
  220 CONTINUE
C    SURFACE WATER IRR
      DPERCT(IR,ID)=EPER*(AGUSE(IR,ID)-WDEL(IR,ID))
      ACT=SPUMP(IR,ID)+WDEL(IR,ID)-WNET(IR,ID,1)
      DUM=AMAX1(ACT,0.0)
      DPERCF(IR,ID,1)=EPER*EPER1*DUM
      DPERC(IR,ID,1)=DPERCF(IR,ID,1)+DPERCT(IR,ID)
```

```
      RUN(IR,ID,1)=DUM*.1
C  GROUND WATER IRR
      ACT=GPUMP(IR,ID)-WNET(IR,ID,2)
      DUM=AMAX1(ACT,0.0)
      DPERC(IR,ID,2)=EPER*DUM
      RUN(IR,ID,2)=0.0
C*************************************************
  221 CONTINUE
C  TOTALS
      AGRCH(IR,ID)=DPERC(IR,ID,1)+DPERC(IR,ID,2)+
     1  DPERC(IR,ID,3)
      RETAG(IR,ID)=RUN(IR,ID,1)+RUN(IR,ID,2)+RUN(IR,ID,3)
C NO3
      DO 120 IC=1,6
C LEACHING LOAD IN LB
      AGN(IR,ID)=AGN(IR,ID)+CROP(IR,ID,1,IC)*RLOAD(1,IC)*12.*
     1        DPERCF(IR,ID,1)+ CROP(IR,ID,2,IC)*RLOAD(2,IC)*
     2  12.*DPERC(IR,ID,2) + CROP(IR,ID,3,IC)*RLOAD(3,IC)*12.
     3     *DPERC(IR,ID,3)
  120 CONTINUE
C TRANSPORT LOAD
      TGN(IR,ID)=DPERCT(IR,ID)*SNIT(IR)/CON
C AVE CONC
C
      DUM=AGRCH(IR,ID)
      AGNIT(IR,ID)=0.0
      IF(DUM.LT.1.E-15) GO TO 780
      AGNIT(IR,ID)=CON*(TGN(IR,ID)+AGN(IR,ID))/DUM
  780 CONTINUE
C SUBIRR ALTERATIONS
```

```
C DEPTH CHANGE FROM INITIAL
      DD(IR,ID)=DEPTH(IR,ID)-DEPI(IR,ID)
C MAX DROP
      IF(IMONTH.LT.5 .OR. IMONTH.GT.9) GO TO 850
      DDMAX(IR,ID)=AMAX1(DDMAX(IR,ID),DD(IR,ID))
  850 CONTINUE
      RED=SLP(DD(IR,ID),XSUB,YSUB,3)
C ET
      GAVAL=GWS(IR,ID)*GA
      ETS(IR,ID)=SEAS(IMONTH)*RED*((ACRE(IR,ID,4,1)*ALET)
     1  + (ACRE(IR,ID,4,6)*HNET))
      ETS(IR,ID)=AMIN1(ETS(IR,ID),GAVAL)
      GWS(IR,ID)=GWS(IR,ID)-ETS(IR,ID)
C ====================================
C YIELD
      IF(IMONTH.NE.12) GO TO 888
C LOAD SLP
      DO 837 IW=1,6
      DO 837 IC=1,6
        D(1)=YIELD1(IW,IC)
        D(2)=YIELD2(IW,IC)
      CYLD(IR,ID,IW,IC)=SLP(YEAR,XTIME,D,2)
  837 CONTINUE
      YRED(IR,ID)=SLP(DDMAX(IR,ID),XSUB,YSUB,3)
      CYLD(IR,ID,4,1)=CYLD(IR,ID,4,1)*YRED(IR,ID)
      CYLD(IR,ID,4,6)=CYLD(IR,ID,4,6)*YRED(IR,ID)
  888 CONTINUE
 1000 CONTINUE
C ====================================
      RETURN
```

```
:    241          END
```

```
:      1          COMMON SEAS(12),DEPI(11,2),DDMAX(11,2),XSUB(3),YSUB(3)
:      2          COMMON WFAC(11,2)
:      3          COMMON GA
:      4          COMMON WYLDM(11,2)
:      5          COMMON TCHANG(11,2,6)
:      6          COMMON FPERC(12)
:      7          COMMON GWL(11,2),ACRE(11,2,6,6)
:      8          COMMON WGS(11,2,6)
:      9          COMMON WDEL(11,2)
:     10          COMMON RETAG(11,2),DD(11,2)
:     11          COMMON TYPE(11,2,6),CROP(11,2,6,6)
:     12          COMMON TYPE2(11,2,6),CROP1(11,3,6),CROP2(11,3,6)
:     13          COMMON XG(7),YG(7),YG1(7),XG1(7)
:     14          COMMON ALET,HNET,YRED(11,2),TYPE1(11,2,6)
:     15          COMMON YEAR
:     16          COMMON TACRE(11,2),AGUSE(11,2),PUMPAG(11,2)
:     17          COMMON AGRCH(11,2),ETS(11,2),WNET(11,2,6)
:     18          COMMON ED(2),CYLD(11,2,6,6)
:     19          COMMON SPUMP(11,2),GPUMP(11,2),WDIV(11,2,6),EF(2)
:     20          COMMON DPERC(11,2,3),DPERCF(11,2,3),DPERCT(11,2)
:     21          COMMON RNET(11,6),AGNIT(11,2),EPER,EPER1,RAIN(11,12)
:     22          COMMON FPERCD(12),FRUND(12),RUN(11,2,3),CON
:     23          COMMON RLOAD(3,6),AGN(11,2),TGN(11,2),D(2)
:     24          COMMON XTIME(2),YIELD1(6,6),YIELD2(6,6)
:     25          COMMON TPUMPA(11,2),TWDEL(11,2),AGWAT(11,2)
:     26          COMMON CCHECK
```

```
:     1    S AGUSE(ALL,ALL)=0.0
:     2    S ALET=2.85
:     3    S CON=.37
:     4    S CROP(ALL,ALL,ALL,ALL)=.0
:     5    S CROP(1...11,1,4,1)=.5
:     6    S CROP(1...11,1,4,6)=.5
:     7    S CROP(1...11,1,5,6)=1.0
:     8    S CROP(1...11,1,6,6)=1.0
:     9    S CROP(1...11,2,4,1)=.5
:    10    S CROP(1...11,2,4,6)=.5
:    11    S CROP(1...11,2,5,6)=1.0
:    12    S CROP(1...11,2,6,6)=1.0
:    13    S CROP1(ALL,ALL,ALL)=0.0
:    14    S CROP1(1,1,1...6)=.14 .83 .01 .0 .02 .0
:    15    S CROP1(2,1,1...6)=.14 .83 .01 .0 .02 .0
:    16    S CROP1(3,1,1...6)=.14 .83 .01 .0 .02 .0
:    17    S CROP1(4,1,1...6)=.14 .83 .01 .0 .02 .0
:    18    S CROP1(5,1,1...6)=.04 .93 .01 .02 .0 .0
:    19    S CROP1(6,1,1...6)=.04 .93 .01 .02 .0 .0
:    20    S CROP1(7,1,1...6)=.02 .79 .01 .18 .0 .0
:    21    S CROP1(8,1,1...6)=.02 .79 .01 .18 .0 .0
:    22    S CROP1(1,2,1...6)=.14 .83 .01 .0 .02 .0
:    23    S CROP1(2,2,1...6)=.14 .83 .01 .0 .02 .0
:    24    S CROP1(3,2,1...6)=.14 .83 .01 .0 .02 .0
:    25    S CROP1(4,2,1...6)=.14 .83 .01 .0 .02 .0
:    26    S CROP1(5,2,1...6)=.04 .93 .01 .02 .0 .0
:    27    S CROP1(6,2,1...6)=.04 .93 .01 .02 .0 .0
:    28    S CROP1(7,2,1...6)=.02 .79 .01 .18 .0 .0
:    29    S CROP1(8,2,1...6)=.02 .79 .01 .18 .0 .0
:    30    S CROP1(1,3,1...6)=.38 .02 .03 .0 .57 .0
```

```
:    31    S CROP1(2,3,1...6)=.38 .02 .03 .0 .57 .0
:    32    S CROP1(3,3,1...6)=.38 .02 .03 .0 .57 .0
:    33    S CROP1(4,3,1...6)=.38 .02 .03 .0 .57 .0
:    34    S CROP1(5,3,1...6)=.34 .11 .22 .02 .31 .0
:    35    S CROP1(6,3,1...6)=.34 .11 .22 .02 .31 .0
:    36    S CROP1(7,3,1...6)=.09 .40 .1 .35 .06 .0
:    37    S CROP1(8,3,1...6)=.09 .40 .1 .35 .06 .0
:    38    S CROP2(ALL,ALL,ALL)=.1
:    39    S CROP2(1,1,1...6)=.15 .60 .10 .05 .05 .05
:    40    S CROP2(2,1,1...6)=.15 .60 .10 .05 .05 .05
:    41    S CROP2(3,1,1...6)=.15 .60 .10 .05 .05 .05
:    42    S CROP2(4,1,1...6)=.15 .60 .10 .05 .05 .05
:    43    S CROP2(5,1,1...6)=.05 .65 .10 .20 .0 .0
:    44    S CROP2(6,1,1...6)=.05 .65 .10 .20 .0 .0
:    45    S CROP2(7,1,1...6)=.02 .60 .08 .30 .0 .0
:    46    S CROP2(8,1,1...6)=.02 .60 .08 .30 .0 .0
:    47    S CROP2(1,2,1...6)=.15 .60 .10 .05 .05 .05
:    48    S CROP2(2,2,1...6)=.15 .60 .10 .05 .05 .05
:    49    S CROP2(3,2,1...6)=.15 .60 .10 .05 .05 .05
:    50    S CROP2(4,2,1...6)=.15 .60 .10 .05 .05 .05
:    51    S CROP2(5,2,1...6)=.05 .65 .10 .20 .0 .0
:    52    S CROP2(6,2,1...6)=.05 .65 .10 .20 .0 .0
:    53    S CROP2(7,2,1...6)=.02 .60 .08 .30 .0 .0
:    54    S CROP2(8,2,1...6)=.02 .60 .08 .30 .0 .0
:    55    S CROP2(1,3,1...6)=.3 .05 .10 .05 .5 0.
:    56    S CROP2(2,3,1...6)=.3 .05 .10 .05 .5 0.
:    57    S CROP2(3,3,1...6)=.3 .05 .10 .05 .5 0.
:    58    S CROP2(4,3,1...6)=.3 .05 .10 .05 .5 0.
:    59    S CROP2(5,3,1...6)=.3 .05 .3 .1 .25 .0
:    60    S CROP2(6,3,1...6)=.3 .05 .3 .1 .25 .0
```

```
:    61    S CROP2(7,3,1...6)=.05 .2 .3 .4 .05 .0
:    62    S CROP2(8,3,1...6)=.05 .2 .3 .4 .05 .0
:    63    S CYLD(ALL,ALL,ALL,ALL)=0.0
:    64    S DEPI(1,ALL)=60. 70.
:    65    S DEPI(2,ALL)=55. 25.
:    66    S DEPI(3,ALL)=75. 50.
:    67    S DEPI(4,ALL)=40. 40.
:    68    S DEPI(5,ALL)=35. 25.
:    69    S DEPI(6,ALL)=13. 40.
:    70    S DEPI(7,ALL)=35. 40.
:    71    S DEPI(8,ALL)=20. 41.
:    72    S DEPI(9,ALL)=50. 50.
:    73    S DEPI(10,ALL)=50. 50.
:    74    S DEPI(11,ALL)=80. 40.
:    75    S ED(1...2)=.8 1.0
:    76    S EF(1...2)=.6 .7
:    77    S EPER=.9
:    78    S EPER1=.9
:    79    S FPERC(ALL)=0.
:    80    S FPERC(4...5)=.1
:    81    S FPERC(10...11)=.1
:    82    S FPERCD(ALL)=0. 0. 0. .1 0. 0. 0. 0. 0. .1 .1 0.
:    83    S FRUND(ALL)=.1
:    84    S FRUND(1...3)=1.
:    85    S FRUND(12)=1.
:    86    S GA=.75
:    87    S HNET=2.85
:    88    S RAIN(ALL,ALL)=1.0
:    89    S RAIN(ALL,1)=.5
:    90    S RAIN(ALL,2)=.5
```

```
:    91    S RAIN(ALL,3)=1.25
:    92    S RAIN(1...3,3)=1.0
:    93    S RAIN(4...5,3)=1.25
:    94    S RAIN(6...7,3)=1.5
:    95    S RAIN(8,1)=.75
:    96    S RAIN(8,2)=1.0
:    97    S RAIN(8,3)=1.75
:    98    S RAIN(ALL,4)=1.75 1.75 2.0 2.0 2.75 2.5 2.5 2.75
:    99    S RAIN(ALL,5)=3.25 3.25 3.25 3.25 3.5 3.75 3.75 4.0
:   100    S RAIN(ALL,6)=3.5 3.5 4.0 4.5 4.75 4.75 5.0 5.25
:   101    S RAIN(ALL,7)=2.75 2.75 2.75 3.0 3.0 3.25 3.5 3.0
:   102    S RAIN(ALL,8)=2.0 2.0 2.25 2.25 2.5 3.0 3.25 3.5
:   103    S RAIN(ALL,9)=1.75 1.75 2.0 2.25 2.5 3.0 3.0 3.0
:   104    S RAIN(ALL,10)=1.0 1.0 1.0 1.0 1.25 1.25 1.5 1.75
:   105    S RAIN(ALL,11)=.5
:   106    S RAIN(1...5,12)=.25
:   107    S RAIN(6...8,12)=.5
:   108    S RLOAD(1,1...6)=.1 7.5 4.5 .1 1.0 0.0
:   109    S RLOAD(2,1...6)=.1 7.5 4.5 .1 1.0 0.0
:   110    S RLOAD(3,1...6)=.1 4.5 3.8 .1 1.0 0.0
:   111    S RNET(ALL,ALL)=0.0
:   112    S RNET(ALL,1)=17. 17. 17. 13.6 12.9 12.9 12.9 12.9
:   113    S RNET(ALL,2)=13.5 13.5 13.5 10.9 10.4 10.4 10.4 10.4
:   114    S RNET(ALL,3)=12.2 12.2 12.2 10.1 9.6 9.6 9.6 9.6
:   115    S RNET(ALL,4)=13.3 13.3 13.3 11.2 10.7 10.7 10.7 10.7
:   116    S RNET(ALL,5)=9.9 9.9 9.9 8.2 7.8 7.8 7.8 7.8
:   117    S RNET(ALL,6)=17. 17. 17. 13.6 12.9 12.9 12.9 12.9
:   118    S SEAS(ALL)=0.0
:   119    S SEAS(5...9)=0. .15 .35 .35 .15
:   120    S TCHANG(ALL,ALL,ALL)=0.0
```

```
121     S TYPE1(ALL,ALL,ALL)=100.
122     S TYPE1(1,1,1...6)=0. 55. 144. 0. 123. 40.
123     S TYPE1(1,2,1...6)=10. 124. 123. 6. 125. 5.
124     S TYPE1(2,1,1...6)=0. 0. 31. 15. 1081. 5.
125     S TYPE1(2,2,1...6)=40. 3. 90. 0. 50. 0.
126     S TYPE1(3,1,1...6)=1. 5. 12. 2. 410. 0.
127     S TYPE1(3,2,1...6)=0. 38. 21. 10. 160. 5.
128     S TYPE1(4,1,1...6)=45. 195. 109. 25. 346. 0.
129     S TYPE1(4,2,1...6)=15. 78. 48. 17. 230. 15.
130     S TYPE1(5,1,1...6)=15. 385. 72. 23. 187. 48.
131     S TYPE1(5,2,1...6)=100. 144. 35. 15. 58. 8.
132     S TYPE1(6,1,1...6)=0. 175. 15. 20. 60. 30.
133     S TYPE1(6,2,1...6)=0. 52. 18. 10. 46. 12.
134     S TYPE1(7,1,1...6)=0. 152. 237. 19. 46. 20.
135     S TYPE1(7,2,1...6)=0. 55. 90. 10. 30. 11.
136     S TYPE1(8,1,1...6)=0. 67. 39. 10. 0. 12.
137     S TYPE1(8,2,1...6)=0. 93. 833. 0. 28. 141.
138     S TYPE2(ALL,ALL,ALL)=100.
139     S TYPE2(1,1,1...6)=0. 110. 144. 0. 68. 40.
140     S TYPE2(1,2,1...6)=10. 199. 123. 6. 50. 5.
141     S TYPE2(2,1,1...6)=0. 55. 31. 15. 1026. 5.
142     S TYPE2(2,2,1...6)=40. 6. 90. 0. 47. 0.
143     S TYPE2(3,1,1...6)=1. 20. 12. 2. 395. 0.
144     S TYPE2(3,2,1...6)=0. 76. 21. 10. 122. 5.
145     S TYPE2(4,1,1...6)=45. 390. 109. 25. 151. 0.
146     S TYPE2(4,2,1...6)=15. 156. 48. 17. 152. 15.
147     S TYPE2(5,1,1...6)=15. 553. 72. 23. 19. 48.
148     S TYPE2(5,2,1...6)=100. 196. 35. 15. 6. 8.
149     S TYPE2(6,1,1...6)=0. 229. 15. 20. 6. 30.
150     S TYPE2(6,2,1...6)=0. 73. 18. 10. 25. 12.
```

```
151   S TYPE2(7,1,1...6)=0. 193. 237. 19. 5. 20.
152   S TYPE2(7,2,1...6)=0. 82. 90. 10. 3. 11.
153   S TYPE2(8,1,1...6)=0. 67. 39. 10. 0. 12.
154   S TYPE2(8,2,1...6)=0. 118. 833. 0. 3. 141.
155   S WFAC(1,ALL)=1.5 1.0
156   S WFAC(2,ALL)=1.0 1.5
157   S WFAC(3,ALL)=1.0 1.0
158   S WFAC(4,ALL)=1.0 1.0
159   S WFAC(5,ALL)=1.5 1.0
160   S WFAC(6,ALL)=1.5 1.0
161   S WFAC(7,ALL)=1.538 1.0
162   S WFAC(8,ALL)=1.0 1.0
163   S WFAC(9,ALL)=1.0 1.0
164   S WFAC(10,ALL)=1.0 1.0
165   S WFAC(11,ALL)=1.0 1.0
166   S XG(1...7)=100. 200. 300. 400. 500. 750. 850.
167   S XG1(1...7)=75. 100. 200. 300. 400. 500. 750.
168   S XSUB(ALL)=0. 4. 5.
169   S XTIME(1...2)=1. 40.
170   S YG(1...7)=0. .05 .25 .6 .85 1.0 1.0
171   S YG1(1...7)=.0 .1 .32 .55 .8 .92 1.0
172   S YIELD1(ALL,ALL)=0.0
173   S YIELD1(1,1...5)=4.3 129. 94. 46. 52.
174   S YIELD1(2,1...5)=4.3 129. 94. 46. 52.
175   S YIELD1(3,1...5)=2.7 51. 59. 37. 35.
176   S YIELD1(4,1...5)=4.3 0
177   S YIELD2(ALL,ALL)=0.0
178   S YIELD2(1,1...5)=6.5 180. 150. 60. 81.
179   S YIELD2(2,1...5)=6.5 180. 150. 60. 81.
180   S YIELD2(3,1...5)=3.6 64. 88. 48. 55.
```

```
:    181     S YIELD2(4,1)=6.5
:    182     S YSUB(ALL)=1.  .25  .25
```

APPENDIX D. MUNICIPAL/INDUSTRIAL SUBMODEL FILES

```
MUNICIPAL AND INDUSTRIAL VARIABLE DEFINITIONS
=============================================

VARIABLES PRECEDED BY AN * ARE CALCULATED BY
     OTHER SUBMODELS

UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:
     I=RIVER REACH OR PROJECT AREA
     J=DIRECTION FROM RIVER
     K=HYDROELECTRIC OR THERMAL POWER PLANT

  WHERE

     I=1=LEWELLEN TO NORTH PLATTE
     I=2=JULESBURG TO NORTH PLATTE
     I=3=NORTH PLATTE TO BRADY
     I=4=BRADY TO OVERTON
     I=5=OVERTON TO GRAND ISLAND
     I=6=GRAND ISLAND TO DUNCAN
     I=7=DUNCAN TO NORTH BEND
     I=8=NORTH BEND TO LOUISVILLE

     J=1=NORTH OF RIVER
     J=2=SOUTH OF RIVER

     K=1=HYDROELECTRIC PLANT
     K=2=THERMAL PLANT

ATIME=X-ARRAY FOR XS SLP-FUNCTION (YEARS FROM 1982 TO 2030)
DEOUT(I,K)=ANNUAL GROWTH IN ENERGY PRODUCTION (DECIMAL
```

```
:     31                FRACTION)
:     32      DPCWU(I)=ANNUAL GROWTH IN AVERAGE ANNUAL PER CAPITA WATER
:     33              USE (ACRE-FT)
:     34      DPOP(I)=ANNUAL POPULATION GROWTH RATE (DECIMAL FRACTION)
:     35      DPROP(I,J)=FRACTION OF PUMPED WATER WHICH IS RETURN
:     36                FLOW-VARIATION BY AREA
:     37      * DSCH(I,J)=GAIN OR LOSS TO THE RIVER IN CURRENT MONTH
:     38                (ACRE-FT). IF DSCH IS NEGATIVE, MOVEMENT IS
:     39                FROM THE RIVER TO GROUNDWATER; IF POSITIVE,
:     40                MOVEMENT IS FROM GROUNDWATER TO THE RIVER.
:     41                <FROM GROUNDWATER SUBMODEL>
:     42      DX=TEMPORARY VARIABLE FOR CALCULATING PNIT(I,J)
:     43      EOUT(I,K)=ANNUAL ENERGY PRODUCTION (MEGAWATT-HOURS)
:     44      EOUTM(IMONTH)=FRACTION OF ANNUAL ENERGY PRODUCTION
:     45                  PRODUCED IN EACH MONTH
:     46      EOUTR(I,K)=FRACTION OF WATER FOR ENERGY PRODUCTION
:     47                WHICH IS RETURN FLOW
:     48      EOUTW(I,K)=WATER CONSUMPTION PER MEGAWATT-HOUR (ACRE-FT)
:     49      EPL(I,J)=DESIGNATES WHETHER A THERMAL PLANT IN A REACH
:     50              IS NORTH OR SOUTH OF THE RIVER
:     51      * GNIT(I,J)=GROUNDWATER NITRATE CONCENTRATION (PPM)
:     52                <FROM GROUNDWATER SUBMODEL>
:     53      * GWS(I,J)=GROUNDWATER IN STORAGE (ACRE-FT)
:     54                <FROM GROUNDWATER SUBMODEL>
:     55      PCWU(I)=AVERAGE ANNUAL PER CAPITA WATER USE (ACRE-FT)
:     56      PNIT(I,J)=RELATIVE CONTRIBUTION OF SURFACE WATER TO
:     57              MUNICIPAL WELL FIELD NITRATE CONCENTRATIONS
:     58      POP(I,J)=HUMAN POPULATION SIZE
:     59      PUMPMI(I,J)=AMOUNT OF MUNICIPAL AND INDUSTRIAL
:     60                PUMPING (ACRE-FT)
```

```
PX=ENERGY PRODUCTION WATER CONSUMPTION (ACRE-FT)
RETMI(I)=MUNICIPAL AND INDUSTRIAL RETURN FLOW (ACRE-FT)
RFPROP(IMONTH)=FRACTION OF PUMPED WATER WHICH IS RETURN
                FLOW-MONTHLY VARIATION
* SNIT(I)=SURFACE WATER NITRATE CONCENTRATION (PPM)
          <FROM SURFACE WATER SUBMODEL>
TPROP(IMONTH)=PROPORTION OF PCWU(I) USED DURING
               EACH MONTH
UPOP(I,J)=FRACTION OF THE HUMAN POPULATION RESIDING IN
          MUNICIPAL AREAS
XNIT(I,J)=NITRATE CONCENTRATION IN MUNICIPAL WELL
          FIELDS (PPM)
XS=MUNICIPAL AND INDUSTRIAL PUMPING IN OMAHA (ACRE-FT)
YTIME=Y-ARRAY FOR XS SLP-FUNCTION(ACRE-FT PUMPED DAILY)
ZDMAX(I,J)=HYPOTHESIZED MAXIMUM VALUE OF DSCH(I,J) (ACRE-FT)
```

```
      SUBROUTINE XMIND
$CONTINUE WITH PLATTE.C RETURN
C
C MUNICIPAL,INDUSTRIAL, AND ELECTRIC ENERGY
C
C LOOP OVER REACHES
C
      DO 1000 I=1,8
C.....PER CAPITA WATER USE
       IF(IMONTH.GT.1) GO TO 1005
      PCWU(I)=PCWU(I)+DPCWU(I)
 1005 CONTINUE
      DO 1010 J=1,2
      PUMPMI(I,J)=0
C.....HUMAN POPULATION SIZE
      IF(IMONTH.GT.1)GO TO 1006
      POP(I,J)=POP(I,J)*(1+DPOP(I))
 1006 CONTINUE
C.....WELL FIELD NITRATE CONCENTRATIONS
      DX=DSCH(I,J)/ZDMAX(I,J)
      PNIT(I,J)=1-DX
      IF(PNIT(I,J).LT..10)PNIT(I,J)=.10
      IF(PNIT(I,J).GT..90)PNIT(I,J)=.90
      XNIT(I,J)=(SNIT(I)*PNIT(I,J))+(GNIT(I,J)*(1-PNIT(I,J)))
C.....MUNICIPAL & INDUSTRIAL PUMPING AND RETURN FLOWS
      PUMPMI(I,J)=POP(I,J)*PCWU(I)*TPROP(IMONTH)*UPOP(I,J)
      IF(PUMPMI(I,J).GT.GWS(I,J))PUMPMI(I,J)=GWS(I,J)
      GWS(I,J)=GWS(I,J)-PUMPMI(I,J)
      RETMI(I)=PUMPMI(I,J)*RFPROP(IMONTH)*DPROP(I,J)
 1010 CONTINUE
```

```
 1000 CONTINUE
C
C OMAHA WATER USE
C
      XS=SLP(IYEAR,ATIME,YTIME,6)*30.
      IF(XS.GT.GWS(8,1))XS=GWS(8,1)
      GWS(8,1)=GWS(8,1)-XS
      PUMPMI(8,1)=PUMPMI(8,1)+XS
      RETMI(8)=PUMPMI(8,1)*RFPROP(IMONTH)*DPROP(8,1)
C
C ELECTRIC ENERGY PRODUCTION AND WATER USE
C
      DO 1100 I=1,8
      DO 1020 K=1,2
      IF(IMONTH.GT.1)GOTO 1127
      EOUT(I,K)=EOUT(I,K)*(1+DEOUT(I,K))
 1127 CONTINUE
      DO 1030 J=1,2
      PX=EOUT(I,K)*EOUTM(IMONTH)*EOUTW(I,K)*EPL(I,J)
      PUMPMI(I,J)=PX+PUMPMI(I,J)
      RETMI(I)=RETMI(I)+(PX*EOUTR(I,K))
 1030 CONTINUE
 1020 CONTINUE
 1100 CONTINUE
      RETURN
      END
```

```
COMMON PCWU(11),DPCWU(11),POP(11,2),DPOP(11)
COMMON ZOMAX(11,2)
COMMON XNIT(11,2),PNIT(11,2)
COMMON PUMPMI(11,2),TROP(12),RETMI(11)
COMMON DPROP(11,2),RFPROP(12),TPROP(12)
COMMON ATIME(6),YTIME(6)
COMMON EOUT(11,2),EOUTR(11,2),DEOUT(11,2),EPL(11,2)
COMMON EOUTW(11,2),EOUTM(12)
COMMON UPOP(11,2)
```

```
1    S POP(ALL,1)=31253 4104 1324 21344 77692 8737 10909 31250  0
2    S POP(ALL,2)=2280 893 470 2778 3248 960 5346 204599 0
3    S UPOP(ALL,1)=.95 0 .40 .75 .83 .55 .50 .90
4    S UPOP(ALL,2)=.50 0 0 .05 .05 0 .50 .90
5    S DPROP(ALL,1)=.95 0 .25 .75 .85 .50 0 .85
6    S DPROP(ALL,2)=0 0 0 .07 .05 0 .35 .90
7    S YTIME(ALL)=92 111 162 294 296 296
8    S ATIME(ALL)=0 10 20 43 44 100
9    S TPROP(ALL)=.50 .75 .75 1. 1.25 1.75 1.75 1.25 1. .75 .75 .50

10   S PNIT(ALL,ALL)=.90
11   S RFPROP(ALL)=.50 .50 .60 .70 .75 .85 .85 .75 .70 .60 .50 .50
12   S DPROP(ALL,ALL)=.50
13   S EOUT(ALL,1)=0 250000 147463 326458 620 0
14   S EOUT(ALL,2)=5124600 0 0 638000 0 168600 9400 1000850 0
15   S EOUTR(ALL,ALL)=0
16   S EOUTR(ALL,2)=.01
17   S EOUTW(ALL,1)=0
18   S EOUTW(ALL,2)=.0018
19   S RETMI(ALL)=0
20   S PUMPMI(ALL,ALL)=0
21   S EOUTM(ALL)=.06 .06 .06 .06 .08 .11 .13 .13 .11 .08 .06 .06
22   S EPL(ALL,1)=0 0 0 0 0 1 1 0
23   S EPL(ALL,2)=1 0 0 1 0 0 0 1 0
24   S PCWU(ALL)=.04
25   S ZDMAX(ALL,ALL)=10000.
26   S DPCWU(ALL)=.0001
27   S DEOUT(ALL,ALL)=0
28   S DEOUT(1,2)=.02
29   S PNIT(ALL,ALL)=0
30   S DPOP(ALL)=.02
```

```
31      S DPOP(ALL)=.02
```

APPENDIX E. WILDLIFE/RECREATIONAL SUBMODEL FILES

```
1   ************************************************************
2   ************************************************************
3   ***********  PLATTE RIVER FORUM FOR THE FUTURE  ************
4   ***********        NOVEMBER 17, 1982            ************
5   ***********    WILDLIFE/RECREATION SUBMODEL     ************
6   ************************************************************
7   ************************************************************
8
9                        VARIABLE DEFINITIONS
10
11  ============================================================
12
13  UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:
14        IA=DIRECTION FROM RIVER (FOR REACHES ONLY)
15        IL=LOOP COUNTER FOR AGE CLASSES OF SHRUBS
16        IM=MONTH
17        IML=MEADOW AGE CLASSES
18        IR=RIVER REACH
19        ISL=SHRUB AGE CLASSES
20        IT=RIPARIAN HABITAT TYPE
21
22     WHERE:
23
24        IA=1=NORTH OF RIVER
25        IA=2=SOUTH OF RIVER
26
27        IM=1...12 (JAN...DEC)
28
29        IML=1...3 (MEADOW HAS THREE AGE CLASSES)
30
```

```
31          IR=1=LEWELLEN TO NORTH PLATTE
32          IR=2=JULESBURG TO NORTH PLATTE
33          IR=3=NORTH PLATTE TO BRADY
34          IR=4=BRADY TO OVERTON
35          IR=5=OVERTON TO GRAND ISLAND
36          IR=6=GRAND ISLAND TO DUNCAN
37          IR=7=DUNCAN TO NORTH BEND
38          IR=8=NORTH BEND TO LOUISVILLE
39
40          ISL=1...5 (SHRUB HAS FIVE AGE CLASSES)
41
42          IT=1=SAND BAR
43          IT=2=MEADOW
44          IT=3=SHRUB
45          IT=4=TREE
46
47     ==========================================================
48
49     * ACRE(IR,IA,4,6)=SUBIRRIGATED NATIVE HAY < FROM
50                        AGRICULTURE SUBMODEL >
51     ADJF(IR)=ADJUSTMENT OF FLOWS (CFS) TO REFLECT RELATIONSHIP TO
52              FLOW IN REACH 5.  THIS IS USED TO ENABLE USE OF
53              FUNCTIONAL RELATIONSHIPS DEVELOPED FOR REACH 5
54              TO BE USED IN OTHER REACHES. CURRENT VALUES (BY
55              REACH): 1=0.5, 2=2.0, 3=0.5, 4=1.0, 5=1.0, 6=1.0,
56              7=3.0, 8=4.0.
57     AFLOW(IR)=FLOW IN REACH ADJUSTED TO REFLECT RELATIONSHIP TO
58               REACH 5.
59     BOAT(IR,IA)=BOATER USE-DAYS BY REACH AND DIRECTION
60
```

```
BOATP(IR,IA)=BOATER USE-DAYS ADDED DUE TO A  SPECIFIC
             PROJECT.
BOATR(IR)=BOATER USE-DAYS BY REACH
BOATS(IR)=BOATER USE-DAYS AT START OF MODEL RUN.
BPAC=BOATER USE-DAYS/SURFACE ACRE OF FLAT WATER,
     CURRENT VALUE=10.
CCAT(IR)=CHANNEL CATFISH HABITAT RELATIVE TO AMOUNT
         PRESENT AT START OF MODEL RUN.
CMINN(IR)=CYPRINID MINNOW HABITAT RELATIVE TO AMOUNT
          PRESENT AT START OF MODEL RUN.
CRANE(IR)=CRANE HABITAT RELATIVE TO AMOUNT PRESENT
          AT START OF MODEL RUN.
CRFEED(IR)=CRANE FEEDING HABITAT RELATIVE TO AMOUNT
           AT START OF MODEL RUN.
CRFR(IR)=ACRES OF SUBIRRIAGTED NATIVE HAY (ASSUMED TO BE THE
         "WET MEADOWS" CRANES USE FOR FEEDING HABITAT).
         VALUE OBTAINED FROM AGRICULTURE SUBMODEL UNDER
         ASSUMPTION THAT ALL ACRES LIE WITHIN 3.5 MILES
         OF EITHER SIDE OF THE RIVER.
CRFS(IR)=CRANE FEEDING HABITAT AT START OF MODEL RUN.
CVIEW=CRANE VIEWING USE-DAYS.
CVIEWS=CRANE VIEWING USE-DAYS AT START OF MODEL RUN.
DHABM(IR)=DUCK MIGRATORY/HUNTING HABITAT RELATIVE TO
          AMOUNT AT START OF MODEL RUN.
DOLAC(IT)=VALUE/ACRE ($) OF RIPARIAN HABITAT TYPES.
DSAND(IR)=FRACTION OF SAND BARS CONVERTING TO FIRST YEAR
          MEADOW TYPE.
DVIEW=AVERAGE HUMAN POPULATION PER REACH RELATIVE
      TO START OF MODEL RUN.
ETDIST(IR)=EVAPOTRANSPIRATION (ET) (ACRE-FT/YR),
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```
:    91                MONTHLY DISTRIBUTION OF ANNUAL TOTAL.
:    92      ETMD(IR)=EST (ACRE-FT) FOR MEADOW TYPE.
:    93      ETMDR=MAX EST (ACRE-FT) FOR MEADOW TYPE.
:    94      ETR(IR,IA)=MONTHLY EST (ACRE-FT) FOR SUBTRACTION FROM
:    95                GROUNDWATER SUPPLIES.  NOTE: FOR THIS VARIABLE
:    96                ONLY, IR=11 FOR COMPATABILITY WITH THE GROUNDWATER
:    97                SUBMODEL.  VALUES FOR IR=9...11 ARE ALWAYS 0..
:    98      ETSD(IR)=ET (ACRE-FT) FOR SAND BAR TYPE.
:    99      ETSDR=MAXIMUM ANNUAL ET (ACRE-FT) FOR SAND BAR TYPE.
:   100      ETSH(IR)=ET (ACRE-FT) FOR SHRUB TYPE.
:   101      ETSHR=MAXIMUM ANNUAL ET (ACRE-FT) FOR SHRUB TYPE.
:   102      ETTR(IR)=ET (ACRE-FT) FOR TREE TYPE.
:   103      ETTRR=MAXIMUM ANNUAL ET FOR TREE TYPE (ACRE-FT/YR)
:   104      FISH(IR,IA)=FISHING USE-DAYS BY REACH AND DIRECTION
:   105      FISHP(IR,IA)=NUMBER FISHING USE-DAYS ADDED DUE TO A
:   106                  SPECIFIC PROJECT.
:   107      FISHR(IR)=FISHING USE-DAYS BY REACH BY REACH
:   108      FISHS(IR)=NUMBER FISHING USE-DAYS AT START OF MODEL RUN.
:   109      FLO1=TEMPORARY VARIABLE TO STORE JUNE VALUE OF FLOMAX.
:   110      * FLOMAX=MAXIMUM DAILY FLOW AT GRAND ISLAND IN CFS < FROM
:   111               SURFACE WATER SUBMODEL >
:   112      FLOTAR(IR,IM)=ACRE-FT/MONTH REQUESTED TO MEET
:   113                   INSTREAM FLOW NEEDS.
:   114      FOR(IR)=SUM OF SHRUB AND TREE ACRES.
:   115      FORS(IR)=SUM OF SHRUB AND TREE ACRES AT START OF
:   116               MODEL RUN.
:   117      FORSP(IR)=FOREST SPECIES HABITAT RELATIVE TO AMOUNT AT
:   118                START OF MODEL RUN
:   119      FPAC=NUMBER FISHING USE-DAYS/SURFACE ACRE OF FLAT WATER,
:   120           CURRENT VALUE=0.
```

```
GLAG(IR,IML)=ACRES OF MEADOW IN EACH AGE CLASS
GRASS(IR)=ACRES OF RIPARIAN MEADOW TYPE.
* GWS(IR,IA)=GROUNDWATER IN STORAGE AT END OF CURRENT MONTH
                (ACRE-FT) < FROM GROUNDWATER SUBMODEL >
HACRE(IR,IA)=NUMBER OF ACRES ADDED BY A NEW PROJECT AND
                AVAILABLE FOR HUNTING.
HPAC=HUNTING USE DAYS/SURFACE ACRE DUE TO ADDITION
     OF NEW RESERVOIRS.  CURRENT VALUE=0.
HUNT(IR,IA)=HUNTING USE-DAYS BY REACH AND DIRECTION
HUNTP(IR,IA)=HUNTING USE-DAYS ADDED DUE TO A
                SPECIFIC PROJECT.
HUNTR(IR)=HUNTING USE-DAYS BY REACH
HUNTS(IR)=HUNTING USE-DAYS AT START OF A MODEL RUN.
ISHMNT=SWITCH (0=OFF, 1=ON) TO DETERMINE IF MECHANICAL
        REMOVAL OF SHRUBS IS DONE TO MAINTAIN
        SAND BARS.
ITRMNT=SWITCH (0=OFF,1=ON) TO DETERMINE IF MECHANICAL
        MAINTENANCE OF TREES IS DONE TO MAINTAIN
        SAND BARS.
* POP(IR,IA)=HUMAN POPULATION BY REACH AND BY AREA
                < FROM MUNICIPAL/INDUSTRIAL SUBMODEL ***
POPI(IR)=HUMAN POPULATION BY REACH (BOTH SIDES OF RIVER) AT
          BEGINNING OF MODEL RUN.
POPM(IR)=HUMAN POPULATION RELATIVE TO NUMBER AT START
          OF MODEL RUN.
POPS(IR)=HUMAN POPULATION AT START OF MODEL RUN.
ROOST(IR)=CRANE ROOSTING HABITAT RELATIVE TO AMOUNT
           AT START OF MODEL RUN.
RWIDTH=GREATER OF: CALCULATED WIDTH (SWIDTH), OR SET
        VALUE (VWIDTH) TO REPRESENT MECHANICAL MANIPULATION
```

```
151          OF RIPARIAN VEGETATION.
152     SAND(IR)=ACRES OF SAND BAR.
153     SAMNT(IR)=ACRES OF SAND BAR RECOVERED BY MAINTENANCE.
154     * SCOUR=NUMBER OF TIMES DAILY FLOW EQUALS OR EXCEEDS 3800 CFS
155             DURING A YEAR - NOTE: CURRENTLY CALCULATED FOR
156             REACH 5 ONLY. < FROM SURFACE WATER SUBMODEL >
157     SHLAG(IR,ISL)=ACRES OF SHRUB IN EACH AGE CLASS
158     SHMNT(IR)=ACRES OF SHRUB THAT MUST BE PUT BACK INTO
159               SANDBAR TO MAINTAIN THE SAND BAR ACREAGE.
160     SHRIP(IR)=ACRES (OVER MAINTENANCE) THAT ARE REMOVED FROM
161               SHRUB AND PUT INTO SAND BARS.
162     SHRUB(IR)=ACRES OF SHRUB TYPE.
163     SPOPM=SUM OF VALUES FOR POPM(IR).
164     SURFAC(IR,IA)=NUMBER OF SURFACE ACRES OF WATER ADDED BY A NEW
165                   PROJECT AND AVAILABLE FOR BOATING AND FISHING.
166     * SWIDTH=RIVER WIDTH IN FT AT GRAND ISLAND < FROM SUFFACE
167             WATER SUBMODEL >
168     TAR(IR)=TARFLOW(IR,IM) -- FOR SUBSCRIPT COMPATIBILITY WITH
169             SURFACE WATER SUBMODEL.
170     TARFLO(IR,IM)=DAILY FLOW IN CFS NEEDED TO MEET INSTREAM
171                   FLOW NEEDS.
172     TERN(IR)=TERN NESTING HABITAT - FRACTION OF AMOUNT
173             AVAILABLE AT START OF MODEL RUN.
174     TETR(IR)=TOTAL ET (ACRE-FT, ALL AGE CLASSES).
175     * TFLOWC(IR)=FLOW AT THE TOP OF THE REACH IN CFS < FROM
176                 SURFACE WATER SUBMODEL >
177     TMED=TOTAL ACRES OF MEADOW TYPE FOR RIVER.
178     TREE=ACRES OF RIPARIAN TREE TYPE.
179     TRMNT(IR)=ACRES OF TREE HABITAT THAT MUST BE PUT BACK
180               INTO SAND BARS TO MAINTAIN THE SAND BAR ACREAGE.
```

```
TRRIP(IR)=ACRES OF TREES (OVER MAINTENANCE) THAT ARE
          REMOVED AND PUT INTO SAND BAR FROM TREES.
TSAND=TOTAL ACRES OF SAND BAR TYPE FOR RIVER.
TSHRUB=TOTAL ACRES OF SHRUB TYPE FOR RIVER.
TTREE=TOTAL ACRES OF TREE TYPE FOR RIVER.
VALHAB(IR,IT)=DOLLAR VALUE OF EACH RIPARIAN HABITAT TYPE
              IN 1982 DOLLARS.
VIEW(IR,IA)=GENERAL RECREATION USE-DAYS BY REACH
            AND DIRECTION
VIEWP(IR,IA)=GENERAL RECREATION USE-DAYS ADDED BY A SPECIFIC
             NEW PROJECT.
VIEWR(IR)=GENERAL RECREATION USE-DAYS BY REACH
VIEWS(IR)=GENERAL RECREATION USE-DAYS BY REACH ON BOTH SIDES
          OF THE RIVER AT START OF MODEL RUN.
VISIT=TOTAL RECREATION USE-DAYS FROM ALL SOURCES (EXCEPT
      CRANE VIEWING) FOR REACHES 1 THROUGH 8.
VPAC=GENERAL RECREATION USE-DAYS OR HUNTING PER ACRE DUE
     TO ADDITION OF A SPECIFIC NEW PROJECT.
VWIDTH(IR)=RIVER WIDTH (FT) - USED TO ALTER WIDTH
           OF RIVER FOR HABITAT MANIPULATION.
* WIDTH(IR)=RIVER WIDTH (FT) < FROM SURFACE
           WATER SUBMODEL >

=================================================================

*****FOLLOWING ARE THE X-AXIS AND Y-AXIS VARIABLE
     NAMES FOR THE VARIOUS FUNCTIONAL RELATIONSHIPS.


     FORMAT:
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```
211                 PREDICTED VARIABLE NAME, X-AXIS VARIABLE NAME,
212                 Y-AXIS VARIABLE NAME, NUMBER OF X:Y PAIRS.
213
214      CCAT:XCCP,YCCP,4 - SUMMER PRODUCTION
215           :XCCS,YCCS,4 - SPAWNING
216           :XCCW,YCCW,4 - OVERWINTERING
217      CMINN:XCMP,YCMP,4 - SUMMER PRODUCTION
218            :XCMS,YCMS,4 - SPAWNING
219            :XCMW,YCMW,4 - OVERWINTERING
220      DHABM:XDM,YDM,4
221      DSAND:XMED,YMED,4
222      ROOST:XCR,YCR,4
223
224      ==========================================================
225
226      ************************************************************
227      ************************************************************
228      ************   END OF VARIABLE DEFINITIONS   **************
229      ************              FOR                **************
230      ************   WILDLIFE/RECREATION SUBMODEL  **************
231      ************************************************************
232      ************************************************************
```

```
      SUBROUTINE WILD(ITIME)
CCONTINUE WITH PLATTE.C RETURN
C
C*****************************************************
C*****************************************************
C**********  WILDLIFE-RECREATION SUBROUTINE **********
C**********        NOVEMBER 15, 1982         **********
C**********   ORIGINALLY BY: KENT ANDREWS    **********
C**********   U S FISH & WILDLIFE SERVICE    **********
C**********        2627 REDWING ROAD         **********
C**********  FORT COLLINS, COLORADO 80526    **********
C**********          (303) 226-9432          **********
C*****************************************************
C*****************************************************
C
C=====================================================
C
C.....ZERO TEMPROARY VARIABLES AT MONTH 1 OF EACH
C        SIMULATION YEAR.
C
      IF (IMONTH .NE. 1) GO TO 30
      CVIEW = 0.
      SPOPM = 0.
      TSAND = 0.
      TMED = 0.
      TSHRUB = 0.
      TTREE = 0.
      VISIT = 0.
      DO 20 IR = 1, 8
        CRFR(IR) = 0.
```

```
      POPI(IR) = 0.
      SAMNT(IR) = 0.
      SHMNT(IR) = 0.
      TRMNT(IR) = 0.
      DO 10 IA = 1, 2
        BOATP(IR,IA) = 0.
        FISHP(IR,IA) = 0.
        HUNTP(IR,IA) = 0.
        VIEWP(IR,IA) = 0.
   10 CONTINUE
   20 CONTINUE
   30 CONTINUE
C
C=================================================
C
C.....RIPARIAN VEGETATION SECTION
C
C
C  CALCULATE SUCCESSION - CALCULATE MONTH 1 OF
C     EACH SIMULATION YEAR.
C
      IF (IMONTH .GT. 1) GO TO 90
      DO 70 IR = 1, 8
C
C  RATE OF SAND BAR LOSS BASED ON # OF TIMES
C     FLOW IS EQUAL OR GREATER THAN 3800 CFS DURING YEAR
C
C  SCOUR CALCULATED IN SURFACE WATER SUBMODEL
C
      DSAND(IR) = SLP(SCOUR,XMED,YMED,4)
```

```
C
C  MOVE YEAR CLASSES THROUGH MEADOW AND SHRUB TYPES
C    ASSUMING 3 YEARS FROM THE TIME LAND ENTERS
C    MEADOW UNTIL IT BECOMES SHRUB AND 5 YEARS
C    FROM THE TIME LAND ENTERS SHRUB UNTIL IT
C    BECOMES TREE.
C
          GLAG(IR,3) = GLAG(IR,2)
          GLAG(IR,2) = GLAG(IR,1)
          GLAG(IR,1) = DSAND(IR) * SAND(IR)
          GRASS(IR) = GRASS(IR) + GLAG(IR,1)
          GRASS(IR) = GRASS(IR) - GLAG(IR,3)
          SHRUB(IR) = SHRUB(IR) + GLAG(IR,3)
          DO 40 IL = 1, 4
            ISL = 6 - IL
            SHLAG(IR,ISL) = SHLAG(IR,ISL - 1)
40        CONTINUE
          SHLAG(IR,1) = GLAG(IR,3)
C
C  SET BACK SUCCESSION DUE TO MECHANICAL MEANS
C     CAN BE DONE JUST TO EQUAL LOSS OF SAND BARS
C     (SAMNT) OR THE AMOUNT REMOVED FROM SHRUB OR
C     TREE TYPES CAN BE SPECIFIED(SHRIP OR TRRIP).
C
          IF (ISHMNT .EQ. 0) GO TO 50
C
C  CALCULATE AMOUNT OF SHRUB HABITAT THAT MUST
C     BE CONVERTED TO SAND BAR TO EQUAL SAND
C     BAR LOSSES.
C
```

```
      SHMNT(IR) = DSAND(IR) * SAND(IR)
   50 CONTINUE
      IF (ITRMNT .EQ. 0) GO TO 60
C
C  CALCULATE AMOUNT OF TREE HABITAT THAT MUST
C     BE CONVERTED TO SAND BAR TO EQUAL SAND
C     BAR LOSSES.
C
      TRMNT(IR) = DSAND(IR) * SAND(IR)
   60 CONTINUE
C
C  CALCULATE TOTAL ACRES TO BE ADDED TO SAND BARS
C
      SAMNT(IR) = SAMNT(IR) + SHMNT(IR) + TRMNT(IR) +
     1            SHRIP(IR) + TRRIP(IR)
C
C  CORRECT TOTAL ACRES OF SAND BAR TO REFLECT
C    MAINTENANCE ACTIVITIES.
C
      SAND(IR) = SAND(IR) - (DSAND(IR)*SAND(IR)) +
     1           SAMNT(IR)
C
C  CORRECT THE APPROPRIATE HABITAT AGE CLASS AND
C    TOTAL HABITAT ACREAGE FOR SAND BAR
C    MAINTENANCE ACTIVITIES.
C
      SHLAG(IR,1) = SHLAG(IR,1) - SHMNT(IR) - SHRIP(IR)
      SHRUB(IR) = SHRUB(IR) - SHLAG(IR,5) -
     1            SHMNT(IR) - SHRIP(IR)
      TREE(IR) = TREE(IR) + SHLAG(IR,5) -
```

```
     1                TRMNT(IR) - TRRIP(IR)
        SAND(IR) = SAND(IR) + SHRIP(IR) + TRRIP(IR)
C
C   DOLLAR VALUE OF EACH HABITAT TYPE  BY REACH.
C     CALCULATE MONTH 1 OF EACH SIMULATION YEAR
C
        VALHAB(IR,1) = SAND(IR)*DOLAC(1)
        VALHAB(IR,2) = GRASS(IR)*DOLAC(2)
        VALHAB(IR,3) = SHRUB(IR)*DOLAC(3)
        VALHAB(IR,4) = TREE(IR)*DOLAC(4)
   70 CONTINUE
C
C  TOTAL ACRES BY SUCCESSION TYPE(ENTIRE RIVER)
C     CALCULATE MONTH 1 OF EACH SIMULATION YEAR.
C
     DO 80 IR = 1, 8
        TSAND = TSAND + SAND(IR)
        TMED = TMED + GRASS(IR)
        TSHRUB = TSHRUB + SHRUB(IR)
        TTREE = TTREE + TREE(IR)
   80 CONTINUE
   90 CONTINUE
C
C  EVAPOTRANSPORTRATION - CALCULATE MONTHLY.
C
     DO 110 IR = 1, 8
C
C  DISTRIBUTE ANNUAL ET OF EACH HABITAT TYPE ACROSS MONTHS
C
        DUM = ETDIST(IMONTH)
```

```
151              ETSD(IR) = ETSDR * DUM * SAND(IR)
152              ETMD(IR) = ETMDR * DUM * GRASS(IR)
153              ETSH(IR) = ETSHR * DUM * SHRUB(IR)
154              ETTR(IR) = ETTRR * DUM * TREE(IR)
155              TETR(IR) = ETSD(IR) + ETMD(IR) + ETSH(IR) + ETTR(IR)
156              DO 100 IA = 1, 2
157       C
158       C  DIVIDE REACH ET NORTH AND SOUTH OF RIVER
159       C
160                 ETR(IR,IA) = TETR(IR) / 2.
161       C
162       C  CHECK IF ENOUGH GROUND WATER TO SUPPLY ET
163       C
164                 ETR(IR,IA) = AMIN1(ETR(IR,IA),GWS(IR,IA))
165       C
166       C  REMOVE ET FROM GROUND WATER
167       C
168                 GWS(IR,IA) = GWS(IR,IA) - ETR(IR,IA)
169          100   CONTINUE
170          110 CONTINUE
171       C
172       C==========================================================
173       C
174       C  ADJUST FLOWS RECEIVED TO COMMON BASE OF REACH 5
175       C   AND CONVERT FLOW TARGETS FROM CFS TO AC FT
176       C
177             DO 130 IR = 1, 8
178               AFLOW(IR) = TFLOWC(IR) / ADJF(IR)
179       C       TFLOWC CALCULATED BY SURFACE WATER SUBMODEL.
180       C
```

```
      DO 120 IM = 1, 12
        FLOTAR(IR,IM) = TARFLO(IR,IM) / 0.0168
C  DIVISION BY 0.0168 CONVERTS FROM
C    CFS TO ACRE-FT/MONTH.
C
        TAR(IR) = TARFLO(IR,IM)
  120   CONTINUE
  130 CONTINUE
C
C==================================================
C
C.....CRANE HABITAT SECTION
C
     DO 170 IR = 4, 5
       IF (IMONTH .NE. 1) GO TO 150
       DO 140 IA = 1, 2
C
C  CALCULATE TOTAL WET MEADOWS THIS YEAR(ASSUME ALL
C    WET MEADOWS OCCUR WITHIN 3.5 MILES OF RIVER)
C
        CRFR(IR) = CRFR(IR) + ACRE(IR,IA,4,6)
  140   CONTINUE
C
C  WET MEADOWS THIS YEAR RELATIVE TO START OF RUN.
C
       CRFEED(IR) = CRFR(IR) / CRFS(IR)
  150  CONTINUE
       IF (IMONTH .EQ. 1) GO TO 160
       IF (IMONTH .GT. 5 .OR. IMONTH .LT. 10) GO TO 160
       IF (IMONTH .EQ. 12) GO TO 160
```

```
C
C
C  SET RIVER WIDTH (RWIDTH) TO GREATER OF: VALUE
C    CALCULATED BY SURFACE WATER SUBMODEL(SWIDTH)
C    OR VALUE SET (VWIDTH) DUE TO MECHANICAL
C    ALTERATION.
C
        RWIDTH = AMAX1(VWIDTH(IR),SWIDTH)
C
C  ROOSTING HABITAT (RELATIVE TO START OF RUN)
C     BASED ON RIVER WIDTH
C
        ROOST(IR) = SLP(RWIDTH,XCR,YCR,4)
C
C  RELATIVE CRANE HABITAT NOW.
C
        CRANE(IR) = AMIN1(CRFEED(IR),ROOST(IR))
  160   CONTINUE
  170 CONTINUE
C
C==================================================
C
C.....TERN NESTING SUCCESS SECTION
C
        IF (IMONTH .EQ. 6) FLO1 = FLOMAX
        IF(IMONTH .NE. 6) GO TO 181
        DO 180 IR = 1, 8
        TERN(IR)=1.0
C
C  CHECK TO SEE IF FLOW LOW ENOUGH TO LEAVE
```

```
C      EXPOSED NESTING HABITAT
C
         IF (AFLOW(IR) .GE. (1500.*ADJF(IR))) TERN(IR) = 0.
  180 CONTINUE
  181 CONTINUE
      IF (IMONTH .LT. 7 .OR. IMONTH .GT. 8) GO TO 190
C
C  CHECK TO SEE IF NESTS ARE DROWNED OUT
C
      DO 185 IR = 1, 8
         IF (FLOMAX .GT. FLO1) TERN(IR) = 0.
  185 CONTINUE
  190 CONTINUE
      IF (IMONTH .NE. 8) GO TO 210
      DO 200 IR = 1, 8
         TERN(IR) = 0.
  200 CONTINUE
  210 CONTINUE
C
C==================================================
C
C.....DUCK HABITAT SECTION
C
      DO 240 IR = 2, 8
C
C  MIGRATORY & HUNTING HABITAT
C
         IF (IMONTH .EQ. 2) GO TO 220
         IF (IMONTH .EQ. 3) GO TO 220
         IF (IMONTH .EQ. 4) GO TO 220
```

```
271              IF (IMONTH .EQ. 10) GO TO 220
272              IF (IMONTH .EQ. 11) GO TO 220
273              GO TO 230
274        C
275        C  AMOUNT OF MIGRATORY/HUNTING HABITAT RELATIVE
276        C     START OF RUN BASED ON FLOW
277        C
278          220   DHABM(IR) = SLP(AFLOW(IR),XDM,YDM,4)
279          230   CONTINUE
280          240 CONTINUE
281        C
282        C==================================================
283        C
284        C.....FISH HABITAT SECTION
285        C
286        C  CHANNEL CATFISH HABITAT
287        C
288              DO 250 IR = 2, 8
289        C
290        C  RELATIVE CHANNEL CAT WINTER HABITAT BASED ON FLOW
291        C
292              IF (IMONTH .LT. 6) CCAT(IR) =
293            1                    SLP(AFLOW(IR),XCCW,YCCW,4)
294              IF (IMONTH .GT. 9) CCAT(IR) =
295            1                    SLP(AFLOW(IR),XCCW,YCCW,4)
296        C
297        C  RELATIVE CHANNEL CAT SPAWNING HABITAT BASED ON FLOW
298        C
299              IF (IMONTH .EQ. 6) CCAT(IR) =
300            1                    SLP(AFLOW(IR),XCCS,YCCS,4)
```

```
C
C  RELATIVE CHANNEL CAT SUMMER PRODUCTION(REARING) HABITAT
C      BASED ON FLOW
C
          IF (IMONTH .GT. 6 .AND. IMONTH .LT. 10) CCAT(IR) =
     1          SLP(AFLOW(IR),XCCP,YCCP,4)
  250 CONTINUE
C
C  FORAGE FISH(CYPRINID MINNOW) HABITAT
C
      DO 260 IR = 1, 8
C
C  RELATIVE FORAGE FISH WINTER HABITAT BASED ON FLOW
C
          IF (IMONTH .LT. 5) CMINN(IR) =
     1          SLP(AFLOW(IR),XCMW,YCMW,4)
          IF (IMONTH .GT. 9) CMINN(IR) =
     1          SLP(AFLOW(IR),XCMW,YCMW,4)
C
C  RELATIVE FORAGE FISH SPAWNING HABITAT BASED ON FLOW
C
          IF (IMONTH .EQ. 5) CMINN(IR) =
     1          SLP(AFLOW(IR),XCMS,YCMS,4)
C
C  RELATIVE FORAGE FISH SUMMER PRODUCTION(REARING) HABITAT
C      BASED ON FLOW
C
          IF (IMONTH .GT. 5 .AND. IMONTH .LT. 10) CMINN(IR) =
     1          SLP(AFLOW(IR),XCMP,YCMP,4)
  260 CONTINUE
```

```
C
C==================================================
C
C.....FOREST WILDLIFE HABITAT SECTION
C
      IF (IMONTH .NE. 1) GO TO 320
      DO 270 IR = 1, 8
C
C  TOTAL HABITAT AVAILABLE TO "FOREST" SPECIES
C
        FOR(IR) = SHRUB(IR) + TREE(IR)
C
C  FOREST HABITAT RELATIVE TO AMOUNT AT START OF RUN.
C
        FORSP(IR) = FOR(IR) / FORS(IR)
  270 CONTINUE
C
C==================================================
C
C.....RECREATIONAL USE-DAYS SECTION
C  HUMAN POPULATION CHARACTERISTICS - CALCULATE
C      MONTH 1 OF EACH SIMULATION YEAR
C
      DO 290 IR = 1, 8
        DO 280 IA = 1, 2
C
C  REACH POPULATION (NORTH + SOUTH) AT START OF RUN
C
          IF (ITIME .EQ. 1) POPS(IR) = POPS(IR) + POP(IR,IA)
C
```

```
C  REACH POPULATION (NORTH + SOUTH) NOW
C     POP(IR,IA) D IN MUNICIPAL/INDUSTRIAL SUBMODEL.
C
            POPI(IR) = POPI(IR) + POP(IR,IA)
  280   CONTINUE
C
C  POPULATION NOW RELATIVE TO START OF RUN
C
          POPM(IR) = POPI(IR) / POPS(IR)
C
C  POPULATION (TOTAL FOR RIVER) RELATIVE TO
C     START OF RUN.
C
          SPOPM = SPOPM + POPM(IR)
  290 CONTINUE
C
C  POPULATION (AVERAGE PER REACH) RELATIVE TO
C     START OF RUN
C
      DVIEW = SPOPM / 8.
C
C
C.....RECREATIONAL USE-DAYS (INCLUDES - BOATING, FISHING,
C           HUNTING, GENERAL NON-CONSUMPTIVE ACTIVITIES, AND
C           CRANE VIEWING).
C
C  USE-DAYS "NOW" BASED ON USE-DAYS AT START OF
C    MODEL RUN * POPULATION "NOW" RELATIVE TO
C    POPULATION AT START OF RUN.
C
```

```
      DO 310 IR = 1, 8
        HUNTR(IR) = HUNTS(IR) * POPM(IR)
        FISHR(IR) = FISHS(IR) * POPM(IR)
        BOATR(IR) = BOATS(IR) * POPM(IR)
        VIEWR(IR) = VIEWS(IR) * POPM(IR)
C
C  NUMBER OF FISHERMEN, HUNTERS, BOATERS,
C    AND GENERAL RECREATIONISTS ADDED BY NEW PROJECTS.
C
        DO 300 IA = 1, 2
          FISHP(IR,IA) = SURFAC(IR,IA) * FPAC
          HUNTP(IR,IA) = HACRE(IR,IA) * HPAC
          BOATP(IR,IA) = SURFAC(IR,IA) * BPAC
          VIEWP(IR,IA) = HACRE(IR,IA) * VPAC
C
C  NUMBER OF "USE DAYS" NORTH AND SOUTH OF
C    RIVER ADDING PROJECT EFFECTS.
C
          BOAT(IR,IA) = BOATR(IR) / 2. + BOATP(IR,IA)
          HUNT(IR,IA) = HUNTR(IR) / 2. + HUNTP(IR,IA)
          FISH(IR,IA) = FISHR(IR) / 2. + FISHP(IR,IA)
          VIEW(IR,IA) = VIEWR(IR) / 2. + VIEWP(IR,IA)
C
C  UPDATE INITIAL (OR BASELINE) USE DAYS BY REACH
C
          BOATS(IR) = BOATS(IR) + BOATP(IR,IA)
          HUNTS(IR) = HUNTS(IR) + HUNTP(IR,IA)
          FISHS(IR) = FISHS(IR) + FISHP(IR,IA)
          VIEWS(IR) = VIEWS(IR) + VIEWP(IR,IA)
C
```

```
C  TOTAL USE-DAYS BY REACH AND BY CATEGORY.
C
          BOATR(IR) = BOATR(IR) + BOATP(IR,IA)
          FISHR(IR) = FISHR(IR) + FISHP(IR,IA)
          HUNTR(IR) = HUNTR(IR) + HUNTP(IR,IA)
          VIEWR(IR) = VIEWR(IR) + VIEWP(IR,IA)
  300   CONTINUE
C
C  CRANE VIEWING USE-DAYS
C
C  RELATIVE CRANE VIEWERS BASED ON RELATIVE POPULATION
C     AND RELATIVE CRANE HABITAT
C
        CVIEW = CVIEWS * DVIEW * CRANE(5)
C
C  TOTAL RECREATION "USE DAYS" FOR RIVER
C
        VISIT = VISIT + BOATR(IR) + FISHR(IR) +
     1          HUNTR(IR) + VIEWR(IR)
C
  310 CONTINUE
      VISIT = VISIT + CVIEW
  320 CONTINUE
C
C==================================================================
C
C*****************************************************************
C*****************************************************************
C**********  END OF WILDLIFE-RECREATION SUBMODEL  **********
C*****************************************************************
```

```
C*****************************************************************
C
      RETURN
      END
```

```
:      1        COMMON ADJF(8), AFLOW(8), BOAT(8,2), BOATP(8,2)
:      2        COMMON BOATR(8), BOATS(8), BPAC, CCAT(8), CMINN(8)
:      3        COMMON CRANE(8), CRFEED(8), CRFR(8), CRFS(8), CVIEW
:      4        COMMON CVIEWS, DHABM(8), DOLAC(4), DSAND(8), DVIEW
:      5        COMMON ETDIST(12), ETMD(8), ETMDR, ETR(11,2), ETSD(8)
:      6        COMMON ETSDR, ETSH(8), ETSHR, ETTR(8), ETTRR, FISH(8,2)
:      7        COMMON FISHP(8,2), FISHR(8), FISHS(8), FLO1
:      8        COMMON FLOTAR(8,12), FOR(8), FORS(8), FORSP(8)
:      9        COMMON FPAC, GLAG(8,3), GRASS(8), HACRE(8,2), HPAC
:     10        COMMON HUNT(8,2), HUNTP(8,2), HUNTR(8), HUNTS(8)
:     11        COMMON ISHMNT, ITRMNT, POPI(8), POPM(8), POPS(8)
:     12        COMMON ROOST(8), RWIDTH, SAMNT(8), SAND(8), SHLAG(8,5)
:     13        COMMON SHMNT(8), SHRIP(8), SHRUB(8), SPOPM
:     14        COMMON TAR(8), TARFLO(8,12), TERN(8), TETR(8), TMED
:     15        COMMON TREE(8), TRMNT(8), TRRIP(8), TSAND, TSHRUB
:     16        COMMON TTREE, VALHAB(8,4), VIEW(8,2), VIEWP(8,2)
:     17        COMMON VIEWR(8), VIEWS(8), VISIT, VPAC, VWIDTH(8)
:     18        COMMON XCCP(4), YCCP(4), XCCS(4), YCCS(4)
:     19        COMMON XCCW(4), YCCW(4), XCMP(4), YCMP(4)
:     20        COMMON XCMS(4), YCMS(4), XCMW(4), YCMW(4)
:     21        COMMON XCR(4), YCR(4), XDM(4), YDM(4), XMED(4), YMED(4)
```

```
:     1     S ADJF(ALL)=0.5 2. 0.5 1. 1. 1. 3. 4.
:     2     S BOATS(1...4)=134400. 276897. 16030. 58296.
:     3     S BOATS(5...8)=6170. 4960. 22400. 13647.
:     4     S BPAC=10.
:     5     S CCAT(ALL)=1.
:     6     S CMINN(ALL)=1.
:     7     S CRANE=1.
:     8     S CRFEED(ALL)=0. 0. 0. 1.0 1.0 0. 0. 0.
:     9     S CRFS(ALL)=0. 0. 0. 21000. 19000. 0. 0. 0.
:    10     S CVIEWS=20000.
:    11     S DHABM(ALL)=1.
:    12     S DOLAC(ALL)=300. 1250. 300. 300.
:    13     S DVIEW=1.
:    14     S ETDIST(1...6)=0. 0. 0. .1 .2 .25
:    15     S ETDIST(7...12)=.3 .1 .05 0. 0. 0.
:    16     S ETR(ALL,ALL)=0.
:    17     S ETSDR=2.
:    18     S ETMDR=2.
:    19     S ETSHR=3.
:    20     S ETTRR=3.
:    21     S FISHS(1...4)=106828. 284000. 16000. 140080.
:    22     S FISHS(5...8)=75844. 36924. 138640. 116000.
:    23     S FLO1=0.
:    24     S FLOTAR(ALL,ALL)=0.
:    25     S FORS(1...4)=30341. 23570. 10161. 23878.
:    26     S FORS(5...8)=21762. 17237. 13104. 15142.
:    27     S FORSP(ALL)=0.
:    28     S FPAC=0.
:    29     S GLAG(1,ALL)=2408.
:    30     S GLAG(2,ALL)=2277.
```

```
:    31    S GLAG(3,ALL)=89.
:    32    S GLAG(4,ALL)=971.
:    33    S GLAG(5,ALL)=1876.
:    34    S GLAG(6,ALL)=2128.
:    35    S GLAG(7,ALL)=840.
:    36    S GLAG(8,ALL)=971.
:    37    S GRASS(1...4)=7224. 6832. 266. 2912.
:    38    S GRASS(5...8)=5628. 6384. 2520. 2912.
:    39    S HACRE(ALL,ALL)=0.
:    40    S HPAC=0.
:    41    S HUNTS(1...4)=19793. 59100. 11790. 41894.
:    42    S HUNTS(5...8)=84215. 37069. 59471. 48054.
:    43    S ISHMNT=0
:    44    S ITRMNT=0
:    45    S POPM(ALL)=1.
:    46    S POPS(ALL)=0.
:    47    S ROOST(ALL)=1.0
:    48    S SAND(1...4)=12040. 5124. 266. 2912.
:    49    S SAND(5...8)=11256. 95761. 10080. 11648.
:    50    S SHLAG(1,ALL)=1926.
:    51    S SHLAG(2,ALL)=1366.
:    52    S SHLAG(3,ALL)=319.
:    53    S SHLAG(4,ALL)=874.
:    54    S SHLAG(5,ALL)=1126.
:    55    S SHLAG(6,ALL)=958.
:    56    S SHLAG(7,ALL)=1008.
:    57    S SHLAG(8,ALL)=1165.
:    58    S SHRIP(ALL)=0.
:    59    S SHRUB(1...4)=9632. 6832. 1596. 4368.
:    60    S SHRUB(5...8)=5628. 4788. 5040. 5824.
```

```
:    61    S SURFAC(ALL,ALL)=0.
:    62    S TARFLO(ALL,ALL)=0.
:    63    S TERN(ALL)=0.
:    64    S TREE(1...4)=19264. 15372. 8512. 18928.
:    65    S TREE(5...8)=15008. 11172. 7560. 8736.
:    66    S TRRIP(ALL)=0.
:    67    S VIEWS(1...4)=417000. 278000. 108000. 216000.
:    68    S VIEWS(5...8)=54000. 54000. 81000. 27000.
:    69    S VPAC=0.
:    70    S VWIDTH(ALL)=0.
:    71    S XCCP(ALL)=300. 600. 1000. 10000.
:    72    S YCCP(ALL)=0. .4 .7 1.
:    73    S XCCS(ALL)=300. 600. 1000. 10000.
:    74    S YCCS(ALL)=0. .9 1.
:    75    S XCCW(ALL)=300. 600. 1000. 1005.
:    76    S YCCW(ALL)=0. .5 .9 1.
:    77    S XCMP(ALL)=100. 300. 2500. 5000.
:    78    S YCMP(ALL)=0. .15 .5 1.
:    79    S XCMS(ALL)=100. 300. 600. 5000.
:    80    S YCMS(ALL)=0. .5 .9 1.
:    81    S XCMW(ALL)=100. 300. 600. 5000.
:    82    S YCMW(ALL)=0. .1 .9 1.
:    83    S XCR(ALL)=150. 250. 400. 500.
:    84    S YCR(ALL)=.01 .1 .5 1.
:    85    S XDM(ALL)=150. 750. 1000. 2000.
:    86    S YDM(ALL)=.1 1. .75 .25
:    87    S XMED(ALL)=0. 15. 20. 23.
:    88    S YMED(ALL)=.05 .02 .01 .001
```

APPENDIX F. GROUNDWATER SUBMODEL FILES

```
GROUNDWATER SUBMODEL VARIABLE DEFINITIONS
=========================================

VARIABLES PRECEDED BY AN * ARE CALCULATED BY
OTHER SUBMODELS

UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:
     I=RIVER REACH OR PROJECT AREA
     J=DIRECTION FROM RIVER (FOR REACHES ONLY)
     K=MONTH OF YEAR

  WHERE

     I=1=LEWELLEN TO NORTH PLATTE
     I=2=JULESBURG TO NORTH PLATTE
     I=3=NORTH PLATTE TO BRADY
     I=4=BRADY TO OVERTON
     I=5=OVERTON TO GRAND ISLAND
     I=6=GRAND ISLAND TO DUNCAN
     I=7=DUNCAN TO NORTH BEND
     I=8=NORTH BEND TO LOUISVILLE
     I=9=ENDERS PROJECT AREA
     I=10=LITTLE BLUE PROJECT AREA
     I=11=BIG BLUE PROJECT AREA

     J=1=NORTH OF RIVER
     J=2=SOUTH OF RIVER

     K=1...12=JAN...DEC
```

```
31      ABDSCH=ABSOLUTE VALUE OF DSCH(I,J) (ACRE-FT)
32      AGNIT(I,J)=NITRATE CONCENTRATION IN AGRICULTURAL RECHARGE
33                 (PPM)
34      * AGRCH(I,J)=AGRICULTURAL RECHARGE IN CURRENT MONTH (ACRE-FT)
35                   (FROM AGRICULTURE SUBMODEL)
36      AGRIN(I,J,K)=BASE CONDITION FOR AGRICULTURAL RECHARGE
37                   (ACRE-FT)
38      AQEL(I,J)=AVERAGE ELEVATION OF BASE OF AQUIFER
39                (FT ABOVE SEA LEVEL)
40      CAGP(I,J)=DIFFERENCE IN AGRICULTURAL PUMPING BETWEEN CURRENT
41                MONTH AND BASE CONDITION (ACRE-FT)
42      CAGRCH(I,J)=DIFFERENCE IN AGRICULTURAL RECHARGE BETWEEN
43                  CURRENT MONTH AND BASE CONDITION (ACRE-FT)
44      CETR(I,J)=DIFFERENCE IN EVAPOTRANSPIRATION BY RIPARIAN
45                VEGETATION BETWEEN CURRENT MONTH AND BASE
46                CONDITION (ACRE-FT)
47      CETS(I,J)=DIFFERENCE IN EVAPOTRANSPIRATION FROM SUBIRRIGATED
48                LANDS BETWEEN CURRENT MONTH AND BASE CONDITION
49                (ACRE-FT)
50      CMIP(I,J)=DIFFERENCE IN MUNICIPAL/INDUSTRIAL PUMPING BETWEEN
51                CURRENT MONTH AND BASE CONDITION (ACRE-FT)
52      CNIT=PROPORTION OF NITRATE PRESENT AT START OF MONTH
53           THAT REMAINS AT END OF MONTH (I.E., DENITRIFICATION,
54           IF ANY)
55      CSTRCH(I,J)=DIFFERENCE IN RECHARGE FROM STORAGE FACILITIES
56                  BETWEEN CURRENT MONTH AND BASE CONDITION
57                  (ACRE-FT)
58      DC(I,J)=DISCHARGE COEFFICIENT RELATING DELTA(I,J)
59              TO AMOUNT OF WATER EXCHANGED WITH RIVER
60              (DIMENSIONLESS)
```

```
DELTA(I,J)=CUMULATIVE NET CHANGE FROM BASE CONDITION
           FOR ALL EVAPOTRANSPIRATION, PUMPING, AND
           RECHARGE FACTORS (ACRE-FT)
DEPTH(I,J)=DEPTH TO WATER TABLE (FT)
DSCH(I,J)=GAIN OR LOSS TO THE RIVER IN CURRENT MONTH
          (ACRE-FT).  IF DSCH IS NEGATIVE, MOVEMENT IS FROM
          THE RIVER INTO GROUNDWATER; IF POSITIVE, MOVEMENT
          IS FROM GROUNDWATER TO THE RIVER.
DUMB=TEMPORARY VARIABLE USED IN COMPUTING EXCHANGES BETWEEN
     THE RIVER AND THE BIG BLUE PROJECT AREA.
* ETR(I,J)=EVAPOTRANSPIRATION BY RIPARIAN VEGETATION IN
           CURRENT MONTH (ACRE-FT)
           <FROM WILDLIFE/RECREATION SUBMODEL>
* ETS(I,J)=EVAPOTRANSPIRATION FROM SUBIRRIGATED LANDS
           IN CURRENT MONTH (ACRE-FT)
           <FROM AGRICULTURE SUBMODEL>
GNIT(I,J)=NITRATE CONCENTRATION IN GROUNDWATER AT END OF
          CURRENT MONTH (PPM)
GWS(I,J)=GROUNDWATER IN STORAGE AT END OF CURRENT MONTH
         (ACRE-FT)
GWSIN(I,J)=INITIAL AMOUNT OF GROUNDWATER IN STORAGE
           (ACRE-FT)
* IMONTH=MONTH OF YEAR, WHERE 1=JAN, 12=DEC
         <FROM SYSTEM MODEL>
ISET=PARAMETER THAT DETERMINES WHETHER BASE CONDITIONS
     FOR EVAPOTRANSPIRATION, PUMPING, AND RECHARGE
     ARE SET BASED ON THE FIRST YEAR OF SIMULATION (ISET=1)
     OR ARE READ IN AS DATA (ISET=0)
* IYEAR=SIMULATION YEAR <FROM SYSTEM MODEL>
PAGIN(I,J,K)=BASE CONDITION FOR AGRICULTURAL PUMPING
```

```
:    91                    (ACRE-FT)
:    92        PERM(I,J)=PERMEABILITY OF AQUIFER (GPD/FT**2)
:    93        PMIIN(I,J,K)=BASE CONDITION FOR MUNICIPAL/INDUSTRIAL
:    94                    PUMPING (ACRE-FT)
:    95        * PUMPAG(I,J)=AGRICULTURAL PUMPING IN CURRENT MONTH
:    96                   (ACRE-FT) <FROM AGRICULTURE SUBMODEL>
:    97        * PUMPMI(I,J)=MUNICIPAL/INDUSTRIAL PUMPING IN CURRENT MONTH
:    98                   (ACRE-FT) <FROM MUNICIPAL/INDUSTRIAL SUBMODEL>
:    99        RIPIN(I,J,K)=BASE CONDITION FOR EVAPOTRANSPIRATION BY
:   100                    RIPARIAN VEGETATION (ACRE-FT)
:   101        RUNOFF(I,J)=AMOUNT OF WATER MOVING TO RIVER IF GROUNDWATER
:   102                   LEVEL BECOMES HIGHER THAN SURFACE ELEVATION
:   103                   (ACRE-FT)
:   104        * SNIT(I)=NITRATE CONCENTRATION IN RIVER (PPM)
:   105                 <FROM SURFACE WATER SUBMODEL>
:   106        STC(I,J)=AVERAGE STORAGE COEFFICIENT OF AQUIFER
:   107                (DECIMAL FRACTION)
:   108        * STRCH(I,J)=RECHARGE FROM STORAGE FACILITIES IN CURRENT
:   109                    MONTH (ACRE-FT) <FROM SURFACE WATER SUBMODEL>
:   110        STRIN(I,J,K)=BASE CONDITION FOR RECHARGE FROM STORAGE
:   111                    FACILITIES (ACRE-FT)
:   112        SUBIN(I,J,K)=BASE CONDITION FOR EVAPOTRANSPIRATION FROM
:   113                    SUBIRRIGATED LANDS (ACRE-FT)
:   114        SURFEL(I,J)=AVERAGE SURFACE ELEVATION (FT ABOVE SEA LEVEL)
:   115        * TACRE(I,J)=TOTAL SURFACE AREA (ACRES)
:   116                    <FROM AGRICULTURE SUBMODEL>
:   117        * TFLOWA(I)=RIVER FLOW AT TOP OF REACH (ACRE-FT)
:   118                   <FROM SURFACE WATER SUBMODEL>
:   119        THIK(I,J)=SATURATED THICKNESS OF AQUIFER (FT)
:   120        TNIT=TOTAL NITRATE LOAD IN GROUNDWATER AT BEGINNING
```

```
:   121          OF CURRENT MONTH (KG)
:   122     TWAT=TOTAL GROUNDWATER IN STORAGE AT BEGINNING
:   123          OF CURRENT MONTH (L)
:   124     WC=A CONSTANT USED IN CONVERTING SATURATED THICKNESS
:   125        AND PERMEABILITY TO WELL YIELD (DIMENSIONLESS ?)
:   126     WTEL(I,J)=WATER TABLE ELEVATION AT END OF CURRENT MONTH
:   127               (FT ABOVE SEA LEVEL)
:   128     WTELIN(I,J)=INITIAL WATER TABLE ELEVATION
:   129                 (FT ABOVE SEA LEVEL)
:   130     WYLD(I,J)=AVERAGE WELL YIELD (GPM)
```

```
      SUBROUTINE GWAT
$CONTINUE WITH PLATTE.C RETURN
      K=IMONTH
C.....BEGIN REACH AND DIRECTION LOOP
      DO 10 I=1,11
      DO 10 J=1,2
      RUNOFF(I,J)=0.
C.....SET HISTORICAL VALUES AS BASE
C.....FOR CALCULATING CHANGES
      IF(IYEAR.NE.1) GO TO 1
C.....IF DONE IN DATA, SKIP THIS PART
      IF(ISET.EQ.0) GO TO 1
      RIPIN(I,J,K)=ETR(I,J)
      SUBIN(I,J,K)=ETS(I,J)
      PMIIN(I,J,K)=PUMPMI(I,J)
      PAGIN(I,J,K)=PUMPAG(I,J)
      AGRIN(I,J,K)=AGRCH(I,J)
      STRIN(I,J,K)=STRCH(I,J)
    1 CONTINUE
C.....SAVE NITRATE LOAD AND WATER
C.....(KG AND L)
      TNIT=GWS(I,J)*GNIT(I,J)*1.23345
      TWAT=GWS(I,J)*1233450.
C.....CHANGE IN PUMPING AND RECHARGE
      CETR(I,J)=ETR(I,J)-RIPIN(I,J,K)
      CETS(I,J)=ETS(I,J)-SUBIN(I,J,K)
      CMIP(I,J)=PUMPMI(I,J)-PMIIN(I,J,K)
      CAGP(I,J)=PUMPAG(I,J)-PAGIN(I,J,K)
      CAGRCH(I,J)=AGRCH(I,J)-AGRIN(I,J,K)
      CSTRCH(I,J)=STRCH(I,J)-STRIN(I,J,K)
```

```
C.....NET CHANGE IN PUMPING AND RECHARGE
      DELTA(I,J)=DELTA(I,J)+CAGRCH(I,J)+CSTRCH(I,J)
     1          -CETR(I,J)-CETS(I,J)
     2          -CMIP(I,J)-CAGP(I,J)
C.....GAIN OR LOSS TO RIVER
      DSCH(I,J)=DELTA(I,J)*DC(I,J)
      IF(DSCH(I,J).LT.0.) GO TO 2
      DSCH(I,J)=AMIN1(DSCH(I,J),GWS(I,J))
      GO TO 3
    2 CONTINUE
      DSCH(I,J)=AMIN1(DSCH(I,J),TFLOWA(I))
      IF(J.EQ.1) GO TO 11
      DUMD=TFLOWA(I)-DSCH(I,1)
      DSCH(I,J)=AMIN1(DSCH(I,J),DUMD)
   11 CONTINUE
C.....BIG BLUE EXCHANGES
      IF(I.NE.11) GO TO 12
      IF(J.NE.1) GO TO 12
      DUMD=TFLOWA(6)-DSCH(6,1)-DSCH(6,2)
      DSCH(11,1)=AMIN1(DSCH(11,1),DUMD)
   12 CONTINUE
    3 CONTINUE
C.....UPDATE NET CHANGE AND TOTAL VOLUME
      DELTA(I,J)=DELTA(I,J)-DSCH(I,J)
      GWS(I,J)=GWSIN(I,J)+DELTA(I,J)
C.....WATER TABLE ELEVATION
      WTEL(I,J)=WTELIN(I,J)+DELTA(I,J)/TACRE(I,J)/STC(I,J)
C.....WATER CAN'T BE HIGHER THAN LAND
      IF(WTEL(I,J).LE.SURFEL(I,J)) GO TO 5
      RUNOFF(I,J)=(WTEL(I,J)-SURFEL(I,J))*TACRE(I,J)*STC(I,J)
```

```
      WTEL(I,J)=SURFEL(I,J)
      DELTA(I,J)=DELTA(I,J)-RUNOFF(I,J)
      DSCH(I,J)=DSCH(I,J)+RUNOFF(I,J)
      GWS(I,J)=GWS(I,J)-RUNOFF(I,J)
    5 CONTINUE
C.....DEPTH OF WATER TABLE
      DEPTH(I,J)=SURFEL(I,J)-WTEL(I,J)
C.....WELL YIELD
      THIK(I,J)=WTEL(I,J)-AQEL(I,J)
      WYLD(I,J)=THIK(I,J)*PERM(I,J)/WC
C.....NITROGEN MASS BALANCE
C.....DENITRIFY WHAT IS IN STORAGE
      TNIT=TNIT*CNIT
C.....ADD NEW CONTRIBUTIONS
      TNIT=TNIT+AGRCH(I,J)*AGNIT(I,J)*1.23345
      TWAT=TWAT+AGRCH(I,J)*1233450.
     1     +STRCH(I,J)*1233450.
      IF(DSCH(I,J).GE.0.) GO TO 6
      ABDSCH=ABS(DSCH(I,J))
      TNIT=TNIT+ABDSCH*SNIT(I)*1.23345
      TWAT=TWAT+ABDSCH*1233450.
    6 CONTINUE
      IF(TWAT.NE.0.) GO TO 7
      GNIT(I,J)=0.
      GO TO 10
    7 CONTINUE
      GNIT(I,J)=1000000.*TNIT/TWAT
   10 CONTINUE
      RETURN
      END
```

```
      COMMON RUNOFF(11,2),ISET,RIPIN(11,2,12)
      COMMON SUBIN(11,2,12),PMIIN(11,2,12),PAGIN(11,2,12)
      COMMON AGRIN(11,2,12),STRIN(11,2,12),TNIT,TWAT
      COMMON GWS(11,2),CETR(11,2),CETS(11,2),CMIP(11,2)
      COMMON CAGP(11,2),CAGRCH(11,2),CSTRCH(11,2),DELTA(11,2)
      COMMON STC(11,2),SURFEL(11,2),DEPTH(11,2),THIK(11,2)
      COMMON AQEL(11,2),WYLD(11,2),PERM(11,2),WC
      COMMON CNIT,GNIT(11,2),STRCH(11,2),DSCH(11,2)
      COMMON WTEL(11,2),WTELIN(11,2),GWSIN(11,2),DC(11,2)
```

```
:    1    S RUNOFF(ALL,ALL)=0.
:    2    S WYLD(ALL,ALL)=1000.
:    3    S RIPIN(ALL,ALL,ALL)=0.
:    4    S SUBIN(ALL,ALL,ALL)=0.
:    5    S FMIIN(ALL,ALL,ALL)=0.
:    6    S FAGIN(ALL,ALL,ALL)=0.
:    7    S AGRIN(ALL,ALL,ALL)=0.
:    8    S STRIN(ALL,ALL,ALL)=0.
:    9    S STRCH(ALL,ALL)=0.
:   10    S TNIT=0.
:   11    S GWS(1,ALL)=18100000. 24560000.
:   12    S GWS(2,ALL)=141500000. 9150000.
:   13    S GWS(3,ALL)=64500000. 29250000.
:   14    S GWS(4,ALL)=81000000. 40300000.
:   15    S GWS(5,ALL)=7300000. 18000000.
:   16    S GWS(6,ALL)=7500000. 5180000.
:   17    S GWS(7,ALL)=17780000. 7350000.
:   18    S GWS(8,ALL)=3200000. 27380000.
:   19    S GWS(9,ALL)=0. 0.
:   20    S GWS(10,ALL)=0. 0.
:   21    S GWS(11,ALL)=90000000. 0.
:   22    S GNIT(1,ALL)=1. 1.
:   23    S GNIT(2,ALL)=1. 1.
:   24    S GNIT(3,ALL)=2. 2.
:   25    S GNIT(4,ALL)=3. 2.
:   26    S GNIT(5,ALL)=6. 3.
:   27    S GNIT(6,ALL)=12. 5.
:   28    S GNIT(7,ALL)=13. 6.
:   29    S GNIT(8,ALL)=3. 3.
:   30    S GNIT(9,ALL)=0. 0.
```

```
:    31    $ GNIT(10,ALL)=0. 0.
:    32    $ GNIT(11,ALL)=2. 0.
:    33    $ CETR(ALL,ALL)=0.
:    34    $ CETS(ALL,ALL)=0.
:    35    $ CMIP(ALL,ALL)=0.
:    36    $ CAGP(ALL,ALL)=0.
:    37    $ CAGRCH(ALL,ALL)=0.
:    38    $ CSTRCH(ALL,ALL)=0.
:    39    $ DELTA(ALL,ALL)=0.
:    40    $ DSCH(ALL,ALL)=
:    41    $ DC(1,ALL)=0.019 0.010
:    42    $ DC(2,ALL)=0.001 0.070
:    43    $ DC(3,ALL)=0.002 0.006
:    44    $ DC(4,ALL)=0.001 0.004
:    45    $ DC(5,ALL)=0.001 0.008
:    46    $ DC(6,ALL)=0.003 0.055
:    47    $ DC(7,ALL)=0.001 0.004
:    48    $ DC(8,ALL)=0.055 0.001
:    49    $ DC(9,ALL)=0. 0.
:    50    $ DC(10,ALL)=0. 0.
:    51    $ DC(11,ALL)=0.001 0.0
:    52    $ WTELIN(1,ALL)=3300. 3100.
:    53    $ WTELIN(2,ALL)=3375. 3300.
:    54    $ WTELIN(3,ALL)=2900. 2800.
:    55    $ WTELIN(4,ALL)=2550. 2550.
:    56    $ WTELIN(5,ALL)=2050. 2150.
:    57    $ WTELIN(6,ALL)=1650. 1600.
:    58    $ WTELIN(7,ALL)=1450. 1425.
:    59    $ WTELIN(8,ALL)=1200. 1200.
:    60    $ WTELIN(9,ALL)=0. 0.
```

```
:    61    S WTELIN(10,ALL)=0. 0.
:    62    S WTELIN(11,ALL)=1575. 0.
:    63    S WTEL(ALL,ALL)=0.
:    64    S STC(ALL,ALL)=0.25
:    65    S SURFEL(1,ALL)=3360. 3170.
:    66    S SURFEL(2,ALL)=3430. 3325.
:    67    S SURFEL(3,ALL)=2975. 2850.
:    68    S SURFEL(4,ALL)=2590. 2590.
:    69    S SURFEL(5,ALL)=2085. 2175.
:    70    S SURFEL(6,ALL)=1663. 1640.
:    71    S SURFEL(7,ALL)=1485. 1465.
:    72    S SURFEL(8,ALL)=1220. 1241.
:    73    S SURFEL(9,ALL)=0. 0.
:    74    S SURFEL(10,ALL)=0. 0.
:    75    S SURFEL(11,ALL)=1655. 0.
:    76    S DEPTH(1,ALL)=60. 70.
:    77    S DEPTH(2,ALL)=55. 25.
:    78    S DEPTH(3,ALL)=75. 50.
:    79    S DEPTH(4,ALL)=40. 40.
:    80    S DEPTH(5,ALL)=35. 25.
:    81    S DEPTH(6,ALL)=13. 40.
:    82    S DEPTH(7,ALL)=35. 40.
:    83    S DEPTH(8,ALL)=20. 41.
:    84    S DEPTH(9,ALL)=50. 50.
:    85    S DEPTH(10,ALL)=50. 50.
:    86    S DEPTH(11,ALL)=80. 40.
:    87    S THIK(ALL,ALL)=0.
:    88    S AQEL(1,ALL)=3100. 2850.
:    89    S AQEL(2,ALL)=2875. 3100.
:    90    S AQEL(3,ALL)=2300. 2300.
```

```
:    91    $ AQEL(4,ALL)=2100. 2150.
:    92    $ AQEL(5,ALL)=1850. 1950.
:    93    $ AQEL(6,ALL)=1550. 1450.
:    94    $ AQEL(7,ALL)=1300. 1275.
:    95    $ AQEL(8,ALL)=1100. 1100.
:    96    $ AQEL(9,ALL)=0. 0.
:    97    $ AQEL(10,ALL)=0. 0.
:    98    $ AQEL(11,ALL)=1375. 0.
:    99    $ PERM(1,ALL)=250. 400.
:   100    $ PERM(2,ALL)=200. 250.
:   101    $ PERM(3,ALL)=200. 200.
:   102    $ PERM(4,ALL)=275. 375.
:   103    $ PERM(5,ALL)=250. 750.
:   104    $ PERM(6,ALL)=500. 675.
:   105    $ PERM(7,ALL)=325. 500.
:   106    $ PERM(8,ALL)=1000. 1000.
:   107    $ PERM(9,ALL)=0. 0.
:   108    $ PERM(10,ALL)=0. 0.
:   109    $ PERM(11,ALL)=750. 0.
:   110    $ WC=100.
:   111    $ TWAT=0.
:   112    $ CNIT=1.
:   113    $ ISET=1
:   114    $ GWSIN(1,ALL)=18100000. 24560000.
:   115    $ GWSIN(2,ALL)=141500000. 9150000.
:   116    $ GWSIN(3,ALL)=64500000. 29250000.
:   117    $ GWSIN(4,ALL)=81000000. 40300000.
:   118    $ GWSIN(5,ALL)=7300000. 18000000.
:   119    $ GWSIN(6,ALL)=7500000. 5180000.
:   120    $ GWSIN(7,ALL)=17780000. 7350000.
```

```
:   121     S GWSIN(8,ALL)=3200000. 27380000.
:   122     S GWSIN(9,ALL)=0. 0.
:   123     S GWSIN(10,ALL)=0. 0.
:   124     S GWSIN(11,ALL)=90000000. 0.
```

APPENDIX G. ECONOMICS SUBMODEL FILES

```
ECONOMICS SUBMODEL VARIABLE DEFINITIONS
=======================================

VARIABLES PRECEDED BY AN * ARE CALCULATED BY
OTHER SUBMODELS

UNLESS OTHERWISE NOTED, SUBSCRIPTS ARE AS FOLLOWS:

      I=RIVER REACH OR PROJECT AREA
      J=DIRECTION FROM RIVER
      IC=CROP TYPE
      IS=RIPARIAN HABITAT TYPE
      IW=WATER-USE TYPE

  WHERE

      I=1=JULESBURG TO NORTH PLATTE
      I=2=LEWELLEN TO NORTH PLATTE
      I=3=NORTH PLATTE TO BRADY
      I=4=BRADY TO OVERTON
      I=5=OVERTON TO GRAND ISLAND
      I=6=GRAND ISLAND TO DUNCAN
      I=7=DUNCAN TO NORTH BEND
      I=8=NORTH BEND TO LOUISVILLE
      I=9=ENDERS PROJECT AREA
      I=10=LITTLE BLUE PROJECT AREA
      I=11=BIG BLUE PROJECT AREA

      J=1=NORTH OF RIVER
      J=2=SOUTH OF RIVER
```

```
:     31
:     32          IC=1=ALFALFA
:     33          IC=2=CORN
:     34          IC=3=MILO
:     35          IC=4=SOYBEAN
:     36          IC=5=WHEAT
:     37          IC=6=OTHER, ASSUMED TO BE NATIVE HAY
:     38
:     39          IS=1=SAND BAR
:     40          IS=2=MEADOW
:     41          IS=3=SHRUB
:     42          IS=4=TREE
:     43
:     44          IW=1=SURFACE WATER-IRRIGATED
:     45          IW=2=GROUNDWATER-IRRIGATED
:     46          IW=3=DRYLAND CROPLAND
:     47          IW=4=SUBIRRIGATED
:     48          IW=5=PASTURE
:     49          IW=6=OTHER
:     50
:     51     * ACRE(I,J,IW,IC)=AREA BY CROP AND WATER-USE TYPE (ACRES)
:     52                        <FROM AGRICULTURE SUBMODEL>
:     53     AGGBEN)(I,J)=GROSS RETURNS TO AGRICULTURE ($)
:     54     AGMBEN(I,J)=DIRECT PLUS INDIRECT ECONOMIC BENEFITS FROM
:     55                 AGRICULTURE ($)
:     56     AGNBEN(I,J)=NET RETURNS TO AGRICULTURE ($)
:     57     ALTIME=Y-ARRAY USED IN SLP FUNCTION TO ESTIMATE
:     58            FUTURE PRICES FOR ALFALFA
:     59     AMULT=MULTIPLIER USED TO ESTIMATE THE INDIRECT ECONOMIC
:     60           BENEFITS FROM THE AGRICULTURE SECTOR
```

```
AMYR=NUMBER OF AMORTIZATION YEARS USED TO ESTIMATE
     ANNUAL PROJECT CAPITAL COSTS
* BOAT(I,J)=NUMBER OF RECREATION USE-DAYS OF BOATING
            <FROM WILDLIFE/RECREATION SUBMODEL>
CPROD(I,J,IC)=AGRICULTURAL CROP PRODUCTION (BUSHELS OR TONS)
CAPINV=INITIAL CAPITAL INVESTMENT IN DEVELOPMENT
       PROJECTS ($)
COSTK=ANNUAL COST OF CAPITAL OVER THE LIFE OF A
      PROJECT ($)
COSTOP=ESTIMATED PROJECT COSTS FOR OPERATION,
       MAINTENANCE, AND REPLACEMENT ($)
COSTPR(I,J,IW,IC)=FIELD PRODUCTION COSTS FOR
                  AGRICULTURAL CROPS ($)
COSTPU(I,J)=COST OF PUMPING GROUNDWATER FOR
            IRRIGATION ($)
COSTSW(I,J)=COST OF OBTAINING SURFACE WATER FOR
            IRRIGATION ($)
COTIME=Y-ARRAY USED IN SLP FUNCTION TO ESTIMATE
       FUTURE PRICES FOR CORN
* CYLD(I,J,IW,IC)=AGRICULTURAL CROP YIELDS (BUSHELS/ACRE OR
                  TONS/ACRE) <FROM AGRICULTURE SUBMODEL>
DAFL(I,J)=VARIABLE COST OF PUMPING GROUNDWATER
          ($/ACRE-FT/FT OF LIFT)
* DEPTH(I,J)=DEPTH FROM SURFACE TO GROUNDWATER LEVEL (FT)
             <FROM GROUNDWATER SUBMODEL>
EMPLOY=NUMBER OF PEOPLE EMPLOYED IN THE AGRICULTURE SECTOR
* EOUT(I,J)=ELECTRICITY GENERATED IN EACH SPATIAL SUBUNIT
           (MWH).  NOTE THAT SUBSCRIPT J IN THIS CASE
           REFERS TO HYDROELECTRIC PLANTS (J=1) OR THERMAL
           PLANTS (J=2) <FROM MUNICIPAL/INDUSTRIAL SUBMODEL>
```

```
:    91    * FISH(I,J)=NUMBER OF RECREATION USE-DAYS OF FISHING
:    92                <FROM WILDLIFE/RECREATION SUBMODEL>
:    93    FPUMP=FIXED COST OF PUMPING GROUNDWATER FOR IRRIGATION
:    94          ($/ACRE-FT)
:    95    * HUNT(I,J)=NUMBER OF RECREATION USE-DAYS OF HUNTING
:    96    * IYEAR=SIMULATION YEAR <FROM SYSTEM MODEL>
:    97    PRBOAT=PRICE OR VALUE OF BOATING ($/RECREATION USE-DAY)
:    98    PRCROP(IC)=PROJECTED PRICES FOR AGRICULTURAL CROPS
:    99               ($/BUSHEL OR $/TON)
:   100    PRFISH=PRICE OR VALUE OF FISHING ($/RECREATION USE-DAY)
:   101    PRHUNT=PRICE OR VALUE OF HUNTING ($/RECREATION USE-DAY)
:   102    PRPR(IW,IC)=FIELD PRODUCTION COSTS ($/ACRE)
:   103    PRSW(I,J)=COST OF DELIVERING SURFACE WATER TO THE FIELD
:   104              ($/ACRE-FT)
:   105    PRVIEW=PRICE OR VALUE OF VIEWING SANDHILL CRANES
:   106           ($/RECREATION USE-DAY)
:   107    PRWATT=PRICE OF ELECTRIC POWER ($/MWH)
:   108    RECBEN=DIRECT BENEFITS TO RECREATION ($)
:   109    REMBEN=DIRECT PLUS INDIRECT RETURNS (OR BENEFITS)
:   110           TO RECREATION
:   111    RINT=REAL RATE OF INTEREST USED IN AMORTIZING PROJECT COSTS
:   112    RJOBS=NUMBER OF JOBS IN THE AGRICULTURE SECTOR FOR EACH
:   113          MILLION DOLLARS OF GROSS RETURNS TO AGRICULTURE
:   114    RMULT=MULTIPLIER USED TO ESTIMATE INDIRECT ECONOMIC BENEFITS
:   115          IN THE RECREATION SECTOR
:   116    SOTIME=Y-ARRAY USED IN SLP FUNCTION TO ESTIMATE
:   117           FUTURE PRICES FOR SOYBEANS
:   118    TAGBEN=TOTAL DIRECT GROSS RETURNS TO AGRICULTURE SUMMED
:   119           ACROSS ALL SPATIAL SUBUNITS ($)
:   120    TAMBEN=TOTAL DIRECT GROSS RETURNS TO AGRICULTURE PLUS
```

```
:  121          INDIRECT ECONOMIC BENEFITS IN THE AGRICULTURE SECTOR
:  122          SUMMED ACROSS ALL SPATIAL SUBUNITS ($)
:  123     TANBEN=TOTAL DIRECT NET RETURNS TO AGRICULTURE SUMMED
:  124          ACROSS ALL SPATIAL SUBUNITS ($)
:  125     TB(1)=TOTAL DIRECT PROJECT BENEFITS MINUS PROJECT COSTS ($)
:  126     TB(2)=TOTAL DIRECT PROJECT BENEFITS PLUS INDIRECT PROJECT
:  127          BENEFITS ($)
:  128     TCOSTA(I,J)=TOTAL COSTS OF AGRICULTURE PRODUCTION, INCLUDING
:  129                 FIELD PRODUCTION COSTS AND IRRIGATION COSTS ($)
:  130     TCOSTP(I,J)=TOTAL FIELD PRODUCTION COSTS FOR AGRICULTURE ($)
:  131     THYBEN=RETURNS TO ELECTRIC POWER GENERATION SUMMED ACROSS
:  132          REACHES AND PLANT TYPES
:  133     * TPUMPA(I,J)=GROUNDWATER USED FOR IRRIGATION (ACRE-FT)
:  134                   <FROM AGRICULTURE SUBMODEL>
:  135     TRCBEN=TOTAL DIRECT BENEFITS TO RECREATION SUMMED
:  136          ACROSS ALL SPATIAL SUBUNITS ($)
:  137     TRMBEN=TOTAL DIRECT BENEFITS TO RECREATION PLUS INDIRECT
:  138          ECONOMIC IMPACTS FROM THE RECREATION SECTOR SUMMED
:  139          ACROSS ALL SPATIAL SUBUNITS ($)
:  140     TVH=TOTAL VALUE OF RIPARIAN HABITATS SUMMED ACROSS ALL
:  141         SPATIAL SUBUNITS ($)
:  142     TVHAB(I)=TOTAL VALUE OF RIPARIAN HABITATS IN A REACH ($)
:  143     * TWDEL(I,J)=SURFACE WATER DELIVERED FOR IRRIGATION
:  144                  (ACRE-FT)
:  145     TYEAR=SIMULATION YEAR
:  146     * VALHAB(I,IS)=VALUES FOR RIPARIAN HABITAT TYPES IN EACH
:  147                    REACH ($) <FROM WILDLIFE/RECREATION SUBMODEL>
:  148     * VIEW(I,J)=RECREATION USE-DAYS OF SANDHILL CRANE VIEWING
:  149                 <FROM WILDLIFE/RECREATION SUBMODEL>
:  150     WATTHR=TOTAL ELECTRIC POWER GENERATION SUMMED ACROSS ALL
```

```
:   151          SPATIAL SUBUNITS (MWH)
:   152     WHTIME=Y-ARRAY USED IN SLP FUNCTION TO ESTIMATE
:   153          FUTURE PRICES FOR WHEAT
:   154     XMTIME=Y-ARRAY USED IN SLP FUNCTION TO ESTIMATE
:   155          FUTURE PRICES FOR MILO
:   156     ZTIME=X-ARRAY USED IN SLP FUNCTION TO ESTIMATE FUTURE
:   157          PRICES FOR ALL CROPS
```

```
      SUBROUTINE ECON
$CONTINUE WITH PLATTE.C RETURN
C
C BENEFIT/COSTS
C AGRICULTURAL
C
      TYEAR=IYEAR
      PRWATT=98.80+(TYEAR*.06)
      PRCROP(1)=SLP(TYEAR,ZTIME,ALTIME,6)
      PRCROP(2)=SLP(TYEAR,ZTIME,COTIME,6)
      PRCROP(3)=SLP(TYEAR,ZTIME,XMTIME,6)
      PRCROP(4)=SLP(TYEAR,ZTIME,SOTIME,6)
      PRCROP(5)=SLP(TYEAR,ZTIME,WHTIME,6)
      TAGBEN=0
      TRMBEN=0
      TRCBEN=0
      TAMBEN=0
      TANBEN=0
      WATTHR=0.
      TVH=0
      DO 5000 I=1 ,11
      DO 5010 J=1,2
      AGGBEN(I,J)=0
      TCOSTA(I,J)=0
      TCOSTP(I,J)=0
      DO 5020 IC=1,6
      CPROD(I,J,IC)=0
      DO 5030 IW=1,6
      CPROD(I,J,IC)=CYLD(I,J,IW,IC)*ACRE(I,J,IW,IC)+
     1              CPROD(I,J,IC)
```

```
C
C PRODUCTION COSTS
      COSTPR(I,J,IW,IC)=PRPR(IW,IC)*ACRE(I,J,IW,IC)
      TCOSTP(I,J)=TCOSTP(I,J)+COSTPR(I,J,IW,IC)
 5030 CONTINUE
      AGGBEN(I,J)=CPROD(I,J,IC)*PRCROP(IC)+AGGBEN(I,J)
 5020 CONTINUE
C GROUND PUMPING COSTS
      COSTPU(I,J)=(DAFL(I,J)*DEPTH(I,J)+FPUMP)*TPUMPA(I,J)
C SURFACE APPLICATION
      COSTSW(I,J)=TWDEL(I,J)*PRSW(I,J)
C COST BY REACH
      TCOSTA(I,J)=TCOSTA(I,J)+TCOSTP(I,J)+COSTPU(I,J)+
     1            COSTSW(I,J)
C NET BENEFIT BY REACH
      AGNBEN(I,J)=AGGBEN(I,J)-TCOSTA(I,J)
C MULTIPLIER
      AGMBEN(I,J)=AMULT*AGGBEN(I,J)
C RECREATION BENEFITS
      IF(I.GT.8)GO TO 5007
      RECBEN(I,J)=(HUNT(I,J)*PRHUNT)+(FISH(I,J)*PRFISH)
      RECBEN(I,J)=RECBEN(I,J)+(BOAT(I,J)*PRBOAT)+(VIEW(I,J)*
     1            PRVIEW)
      REMBEN(I,J)=RECBEN(I,J)*RMULT
 5007 CONTINUE
C
C AGGREGATE
C
      TANBEN=AGNBEN(I,J)+TANBEN
      TAMBEN=AGMBEN(I,J)+TAMBEN
```

```
      IF(I.GT.8)GO TO 5008
      TRCBEN=RECBEN(I,J)+TRCBEN
      TRMBEN=RECBEN(I,J)+TRMBEN
 5008 CONTINUE
      WATTHR=WATTHR+EOUT(I,J)
      THYBEN=WATTHR*PRWATT
      TAGBEN=TAGBEN+AGGBEN(I,J)
 5010 CONTINUE
C
C
C HABITAT VALUES
C
      TVHAB(I)=0
      IF(I.GT.8)GOTO 5009
      DO 5100 IS=1,4
      TVHAB(I)=TVHAB(I)+VALHAB(I,IS)
 5100 CONTINUE
      TVH=TVH+TVHAB(I)
 5009 CONTINUE
 5000 CONTINUE
      COSTK=CAPINV*(RINT*(1+RINT)**AMYR)/((1+RINT)**AMYR-1)
C
C AGGREGATE INDICATORS
C
      TB(1)=TANBEN+TRCBEN+THYBEN-COSTK
      TB(2)=TAMBEN+TRMBEN+THYBEN
      EMPLOY=RJOBS*TAGBEN/1.E6
      RETURN
      END
```

```
:     1        COMMON PRWATT,PRFISH, PRHUNT, PRBOAT, PRVIEW,PRCROP(6)
:     2        COMMON ZTIME(10), ALTIME(6),SOTIME(6)
:     3        COMMON WHTIME(6),HATIME(6)
:     4        COMMON TRMBEN,TRCBEN, TAMBEN, TANBEN
:     5        COMMON TB(5),AGGBEN(11,2)
:     6        COMMON PRSW(11,2)
:     7        COMMON TCOSTA(11,2),CPROD(11,2,6)
:     8        COMMON COSTPR(11,2,6,6), PRPR(6,6)
:     9        COMMON TCOSTP(11,2),COSTPU(11,2),DAFL(11,2),FPUMP
:    10        COMMON AGNBEN(11,2), AGMBEN(11,2), AMULT,RECBEN(11,2)
:    11        COMMON REMBEN(11,2),RMULST, TVHAB(11), TVH
:    12        COMMON THYBEN, TAGBEN, RJOBS, EMPLOY,COSTK
:    13        COMMON COSTOP, CAPINV, RINT, AMYR
:    14        COMMON COSTSW(11,2)
:    15        COMMON COTIME(6),XMTIME(6),RMULT
:    16        COMMON WATTHR
```

```
:    1    S ZTIME(ALL)=0 5 10 20 40 200
:    2    S WHTIME(ALL)=2.7 2.9 2.9 3.0 3.2 3.2
:    3    S SOTIME(ALL)=6.2 6. 6. 6.2 6.9 6.9
:    4    S COTIME(ALL)=2.2 2.5 2.5 2.7 2.8 2.8
:    5    S XMTIME(ALL)=2. 2.1 2.2 2.3 2.5 2.5
:    6    S ALTIME(ALL)=38 42 43 45 47 47
:    7    S PRCROP(6)=0
:    8    S COSTOP=0
:    9    S CAPINV=0
:   10    S RINT=.05
:   11    S AMYR=50
:   12    S PRSW(ALL,ALL)=15
:   13    S FPUMP=55
:   14    S DAFL(ALL,ALL)=.30
:   15    S PRHUNT=3
:   16    S PRFISH=3
:   17    S PRVIEW=3
:   18    S PRBOAT=3
:   19    S AMULT=2.55
:   20    S RMULT=2.7
:   21    S RJOBS=12
:   22    S PRPR(1,ALL)=121 121 8 117 0
:   23    S PRPR(2,ALL)=208 208 117 0
:   24    S PRPR(3,ALL)=127 127 103 0
:   25    S PRPR(4,ALL)=79 79 69 0
:   26    S PRPR(5,ALL)=73 73 77 0
:   27    S PRPR(6,ALL)=0
:   28    S CYLD(ALL,ALL,ALL,1)=4.3
:   29    S CYLD(ALL,ALL,ALL,2)=100
:   30    S CYLD(ALL,ALL,ALL,3)=94
```

```
:    31    S CYLD(ALL,ALL,ALL,4)=46
:    32    S CYLD(ALL,ALL,ALL,5)=50
:    33    S CYLD(ALL,ALL,ALL,6)=0
:    34    S PUMPAG(ALL,ALL)=100000
:    35    S WDEL(ALL,ALL)=100000
:    36    S WATTHR=120000
:    37    S DEPTH(ALL,ALL)=30
:    38    S ACRE(ALL,ALL,ALL,ALL)=0.
:    39    S ACRE(ALL,ALL,1,ALL)=2000
:    40    S ACRE(ALL,ALL,2,ALL)=10000
:    41    S ACRE(ALL,ALL,3,ALL)=10000
:    42    S HUNT(ALL,ALL)=10
:    43    S FISH(ALL,ALL)=10
:    44    S VIEW(ALL,ALL)=8
:    45    S BOAT(ALL,ALL)=6
:    46    S VALHAB(ALL,ALL)=100
```