PROJECT A-040-IDA

Predicting Attainable Irrigation Efficiencies in the Upper Snake River Region

WATER for IDAHO

A Thesis Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science Major in Civil Engineering

by Brent A. Claiborn

Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho
May, 1975

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AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This thesis of Brent A. Claiborn for the Master of Science degree with major in Civil Engineering and titled "A Prediction of Attainable Irrigation Efficiencies in the Upper Snake River Region", was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

Major Professor C. E. Brockway Date 5/14/75

Committee Members D. W. Fitzsimmons Date 5/14/75

E. L. Michalson Date 5/14/75

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Major Professor ____________________ Date __________

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

LIST OF SYMBOLS

a_i	=	net acreage of crop "i"
A_{wp}	=	wetted area of canal reach
b	=	wetter perimeter
C_{rf}	=	coefficient of return flow
C_s	=	soil seepage coefficient
C_t	=	topwidth coefficient
d	=	number of days in bi-monthly period
$\frac{dS}{dt}$	=	change in system storage with time
d_s	=	average depth of water stored during irrigation
E_a	=	water application efficiency
E_c	=	water conveyance efficiency
E_d	=	water distribution efficiency
E_i	=	overall irrigation efficiency
E_p	=	project irrigation efficiency
E_u	=	unit irrigation efficiency
f	=	climatic factor
F_r	=	district return flow fraction
I_r	=	monthly consumptive irrigation requirement
k_c	=	crop growth stage coefficient
L_r	=	reach length
m	=	number of days in the month in which a specific time period occurs
p	=	monthly percentage of annual daylight hours
q_{act}	=	actual total district return flow
q_i	=	bi-monthly consumptive irrigation requirement for crop "i"

q_{max} = 100% river diversion level

q_{min} = 40% river diversion level

q_{rf} = measured district return flow

q_{rd} = specific daily river diversion

Q_{cir} = consumptive irrigation requirement of crops

Q_{csl} = canal and lateral seepage losses

Q_{cu} = consumptive use of crops

Q_{dpl} = deep percolation loss

Q_{if} = supplementary district inflow

Q_{in} = total system inflow

Q_{out} = total system use and outflow

Q_p = amount of effective precipitation

Q_{rd} = river diversion

Q_{rf} = total district return flow

Q_{tf} = total district inflow

R_e = volume of effective rainfall

S = computed daily seepage rate for a total district

S_{max} = base daily seepage rate computed by the seepage program

S_p = seepage loss in reach of canal

t = mean monthly temperature

T_w = average topwidth of reach

u = monthly consumptive use

V_{et} = volume of water required for evapotranspiration

V_f = amount of water delivered to the field

V_l = volume of water necessary for leaching on a steady-state basis

V_r = amount of water stored in the root zone

W_d = volume of water delivered by the system

W_i = volume of water diverted

W_r = volume of water delivered to the system

y = average numerical deviation in depth of water stored from average depth stored during irrigation

ABSTRACT

Present irrigation efficiencies and reasonably attainable irrigation efficiencies were evaluated in a study conducted on independent irrigation districts in the Upper Snake River Region of southern Idaho. Irrigation water use was investigated on six irrigation districts during the 1974 irrigation season.

The irrigation districts selected typify most irrigation systems in the region, which was divided into 3 sub-areas having similar irrigation water use characteristics. River diversion data, conveyance system seepage loss data, crop distribution and return flow data were compiled. Deep percolation losses and irrigation efficiencies were derived using an inflow-outflow water balance analysis.

Present farm irrigation efficiencies varied from 11 to 62 percent on the districts. Project irrigation efficiencies ranged from 10 to 42 percent. By predicting attainable farm irrigation efficiencies of 60 percent, reasonably attainable project irrigation efficiencies were projected to range from 35 to 51 percent.

Low present farm irrigation efficiencies were attributed to over-irrigation caused by long field runs combined with high intake rate soils. Lining main canal systems to reduce seepage would not significantly increase project irrigation efficiencies. Large decreases in river diversion could be obtained by increasing farm irrigation efficiencies.

CHAPTER I

Introduction and History

Preliminary development of irrigation systems began after the 1870's in the Upper Snake River Region of Idaho. Irrigation has grown since that time and presently encompasses more than 2,300,000 acres in this region which reaches generally east and north upstream from Bliss, Idaho (24). This area encompasses the eastern half of the Snake River Plateau in Southern Idaho. The gentle sloping lands and fertile valleys of this region comprise one of the richest irrigated agricultural areas in the United States. Prior to the 1870's, dense sagebrush and native grass associations covered most of the present farmlands.

The early irrigators in the eastern portion of this region were organized primarily into small independent ditch companies, occasionally memberships consisted exclusively of relatives. Because of the staggering number of manhours needed to bring river water onto each acre of land, the majority of irrigation systems were initially not large. Compared to most large acreage irrigation projects of present day, these early developments were small; generally less than 10,000 acres.

Heavy sagebrush and solid lava rock had a great influence upon the size of these projects. The construction crews, consisting of the hopeful farmer-stockholders of the companies, had only slip scrapers pulled by horses, moldboard plows, picks, shovels, and explosives to excavate the canals. Surveying to put the canals on proper grade was done using a hand-held spirit level. To minimize effort and expense, conveyance channels were designed to follow the natural contour of the land. This practice eliminated the need for flumes, siphons, or other hydraulic structures. However, it did lengthen canals and provided few straight reaches of channels.

Irrigable lands immediately adjacent to the river were usually put under irrigation first. As these lands bordering the river were cleared, tilled, and irrigated, other sections of fertile soil at greater distances from the river channel were developed. Conveying water to these new lands frequently required new channels to be cut through one or more older existing canal systems. Often the new lands were situated at higher elevations than the older farms, necessitating longer channels beginning farther upstream on the Snake River. Intermingling and overlapping canal systems are common as a result.

Since the early days of development these systems have undergone many evolutionary changes. Most rock and timber diversion dams have been replaced with massive concrete structures. Diversion headgates, also of steel and concrete construction have been added to improve water regulation. Other hydraulic structures in the canal systems, that were initially of wooden construction, have been for the most part replaced by stronger, longer lasting materials such as steel and concrete. However, major over-all project renovation, such as consolidation of paralleled canals, combining the smaller individual systems into larger operating entities, and channel alignment have not been implemented to any significant degree. Some of the smaller systems have been combined, but many exist essentially as they did 90 years ago.

Technological advancements in hydraulic and irrigation engineering have been used extensively in designing the more recently constructed irrigation systems on the Upper Snake. Those systems in the western portion of the region fall most often into this category. Conveyance efficiencies have increased along with the reduction of operational and other system water losses on these later irrigation systems. One of the newer systems has been in full operation less than 15 years (21).

Prior to 1906, irrigators in the Upper Snake River area were at the mercy of nature, having no substantial storage reservoirs. Their economic survival was entirely dependent upon heavy runoff and sustained summer river flows. That year, the Jackson Lake impoundment was created by the construction of a log crib dam at its outflow. This structure was later replaced by a combination earth and concrete dam which increased storage in the lake. Each year brought additional new diversion works to the river channel for new canal systems and more irrigation of the land. The demands for the valuable waters of the great river were growing with each new year.

In the spring of 1919, the prospect of a water crisis arose. Before this time, coordination of river operations had been non-existent. This crisis demanded that coordination to insure uniform river diversions be instituted immediately to insure the survival of the rapidly expanding agricultural industry. Following several seasons of relatively low flow, with river operation coordination, the founding fathers of the Upper Snake were convinced that additional storage of substantial magnitude was indeed warranted. This overwhelming concurrence of opinion was the birthright to the construction of American Falls Reservoir, designed to contain in excess of 1,700,000 acre-feet of water. The dam was completed in 1926 and the reservoir filled in 1927. However, since the latter part of the 1960's when the dam was condemned due to concrete deterioration, pool elevation has been restricted to 2/3 of maximun capacity limiting storage to 1,200,000 acre-feet. Loss of 500,000 acre-feet of live storage has at times curtailed water use to an appreciable extent in the region. Fortunately, construction of a new American Falls Dam is scheduled to commence in the near future. In spite of this restoration of the reservoir to full design capacity will not allow any additional land reclamation in the Upper Snake Region.

Palisades, Island Park, Grassy Lake, and Lake Walcott Reservoirs were all constructed to insure that the agricultural production of this region would not diminish in the future below normal runoff years.

Irrigation development on the Upper Snake River has essentially evolved in 3 phases. First, canal and distribution systems were carved out of the virgin soil. Second, relatively lower water levels in the river in subsequent years resulted in diversion dams being built at most headgates. Finally, increased water demands and occasional subnormal runoff called for the construction of the large storage reservoirs. Each phase seemed initially costly, but only a few years had to pass before their benefits were fully realized by the people living in the Upper Snake.

On-farm irrigation methods and practices have in some areas gone through as much evolutionary change as the diversion and storage systems on the river, however, in a number of instances very little modification has taken place.

In the beginning flood and border irrigation were common methods of irrigating in the eastern section of the region and today these methods still prevail. Soils of this section tend to be highly permeable while in the western half soils generally contain larger fractions of clay and silt. Because of their higher silt and clay fractions, these soils are not as permeable as those in the eastern section. Furrow and border irrigation have been and are the dominant forms of irrigation in the lower or western region of the Upper Snake. Sprinkler irrigation is becoming more popular in most all areas of the Upper Snake, and is normally satisfactory on all except the heavier clay soils.

Depending upon soil type, ground slope, length of run, and management practices, border and flood irrigation can be quite efficient. Normally, highly permeable soils, nearly flat runs and lengthy fields do not allow border and flood irrigation to be efficient. In addition, sufficiently large streams of water are needed to achieve satisfactory irrigation of croplands. The combination of high infiltration rates, large stream flows, and long field runs often results in excessive deep percolation and comparatively large water diversion requirements. Likewise, furrow irrigation under similar conditions would in all probability result in low water use efficiencies. Sprinkler irrigation usually functions well over high infiltration rate soils and has in many instances reduced water requirements drastically.

On soils with moderate to low infiltration rates, furrow and border irrigation can be efficient means of irrigation, if land slopes and lengths of run are commensurate with soil permiability. Water requirements and deep percolation should be significantly lower under these conditions compared to some existing conditions with flat slopes and excessive field lengths. Reduction of excessive deep percolation should decrease leaching of valuable soil nutrients considerably, enhancing yields, reducing fertilizer requirements, and augmenting monetary returns to the water user.

Irrigation is not the only use for Idaho's water resources; other uses should not and definitely will not be overlooked in future water resource utilization studies. Industries, municipalities, water quality enhancement schemes, recreational locations, and fish and wildlife requirements are all competitors for this water. Each will no doubt receive serious consideration in allocating future water supplies on the Upper Snake River. The latter four uses can likely be expected to require greater quantities of water compared to municipalities and industries on the Upper Snake in the future. However, all these nonagricultural demands, including industries and municipalities, should grow at least somewhat in correlation with irrigation development in this region. But, none of these individual uses in all probability should exceed irrigation in overall quantitative demand in the foreseeable future in this region.

Food production on irrigated agricultural lands can only be expected to accelerate in the years ahead, barring any catastrophic reduction in world population growth. As nations around the world raise their standard of living, they also begin competing for higher protein foods, including foods grown under irrigation, on the world export markets. Foreign demand has accelerated recently for commodities such as wheat, dry beans, sugar, potatoes, and beef. Countries which had previously shown no interest in purchasing such commodities are placing large export orders for these items. Few reasons exist for believing that this interest will dissipate in the future. Consequently demand for more land to be put under irrigated cultivation has been mounting and will continue to do so.

Idaho has thousands of acres lying idle that could be put under intensive production. In the Upper Snake Region alone, at least 3,824,400 acres of potentially irrigable land along with 396,000 acres of land in need of supplemental water existed as of July 1972 determinations (22). Substantial "potentially irrigable land" also exists downstream of Bliss, Idaho within the state. For the most part these lands above and below Bliss, are presently being grazed, dry farmed, partially irrigated or lying idle. It is the author's opinion that these lands are not being utilized to fulfill, in economic terms at least, their highest and best use. Without sufficient water for irrigation, agricultural production on these lands is severely inhibited.

As pointed out previously, present reservoir storage capacity is not adequate to support any new large scale reclamation development anywhere in the Upper Snake River Region. Annual river discharges in excess of existing reservoir capacity are not sufficiently reliable to insure against massive crop failure on a major irrigation development venture. Under these conditions, only an average of 1,119,000 acre-feet of water per year can be expected to pass Milner Dam at the 1970 level of development (23). Assuming a mean diversion requirement of 5.0 acre feet per acre, only an additional 224,000 acres can be supplied under present irrigation diversion requirements. It must be recognized that this could take place feasibly only with the construction of additional storage either on the river system or off stream.

Construction of additional surface storage reservoirs in this region is highly improbable in the foreseeable future, since few good dam sites remain in the region. In addition, vigorous support of a major new dam building project is not likely to be generated under present public sentiment. Creation of a vast underground storage reservoir might appear to be an alternative to expanding water utilization on the Upper Snake. However, numerous unknowns surround this concept in water storage, including major questions concerning geologic, engineering, and economic feasibility. Seasonally fluctuated storage aquifers of this nature and magnitude have until now received limited research and utilization in the United States.

A more favorable alternative to expanding use of Idaho's water in the Upper Snake is to explore the effects of increased irrigation efficiency on existing irrigation projects on the Upper Snake River System. A number of questions must be addressed before a definite change in water use can be advocated or even predicted. However, preliminary investigation indicates that increased irrigation and conveyance efficiencies would reduce average deep percolation and seepage losses and subsequently project diversion requirements from the river. Looking at the region as a whole, increased water use efficiencies could result in substantial water savings, opening the way to development of supplemental water supplies or new reclamation projects.

CHAPTER II

Objectives and Problem Elements

Research objectives serve to define the limits and boundaries within which the actual research activities occur. The objectives of this study were coordinated to assist in satisfying the purposes of the investigation. In general the objectives of this study were to obtain various water use data during an irrigation season which would be representative of regional and local irrigation water use trends in the Upper Snake River Region. Subsequently this data is used to develop reasonable predictions of future water use trends. This investigation, involving the prediction of attainable irrigation efficiencies was created with three major research objectives, specifically:

1. To obtain accurate, consolidated data on present return flows to the Snake River from typical irrigation systems.

2. To determine current water use and irrigation efficiencies for selected irrigation tracts of typical sub-areas of the region.

3. To develop predictions of reasonable attainable changes in irrigation water use patterns and irrigation efficiencies for these irrigation systems and their associated sub-areas.

These three objectives directly relate to future water resource planning and decision making activities in this region, the remaining portion of the river basin, and the entire State of Idaho. Information and data assembled herein should be useful to the state administrative and planning agencies involved in developing a state water plan for Idaho.

The Upper Snake River Region is a complex hydrologic system sensitive to changes in internal water use patterns. General components of the system include: watershed, storage reservoirs, distinct reaches of the river channel, irrigation diversion works, and the large underground aquifer commonly referred to as the Snake Plain Aquifer. The behavior of each component, not being mutually exclusive of the others, has a definite influence upon the response of each of the other components and consequently the entire hydrologic system. Therefore, the system must be examined as a whole when water use modifications occur or are evaluated. Furthermore, data describing the actual responses of the system to any specific modification is lacking. Supplementary hydrologic or water use data collected on the Upper Snake River Region can only enhance the understanding of the river system. In particular, the Idaho Department of Water Resources Research Division, formerly the Idaho Water Resource Board, has developed a computerized river operations model to simulate flows in the Snake River. This planning tool uses river return flow as an important input parameter. Consequently measurement of return flow is enumerated as the first research objective.

De Sonneville (12) in association with the Water Resources Research Institute has developed a digital computer program model of the Snake Plain Aquifer. This unique research operations tool will undoubtedly play an important role in evaluating the impacts of future water use trends on this region. But, in order for this computer model to maintain viability and contribute significantly to future water use planning, it must be calibrated and updated frequently with current and more advanced data. Much of the water use data collected in this project will be directly utilized by the Snake Plain Computer Model.

Of equal importance and value, the second objective of this research is to provide accurate information on present irrigation efficiencies and the current nature of agricultural water use in the Upper Snake River Region. Studies concerning these two related subjects have not been conducted to a large extent throughout the region. Most data that exists is confined to independent evaluations which have been limited to only local areas in the region such as the quantitative investigations done by Galinato (17), Tyler (35), and the Bureau of Reclamation (39). In addition, the Soil Conservation Service (41) has conducted a Type IV Study on a number of irrigation systems in this region. However, this study was done in primarily a qualitative manner and no attempt was made to obtain measured data. A definite need has existed for a quantitative, broad encompassing examination to be conducted simultaneously over the entire region; a need met by this research effort.

Proper planning of any system must be founded upon well established present operating conditions and accurate justified predictions of future operating levels. To assist evaluation of future water resource planning and expansion of irrigated agriculture in the Upper Snake, this study develops predictive data concerning reasonable changes in irrigation efficiencies as stated in the third objective. Various alternatives were examined in this study and are reported later in this thesis.

Problem Elements

Primarily the problem addressed in this research study is one of the main deficiencies in real quantitative water use data. Lack of consolidated, current data, and information concerning various facets of irrigation water use in the Upper Snake River Region was the principal driving force behind initiating this research. These deficiencies are categorized for reporting purposes as either specific or general deficiencies.

A lack of accurate data in four specific areas has existed until this work was done in 1974. Few previous measurements of seasonal return flow have been done on most of the irrigation districts, except for 2 or 3 special studies conducted on tracts in the extreme lower and central portions of the region (5,1). Since the majority of independent irrigation districts have had no need to be concerned with measurements of return flows to the Snake River, data is sparse and limited. Likewise, net water use data on typical irrigation tracts has not been collected before on a broad scale. Water use data that has been cited has frequently been based solely on volumes of river diversions only. Supplementary inflow and river return flow has often been neglected opening the possibility of misleading water use interpretations. Studies, such as those examined in the next chapter, of actual irrigation efficiency levels are limited and localized. Evaluations of irrigation effeciencies from the total system or total district concept have not been universally conducted previously. Finally, insufficient canal seepage loss data exists on the irrigation systems that consitute this region. Measurements of actual seepage losses on irrigation districts within this region are limited. Indirect methods of seepage loss determination, such as those conducted in this study, have been done only on a few systems in the Upper Snake River Region.

Two general deficiencies in data can be identified. To date, only limited in-depth studies of irrigation water use in this region have been conducted. Previous studies with similar objectives have been concerned primarily with evaluating individual field or farm efficiencies (17,35,39) Nonetheless, while they have provided valuable information and data, these investigations were not designed to analyze efficiencies from the large scale regional concept. Only geographically scattered, quantitative water use research, discussed in Chapter III, has been carried out at the irrigation district level on the Upper Snake River Region. Consequently the research done in this study is geographically somewhat unique.

Secondly, the quantitative effects on water use due to variations in irrigation practices throughout the Upper Snake River Region have not been comparatively studied except to a rather limited extent. An attempt is made in this study to identify some of these effects. However, additional research concerning these aspects is warranted to obtain conclusive results.

In summary, this study was conducted with the goal of providing accurate, consolidated data and information on irrigation water use on typical, representative irrigation tracts located in the Upper Snake River Region. Simultaneously, the study attempts to reduce each of the four specific areas of data deficiency.

CHAPTER III

Literature Review

Published research on the subject of irrigation efficiency is relatively extensive. Numerous studies have been carried out analyzing the components of the term, the sensitivity of it to various factors, and particularly methods of analysis. The overwhelming majority of these studies have been conducted at the individual farm or field level. This is understandable when realizing that most studies intend to identify specific elements constituting irrigation efficiency at the farm level. Only limited emphasis has been directed at analyzing irrigation water use from the system concept; focusing attention upon a complete distinct irrigation unit comparable in size to an irrigation district or project. Some studies concerning the relationship of field or farm efficiency to overall system efficiency have been published (26). System analyses of irrigation districts have been prevously conducted but not necessarily for the primary purposes of evaluating irrigation efficiency. Moreover, some investigations of irrigation efficiency have included a portion or section of their work devoted to a prediction oriented analysis of irrigation efficiency. Together with the concepts and definitions of irrigation efficiency, these subjects are examined in the following text.

Studies in 1939 by Israelson (25), are normally cited as the first attempt to define irrigation efficiency and identify its contributing factors. However, Israelson refers to previous concepts and measurements of irrigation efficiency developed and compiled as early as 1919 and 1926-27.

Israelson defined water application efficiency as "the ratio of the volume of water stored in the soil in one irrigation to the volume delivered to the field." Mathematically, water application efficiency, E_a, is:

$$E_a = \frac{V_r(100\%)}{V_f} \quad (1)$$

Where: E_a = water application efficiency in percent

V_r = amount of water, in inches, stored in the root zone

V_f = amount of water, in inches, delivered to the field.

He continues by noting that water application efficiency is "clearly a dimensionless quantity which is not a direct function of crop responses to irrigation". The influencing factors inherent to water application efficiency, according to Israelson, can be divided into those subject to irrigation control and those not subject to such control. Land preparation, method of irrigation water application, and time and rate elements of irrigation are controllable factors. He identified soil texture, soil depth, soil variability, and soil permeability as those factors being relatively independent of irrigator control--a concept still valid. In addition, Israelson outlined a method of analysis for measurements of field irrigation efficiency, or water application efficiency.

Since Israelson, numerous articles have been written on the subject of irrigation efficiency (14,43,26,44, 15,27,16), and consequently irrigation efficiency has been given assorted definitions and connotations. New concepts of efficiency have also been developed, such as conveyance efficiency, farm efficiency, project efficiency, and water distribution efficiency. Willardson (43) found 20 definitions of irrigation efficiency and noted that to properly distinguish between definitions, the elements contained in each equation of efficiency must be specified. He summarized the situation regarding irrigation efficiency definitions by stating that "efficiency is computed to determine how well a particular goal is being reached".

Willardson presented the concept of irrigation efficiency as being related to both water application efficiency and water distribution efficiency, known also as uniformity coefficient, however, he felt that they were not related in a strict mathematical sense. He used Israelson's definition of water application efficiency but, did not specifically define water distribution efficiency. However, Hansen and Israelson (18) have defined water distribution efficiency, E_d, as:

$$E_d = 100\ (1 - Y/d_2) \qquad (2)$$

Where: E_d = water distribution efficiency, in percent

y = average numerical deviation in depth of water stored during the irrigation

d_s = average depth of water stored during the irrigation.

Examining several methods of irrigation, Willardson showed that high water application efficiencies were coupled to high values of uniformity coefficient or water distribution efficiency. Furthermore, high values of uniformity coefficient are difficult to achieve under conditions of light water application, high intake rate soils, and spacial variation of soil intake rates.

Jensen (26) summarized previous work and concepts by defining and redefining irrigation, irrigation efficiency, water conveyance efficiency, unit irrigation efficiency, and project irrigation efficiency. He defined irrigation as "the application of water to the soil supplementing natural precipitation for the purpose of supplying water essential to plant growth." Irrigation efficiency, E_i, accordingly, is "the ratio of the volume of irrigation water transpired by plants and evaporated from the soil and plant surface plus that necessary to regulate the salt concentration in the soil solution, and that used by the plant in building plant tissue to the total volume of water diverted, stored, or pumped for irrigation". Neglecting that water stored in plant tissue and any change in stored soil water or, in short assuming steady-state conditions, enables overall irrigation efficiency to be written algebraically as:

$$E_i = \frac{V_{et} + V_l - R_e}{W_i} \times 100\% \qquad (3)$$

Where: E_i = overall irrigation efficiency in percent

V_{et} = the volume of water required for evapotranspiration

V_l = the volume of water necessary for leaching on a steady-state basis

R_e = the volume of effective rainfall

W_i = the volume of water diverted.

He further states that effective rainfall is "total rainfall minus runoff and deep percolation that may occur during heavy rains or rains following a thorough irrigation."

Water conveyance efficiency, E_c, according to Jensen is the "ratio of the amount of water delivered by a conveyance system to the amount of water delivered to the conveyance system at the source of supply" or in equation form:

$$E_c = \frac{W_d}{W_r} \times 100\% \qquad (4)$$

Where: E_c = water conveyance efficiency in percent

W_d = amount of water delivered by the system

W_r = amount of water delivered to the system

Water conveyance efficiency is strictly dependent upon the capability of the conveyance system to deliver water. Seepage losses, evapotranspiration losses to bank phreatophytes, operational losses, (return flows), and direct surface evaporational losses are the limiting consituents which govern this efficiency.

Jensen defines unit irrigation efficiency, E_u, as "the amount of water used by evapotranspiration plus the amount required for leaching purposes divided by the amount of water delivered" or algebraically:

$$E_u = \frac{V_{et} + V_l}{W_i} \times 100\% \qquad (5)$$

Where: E_u = unit irrigation efficiency in percent

And: V_{et} and V_l are defined previously

Obviously, unit irrigation efficiency differs only from overall irrigation efficiency by the effective rainfall term.

He has combined mathematically, reservoir storage, efficiency, water conveyance efficiency, and unit irrigation efficiency to formulate the term <u>project irrigation efficiency</u>, E_p. <u>Reservoir storage efficiency</u>, E_s, is defined as "the ratio of the volume of water delivered from the reservoir for irrigation, to the volume of water delivered to the reservoir." The composite equation resulting from combining the three efficiencies is:

$$E_p = \frac{E_s}{100} \frac{E_c}{100} \frac{E_u}{100} \times 100\% \qquad (6)$$

Where: E_p = project irrigation efficiency in percent

E_s = reservoir storage efficiency in percent

E_c = water conveyance efficiency in percent

E_u = unit irrigation efficiency in percent

This composite term allows evaluations of entire irrigation systems on a total overall irrigation efficiency basis.

Irrigation efficiency is dependent upon a number of parameters in addition to those already mentioned. Tyler (36) has cited these factors affecting farm irrigation efficiency: length of field head ditches, length of irrigation runs, crop distribution, field gradients, the irrigation management ability of the farmer, weather conditions, and irrigating for soil conditioning purposes only. He presumed that 75 percent of the variation in irrigation efficiencies could be due to these four factors: soil variation, irrigation frequency, duration of irrigation, and irrigating for soil conditioning purposes. Farmer ability and crop distribution between row crops, and forage crops were also listed as significant components affecting irrigation efficiency. Along with Tyler, Erie (14) attributes irrigation management or farmer ability with having considerable influence upon irrigation efficiencies. Irrigation management deals most frequently with the questions of when to irrigate, how much to apply, and in what manner should water be applied. Irrigation scheduling virtually eliminates these first two questions

Irrigation studies based upon the application of a water balance or water budget type analysis have been conducted only to a limited extent from a total irrigation system approach. The majority of these investigations have been carried out primarily to research water quality characteristics as opposed to actual water usage patterns. However, chemical balances have been used successfully and since similar data is required in each, the same procedure can be applied to water use type water balances.

Sylvester and Seabloom (33) carried out a water in--water out budget analysis on the entire irrigated portion of the Yakima River Valley in Central Washington in the early

1960's. Their work was conducted primarily to determine changes in water quality in the Yakima River caused by irrigation return flow. Although they calculated the actual usage by evapotranspiration, they did not determine any values of irrigation efficiency. Obviously, the determination of irrigation efficiencies can be normally accomplished by simple manipulation of the data components of a water balance.

Brown, et al and Carter, et al, (5,6), have carried out water balance determinations for several consecutive irrigation seasons on 2 large irrigation projects in Southern Idaho. Their work has been aimed at collecting water quality and sedimentation output data in addition to some actual water use pattern data. They monitored concentrations and the rates of inflow, seepage outflow, and surface return flow on a total of about 360,000 acres.

Brockway and deSonneville (2), developed a complete water budget analysis for à 96,000 acre tract near Rigby in eastern Idaho during the 1970, '71, '72 irrigation seasons. The water budget procedure provided the necessary data to allow development of a systems simulation model of groundwater movement through the irrigation tract. Measurements of field irrigation efficiency for both border and furrow irrigation was conducted during initial stages of data collection on the tract. In this study detailed data on canal diversions, return flows, canal seepage losses and evapotranspiration was assembled in order to generate a water balance for the 17 irrigation districts comprising the tract. Canal diversions were obtained from USGS daily records during the irrigation season. Return flow including system outflow data was collected by field measurements during the irrigation season. Utilization of aerial photographs to determine total wetted areas along with field measurements of seepage rates enabled total canal seepage losses to be computed. The Penman combination equation was used to compute evapotranspiration using crop coefficients developed from the measured crop distribution.

From field investigations, Brockway and De Sonneville determined average values of field irrigation efficiency ranging from 50 percent on compacted furrow irrigated potatoes for light applications of about 2 inches of water to less than 20 percent on uncompacted furrow irrigated potatoes during early season irrigation. They estimated that these efficiencies would decrease considerably, later in the season due to the obstruction of furrows by fallen potato plant vines causing increased furrow intake rates. These investigators attributed the low irrigation efficiencies principally to long field runs accompanied by high intake rate soils, poor field leveling, and excessive irrigation field sets over night.

Galinato (17) investigated irrigation efficiencies on 10 seperate fields in the Snake River Fan area near Rigby, Idaho during the 1973 irrigation season. All data was collected on loam soils, and on crops of barley, alfalfa, and potatoes. He found water application efficiencies ranging from 19 to 32 percent, with a mean of 24 percent, for border irrigation of alfalfa and barley. For furrow irrigation of potatoes efficiencies ranging from 47 to 58 percent with a mean of 51 percent were found. Clearly Galinato's data substantiates the earlier findings of Brockway and De Sonneville. He similarly attributes the low efficiencies found to high water intake rate soils, long field runs, and long set times.

Most irrigation researchers concur that irrigation efficiencies generally found in the western states are much lower than they could or should be. However, opinion is divided on how much these efficiencies can be reasonably increased.

Willardson (43), estimated that furrow and border irrigation efficiencies of 60 to 70 percent are reasonably attainable but may be further increased by runoff recovery systems to over 80 percent. Together with Bishop (44), Wilardson predicted 60 percent attainable irrigation efficiencies under most conditions. Likewise Hanson and Israelson (18) have stated that surface irrigation efficiencies in the range of 60 percent and sprinkler irrigation efficiencies around 75 percent are feasible.

Jensen and Howe (28) in contrast, have reported that water application or farm irrigation efficiencies of 80 to

95 percent should be easily attained with border check irrigation methods. These efficiencies were actually obtained on fine sandy loam soils having gentle slopes ranging from near 0 to about 1 percent located near Scottsbluff, Nebraska.

Present irrigation efficiencies vary considerably depending upon where measurements were made. Farm irrigation efficiencies ranging from 31 to 52 percent were reported by the Bureau of Reclamation (40) for conventional surface irrigation systems in Nebraska and Colorado. In a similar study, the Bureau of Reclamation (39) found from field data that present farm irrigation efficiencies on the Minidoka Project, Unit A, near Paul, Idaho ranged from 36.3 to 43.7 percent. Attainable farm irrigation efficiencies on the same study area are predicted to vary from 51 to 64 percent.

Irrigation runoff recovery and pump-back systems have received considerable attention as a practical method of increasing farm irrigation efficiency. Somerhalder and Fischbach (15) concluded that reuse systems could increase average farm irrigation efficiencies from about 65 percent to almost 92 percent, where the difference of 27 percent represents lost field runoff.

Other alternatives such as transition to total sprinkler irrigation and computerized irrigation scheduling (27) are expected to boost irrigation efficiency. Actual values of increased irrigation efficiency due to the implementation of irrigation scheduling have not been evaluated in the articles cited however.

In summary irrigation efficiency can take on numerous interpretations restricted only to the components comprising the defining equation. In addition, wide variations in actual values of present irrigation efficiency have been measured. Ascertaining values of attainable efficiencies is highly dependent upon local soil conditions, irrigation methods and systems, and irrigation management attitudes, to name a few contributing factors.

CHAPTER IV

Study Approach and Procedures

Basic Approach Philosophy

The basic study approach was designed to satisfy the purposes and objectives of the investigation presented in Chapter II. Before predictions of attainable irrigation efficiencies could be made, it was deemed necessary to establish the current operating levels or present irrigation efficiencies of each irrigation district. This operating point is defined by existing water usage and irrigation efficiency at both the farm and district level. After establishment of the operating level from actual historic data, various parameters or conditions unique to each irrigation system which affect irrigation efficiency can be artificially adjusted. The change in efficiency of the total system can be computed and a new synthetic operating level created.

Present operating levels or irrigation efficiencies could best be evaluated by applying a total water budget analysis individually to a select number of typical irrigation systems in the study region. A total water budget analysis implies accounting for all major uses and significant losses of irrigation water in each distinct irrigation unit. The major uses and losses in an irrigation system as shown in Figure 1, page 30, include: diversions from a water source, supplemental inflow, precipitation, system

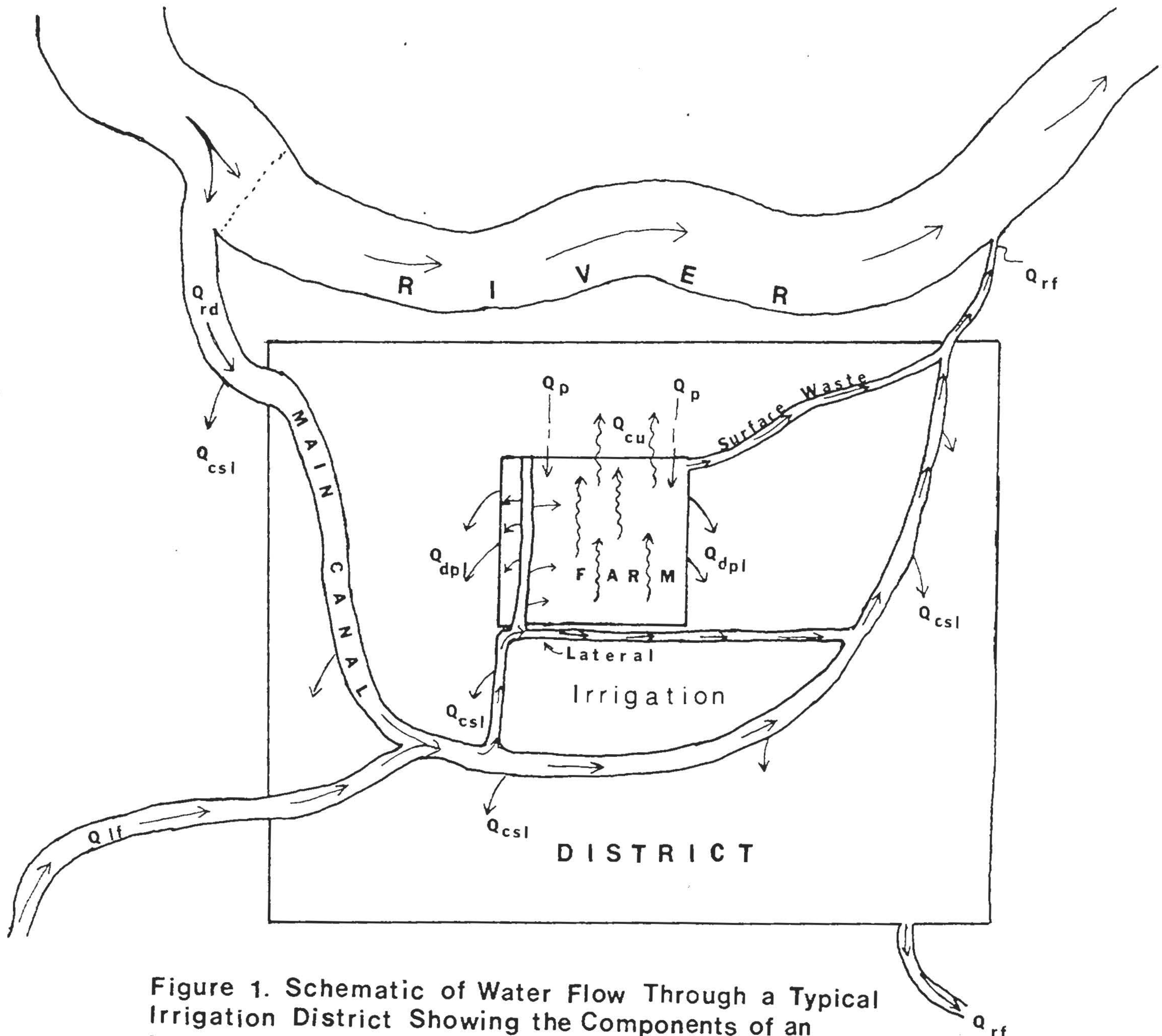


Figure 1. Schematic of Water Flow Through a Typical Irrigation District Showing the Components of an Irrigation Water Balance

return flow, evapotranspiration or crop consumptive uses, conveyance system seepage losses, and deep percolation of applied water beyond the root zone. These seven elements constitute a water in -- water out water budget.

After compiling data necessary to assemble the seven system components, the water balance was used to compute various water use parameters and efficiencies. Present operating levels could then be established. The next step, using economic reasoning and technical feasibility as guidelines, consists of artificially modifying those system parameters which significantly affect irrigation efficiency. The modifications introduced result in the creation of new input data to the system water budget producing new water use patterns and new values of irrigation efficiencies. In this manner, reasonable predictions of attainable irrigation efficiencies for each sub-area of the study region and subsequent changes in diversions from the water sources are developed.

Procedure and Techniques

The initial step in the procedure included two activities to achieve familiarization with the study region. First, attainment of a brief overview of the nature of irrigation methods and practices in the region was accomplished. The second step consisted of inventorying and geographically locating the individual irrigation districts in the region.

After familiarization, the determination of the number of irrigation systems and the actual selection process were begun. The following fundamental condition, outlining the selection process, was established. The number of irrigation districts to be studied should be representative of the major sub-areas of the region. However, simultaneously, the number of districts should not overload research manpower and resources. Under this condition, the number of systems to be selected for study was set at six.

Individual districts were chosen on a preliminary basis according to the following criteria: districts should be considered typical and representative of the systems comprising each sub-area of the region; all prevalent farm irrigation methods should be represented by at least one irrigation district; the irrigated acreage of the systems should not be a restrictive consideration, i.e. districts should not be chosen on a common size basis and; the nature and complexity of the water conveyance and distribution system should pose minimum field measurement difficulty. The six irrigation districts selected for preliminary investigation satisfied these criteria.

Arrangements were made with the six prospective irrigation organizations to secure their permission and enlist their cooperation in participating in the study. A formal condition of study procedure was verbally arranged in which no direct reference to the name of any one irrigation district would appear in any publication associated with this research. Therefore individual irrigation districts or systems will be identified by number only in this thesis. This agreement was incurred in order to obtain and use viable information and data on each irrigation district from the Soil Conservation Service, U.S.D.A.

The next procedural step involved determining what actual data and in what amounts would be required to apply a complete water budget analysis to each irrigation district. In addition, available sources and methods of data procurement were investigated. After initial study, the determination was made that data would be needed on the following components of the water budget analysis: river diversions, supplemental inflow, return flows from the district to the river, including systems outflow not directly returned to the river, crop consumptive uses, conveyance system seepage losses and deep percolation losses below the active root zones. A more complete and detailed discussion of alternative sources for each of these components is presented in Chapter V.

CHAPTER V

Data Collection

During eight months of 1974, data required for this study were collected on six independent irrigation districts located in the Upper Snake River Region of Idaho which is shown on the Study Area Map, Figure 2, page 35. These six districts have a combined total irrigated acreage of just under 300,000 acres and vary in size between 5,900 and 178,000 acres. Between April and October of 1974 discharge data were collected at 63 different measuring stations spanning a distance of over 200 highway miles. These stations are marked on the irrigation district maps on Figures 3 through 8, pages 39, 40, 41, 42, 43 and 44. Collection efforts were directed at obtaining the best possible data to a degree of accuracy considered within the scope and intent of the study. Physical, budgetary, and manpower limitations influenced some phases of the data collection activities. However, considering all aspects of the study, data collection was extensive and thorough.

Descriptions of Sub-Areas and Irrigation Districts

In this study, the Upper Snake River Region was segregated into three basic sub-areas; the Lower, Central and Upper Sub-areas running from South Central to Northeastern Idaho along the Snake River. Each sub-area and the selected irrigation districts included therein are briefly described concerning aspects of geology, topography, climatology,

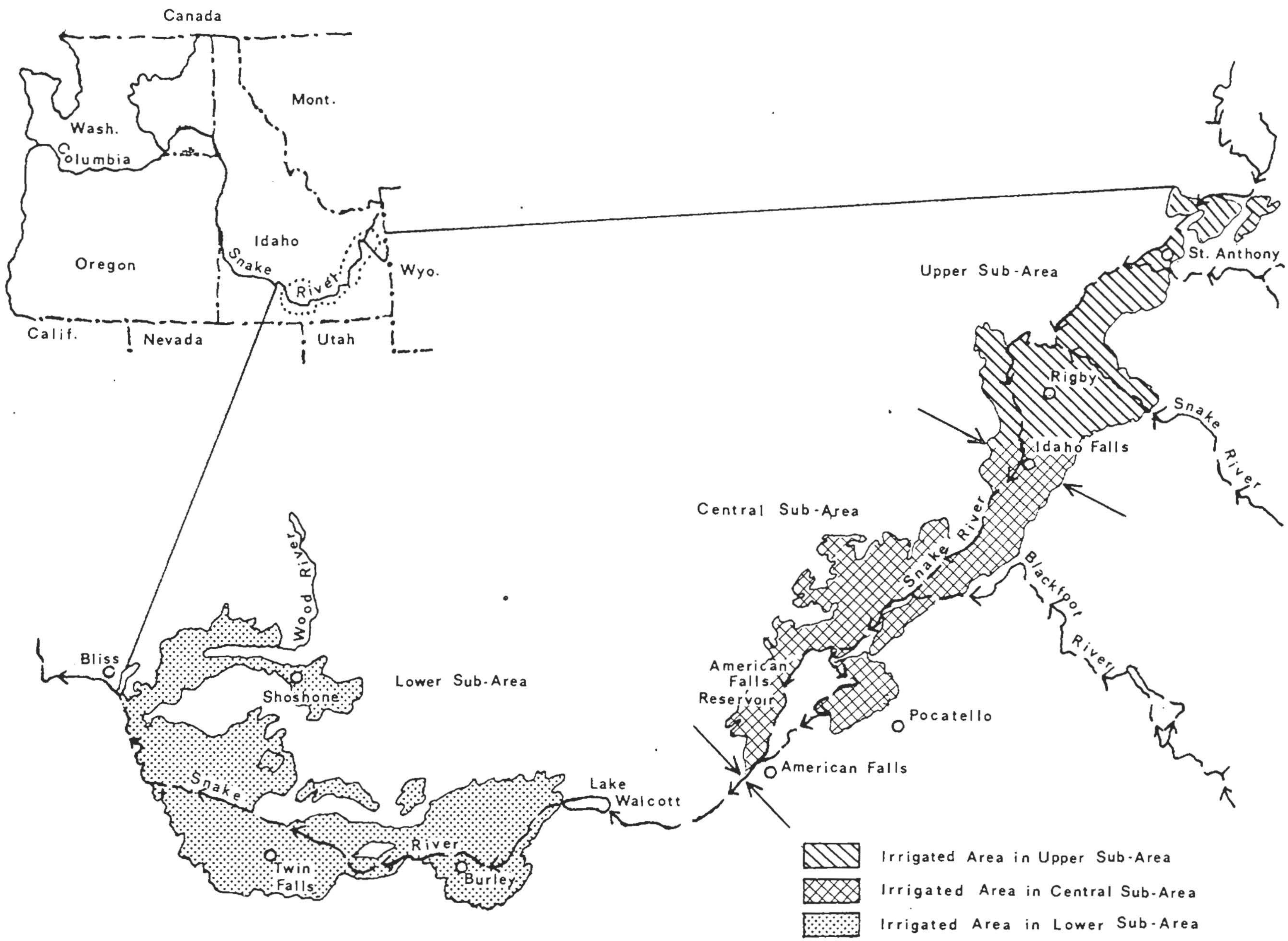


Figure 2. General Location Map and Irrigated Sub-Areas in the Upper Snake River Region

general soil types, cropping patterns, and district operating procedures. This information is summarized in Tables 1, 2 and 3 on pages 35, 36 and 37. Various climatic and topographical information about each sub-area and district are presented in Table 1. Irrigated acreages, water sources, crop information, soil types, and terrain are presented in Table 2. Physical and operational characteristics are given in Table 3. Only general variations in irrigation practices and methods in use throughout the region were examined.

The Lower Sub-area includes those lands lying immediately on either side of the Snake River, running east and south from Bliss to the Rupert-Declo vicinity. The river and deep gorge bisect the irrigated portions of the sub-area. Like the entire Snake River Plateau, the area is underlain by thick basalt formations and the extensive Snake Plain Aquifer which discharges into the river forming Thousand Springs. Land lying 10 to 30 miles south of the river is confined by a short east-west range of low mountains. Exposed barren lava formations generally 5 to 25 miles north of the river border the sub-area in that direction.

Topographically this sub-area lying on the plateau consists primarily of open level plains, slightly rolling hills, and occasional gentle sloping buttes. Warm dry summer and precipitation that is evenly distributed throughout the seasons characterize climatic conditions. Climatic variations between the 3 irrigation districts located in this region are insignificant. However soil variations are not

TABLE 1. Summary of Climatic and Topographic Characteristics of Each Sub-Area and Irrigation District (Taken from 29, 30, 31)

Characteristic	Irrigation Districts 1	2	3	4	5	6
Associated Sub-Area	Lower	Lower	Lower	Central	Central	Upper
Mean Annual Temperature (°F)	50	48	48	46	44	43
Mean Annual Precipitation (inches)	10	8	9	8	7	12
Frost-Free Period (Freezing Level = 32°F)	115-135	115-135	115-135	100-125	100-125	95-105
Range of Elevation (Feet above MSL)	3500-4000	4000-4400	4000-4400	4400 -4500	4600-4800	4800-5000

TABLE 2. Summary of Crops Grown, Soil Types, and Primary Water Sources for Each Sub-Area and Irrigation District (Taken from 7,8,9,10,11,32,41,42,45)

	Irrigation Districts					
Characteristic	1	2	3	4	5	6
Sub-Area	Lower	Lower	Lower	Central	Central	Upper
Gross Acreage (acres)	178,080	14,568	54,170	6,000	37,330	5,908
Net Irrigated Acreage (acres)	151,368	14,568	42,794	4,440	33,597	5,375
Primary Water Sources	Snake River	Snake River & Deep Wells	Snake River	Snake River	Snake River & Flood Rights	Fall River
Major Crops Grown	Sugar Beets, Dry Beans, Peas Corn Silage Grains Potatoes Alfalfa Pasture	Sugar Beets Dry Beans Peas Corn Silage Grains Potatoes Alfalfa Pasture	Sugar Beets Dry Beans Peas Corn Silage Grains Potatoes Alfalfa Pasture Orchards	Sugar Beets Corn Silage Grains Potatoes Alfalfa Pasture	Sugar Beets Peas Corn Silage Grains Potatoes Alfalfa Pasture Orchards	Potatoes Alfalfa Peas Grains Corn Silage Pasture Orchards
Major Soil Types	Silt Loam Sandy Loam Sand	Silt Silt Loam	Loam Silt Loam Sandy Loam	Loam Fine Sandy Loam	Loam Silt Loam Fine Sandy Loam	Silt Loam
Average Terrain Slopes (%)	0-12	0-12	0-4	0-4	0-4	4-12

TABLE 3. Summary of Physical and Operational Characteristics of Each Irrigation District*

Characteristic	Irrigation Districts 1	2	3	4	5	6
Sub-Area	Lower	Lower	Lower	Central	Central	Upper
Type of Irrigation Delivery System	Unlined Open Channel	Unlined Open Channel	Unlined Open Channel	Unlined Open Channel	Unlined Open Channel	Unlined Open Channel
Length of Main Canal (miles).	54.7	19.3	71.3	8.7	79.0	8.5
Length of Distribution Laterals (miles)	692.7	44.7	195.8	11.2	64.0	0.0
Method of Farm Delivery	Continuous Flow	Allotment	Rotation	Combination Demand-Rotation	Combination Continuous Flow-Rotation	Continuous Flow
Are Farm Deliveries Regulated by District Personnel?	Yes	Yes	Yes	No	Some	No
Are All Deliveries Measured?	Yes	Yes	Yes	No	No	No
Major Irrigation Methods	Furrow-90% Sprinkler-10%	Furrow-98% Sprinkler-2%	Furrow-55% Border-44% Sprinkler-1%	Border-79% Furrow-16% Sprinkler-5%	Border-60% Furrow-25% Sprinkler-15%	Sprinkler-85% Furrow-10% Border-5%

*Date given on this page is taken from (28) or from field investigations negligible on the 247,000 acres comprising all 3 districts. Irrigated soils are variable in type, texture, and depth throughout the area. The general soil groups consist of sandy loams, silt loams, loams, and sands (10,8).

Major crops grown in the sub-area are listed in Table 2, page 36. Furrow irrigation is the most popular water application method in all three districts.

Irrigation District No. 1, shown in Figure 3, page 42, largest of the six districts with a net irrigated acreage of 151,368 acres, lies in Minidoka, Jerome, and Gooding Counties. Irrigation was started on this tract in 1909 (5). Water from the Snake River is diverted at Milner Dam and distributed to the irrigated farms through 747 miles of unlined canals and laterals. Farm deliveries are 100 percent measured and regulated on a continuous flow basis (41). According to the Soil Conservation Service (41), approximately 90 percent of all lands within this district rely on furrow or corrugation methods of irrigation while the remaining 10 percent are sprinkler irrigated as shown in Table 3. The major soil types found in this district include silt loams, loams, and fine sandy loams and sands located principally in the southwestern portion of the district. Return flow was measured at twelve stations.

District No. 2, located within Jerome and Minidoka counties contains approximately 14,568 irrigated acres. This system is the newest of the six districts, and has been irrigated only since 1957. Most of the water used in this district is pumped from the Milner Pool on the Snake River, although a portion of the water pumped from deep wells located within the tract. Water is delivered to the farms on an allotment basis (35), by approximately 64 miles of unlined canals and laterals. All farm deliveries are regulated by the district and are measured over Cipolletti weirs. The pricing schedule used by this district to charge farmers for irrigation water is unlike the traditional flat rate operation and maintenance charges levied by other districts in the study area. A minimum charge is assessed for the first three acre-feet of water delivered in the irrigation season. Additional water is then allotted at a higher cost per acre-foot to the farm. This pricing schedule tends to discourage inefficient use of water and over-irrigation.

Eleven stations as shown in Figure 4, page 43, were established to measure return flow on this district.

As determined through field investigation, furrow irrigation is used on nearly all farms in District No. 2. Silt loam soils make up the major soil group found in this district.

Irrigation District No. 3, the second largest tract, containing about 42,794 irrigated acres, is situated entirely within Cassia County. The general shape of the district is shown in Figure 5, page 44. Water is diverted to this district out of Lake Walcott and distributed through approximately 267 miles of unlined canals and laterals. The river

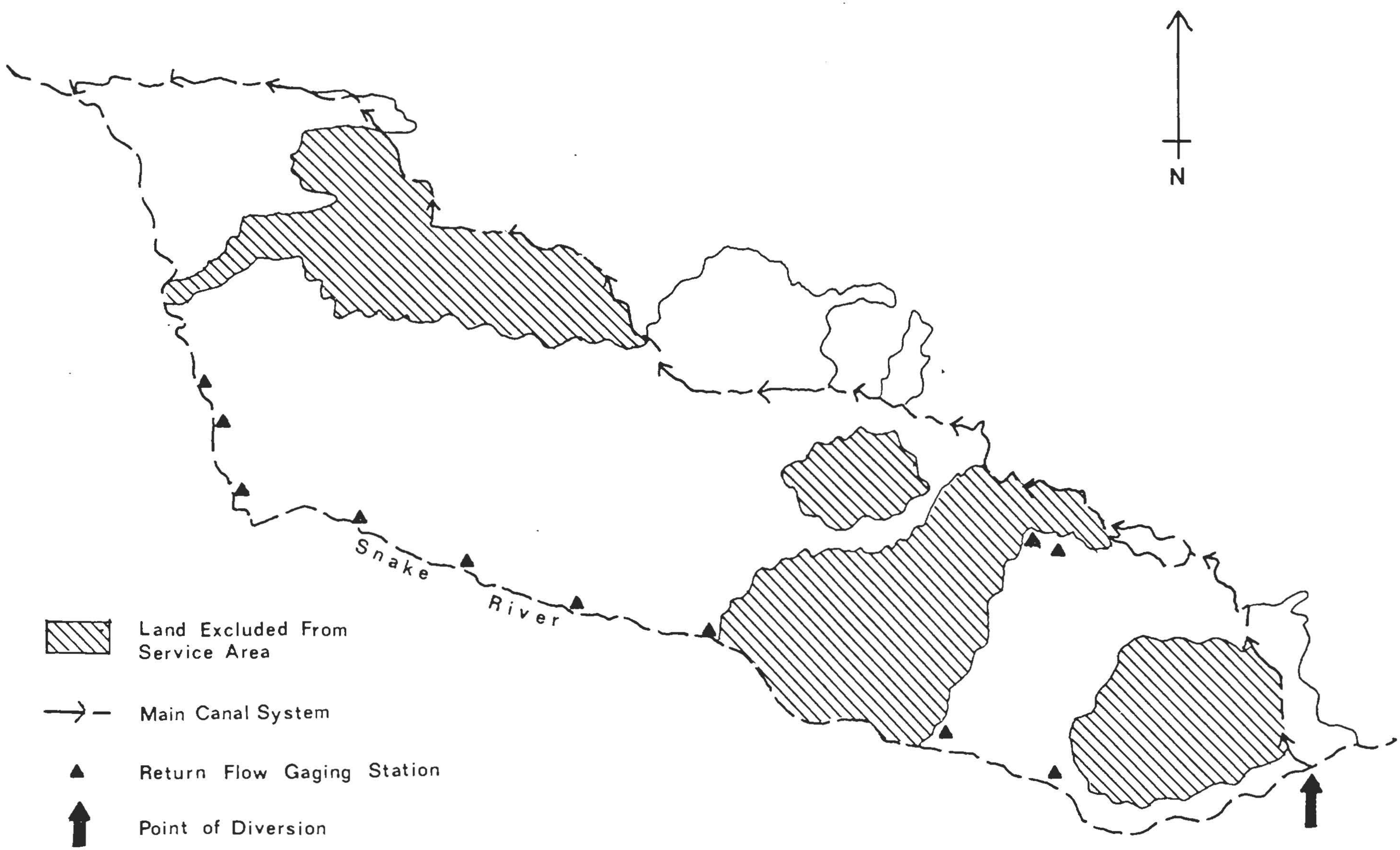


Figure 3. General Service Area of Irrigation District No. 1

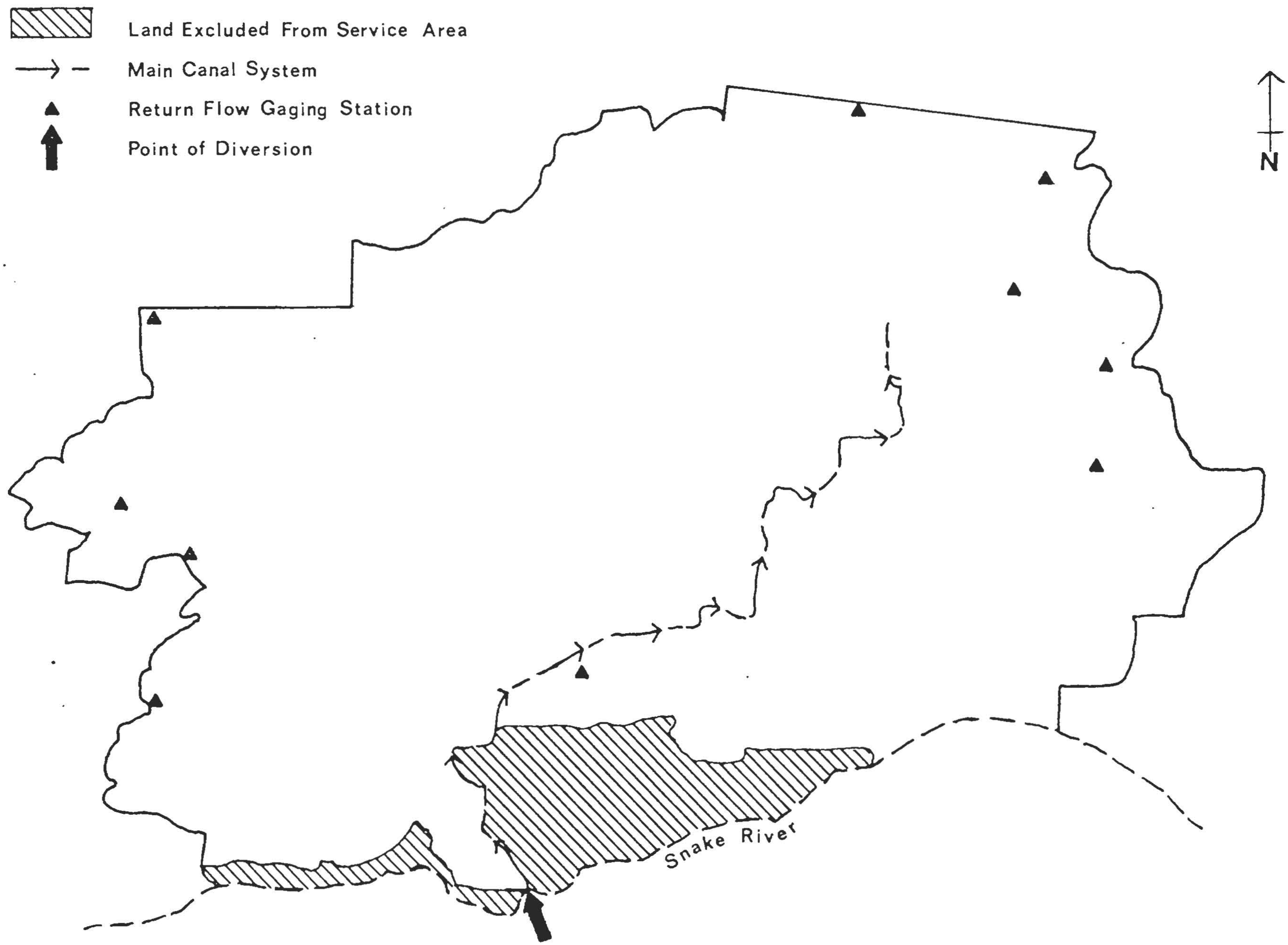


Figure 4. General Service Area of Irrigation District No. 2

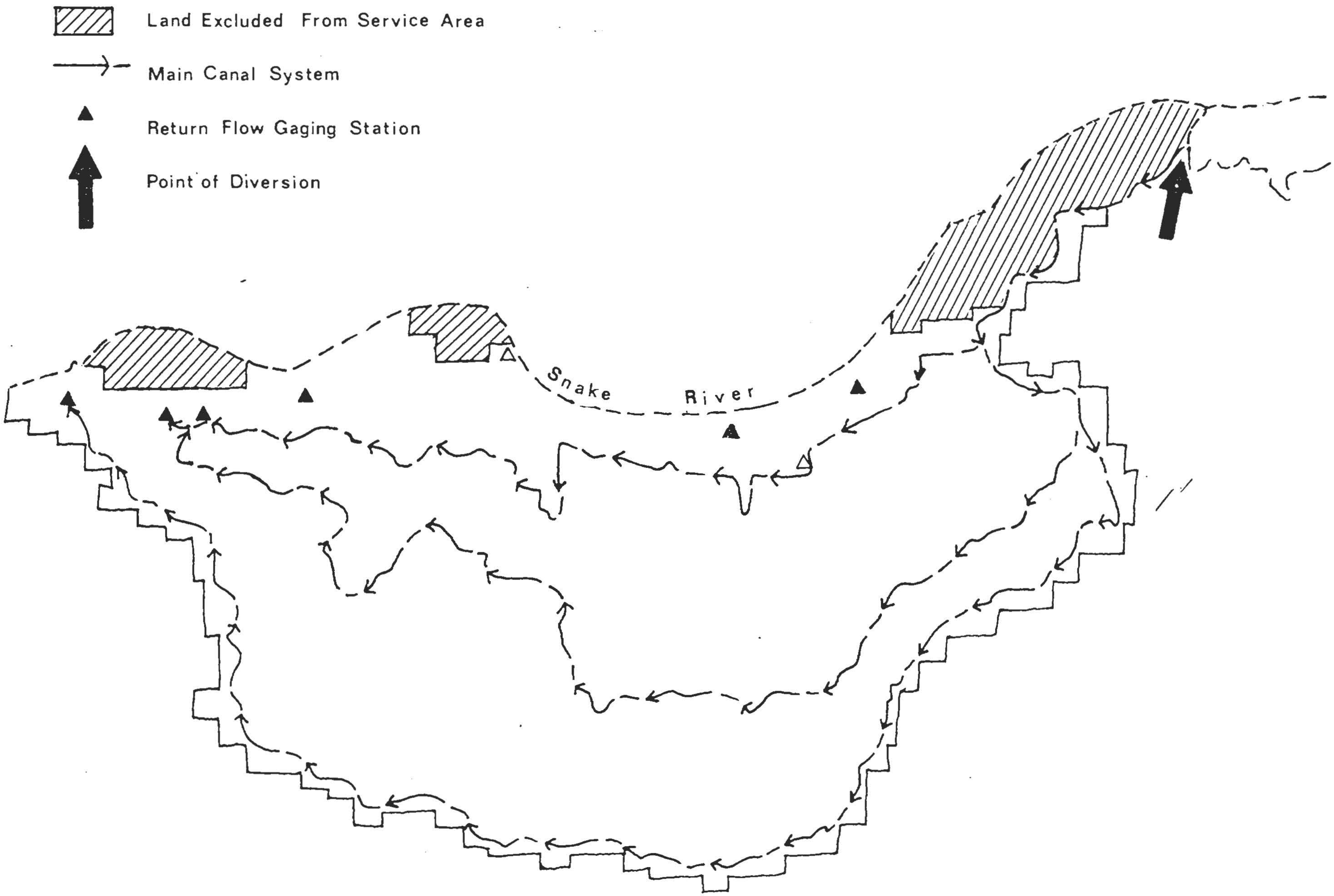


Figure 5. General Service Area of Irrigation District No. 3

bounds the district to the north for about 25 miles of its channel length. Farm deliveries are all measured by submerged orifices or weirs and are made on a rotation basis. Furrow, border, and sprinkler irrigation methods are used on this project. Silt loams, loams, and sandy loams are evenly distributed throughout the irrigated lands on slopes of zero to four percent.

For investigative purposes, the Central Sub-area is designated as that irrigated territory between American Falls Dam, straddling the river north and east to about the Bonneville-Jefferson County Line. This area is bounded to the west by exposed lava outcroppings and to the south and east by low mountain ranges and foothills. Lands on both sides of the river channel are irrigated by water diverted from the Snake and have been in agricultural production longer than the Lower Sub-Area tracts. Since this area also belongs to the Snake River Plateau, it is underlain by basalt formations and the Snake Plain aquifer. Most areas of the Snake River Plateau are known to contribute recharge, due to the combinations of deep percolation losses and geologic formations, to the Snake Plain Aquifer; this area is no exception. Land gradients near the river in this sub-area are considerably smaller than those occurring in the Lower Sub-Area. These flat, broad irrigated areas are infrequently interrupted by gradually sloping buttes and rifts. Hills and draws become more prominent moving south and east towards the foothills of the mountains.

Summers are warm and dry with precipitation occurring throughout the year. Growing seasons or frost-free periods are shorter than those of the Lower Sub-area. Potatoes, small grains, alfalfa, sugar beets, and grass pasture account for the principal crops grown on these lands. Irrigated soil, consisting primarily of loam soils with high intake rates, along the flat lands adjacent to the river do not vary considerably over this sub-area. Located in this Central Sub-Area are Irrigation Districts No. 4 and 5, together totalling about gross 43,330 acres. The most prevalent methods of irrigation found here are, in order of popularity, border, furrow, and sprinkler irrigation. Major differences in soil and climatic ocnditions are not significant between these two irrigation districts.

Located in central Binghan County immediately west of Blackfoot and adjacent to the west bank of the Snake River, Irrigation District No. 4, shown in Figure 6, page 47, diverts water to irrigate about 4,400 acres. Water is diverted and delivered through a twenty mile long system of one main canal and six branching laterals. This irrigation system operates on a combination demand-rotation farm delivery scheme. Flows into the distribution laterals pass through measurement structures and are regulated by district personnel. However, individual farm deliveries from the laterals are not measured or regulated by the irrigation district (41). Return flow leaves this district at only one point as shown on the district map, Figure 6.

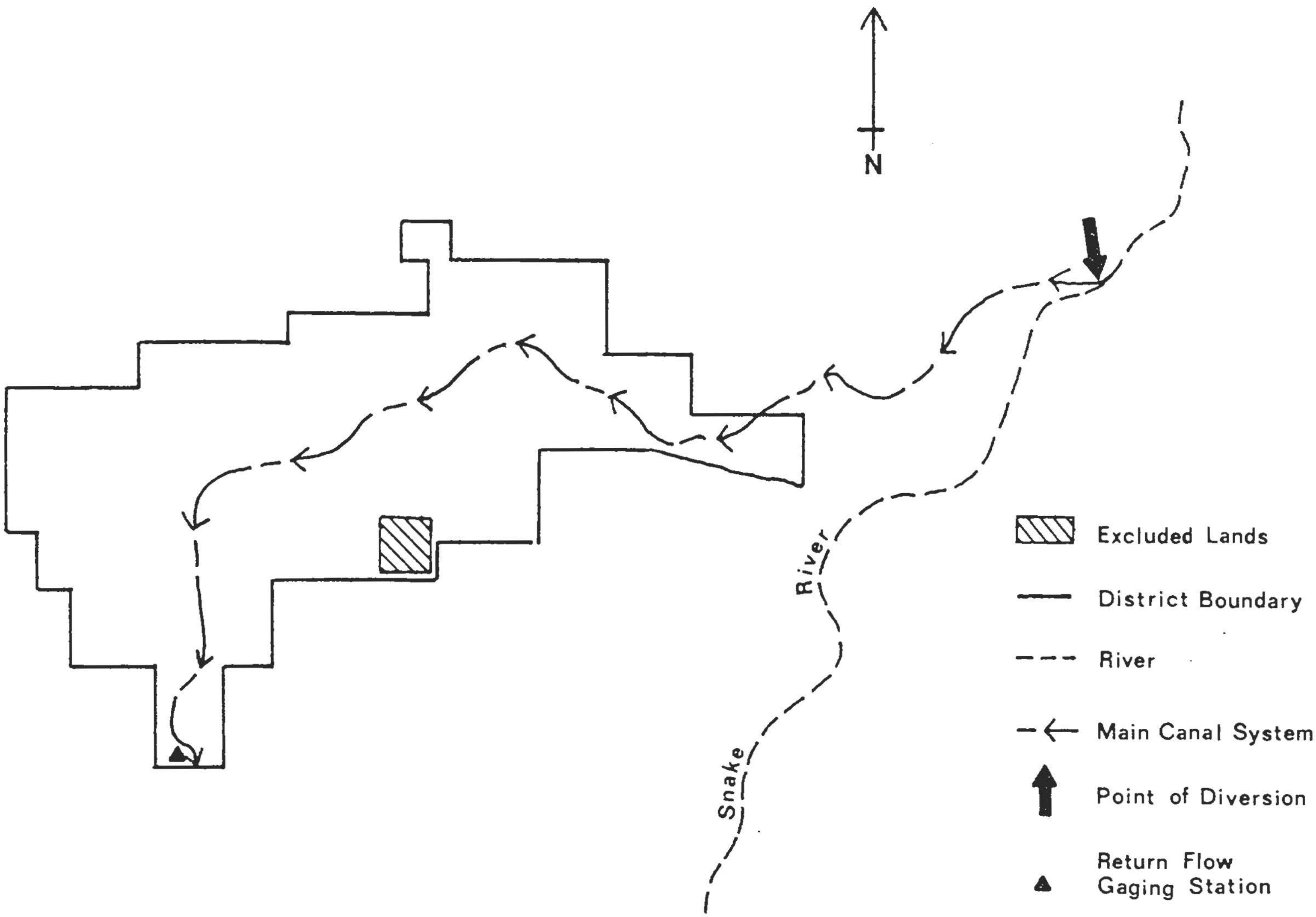


Figure 6. General Service Area of Irrigation District No. 4.

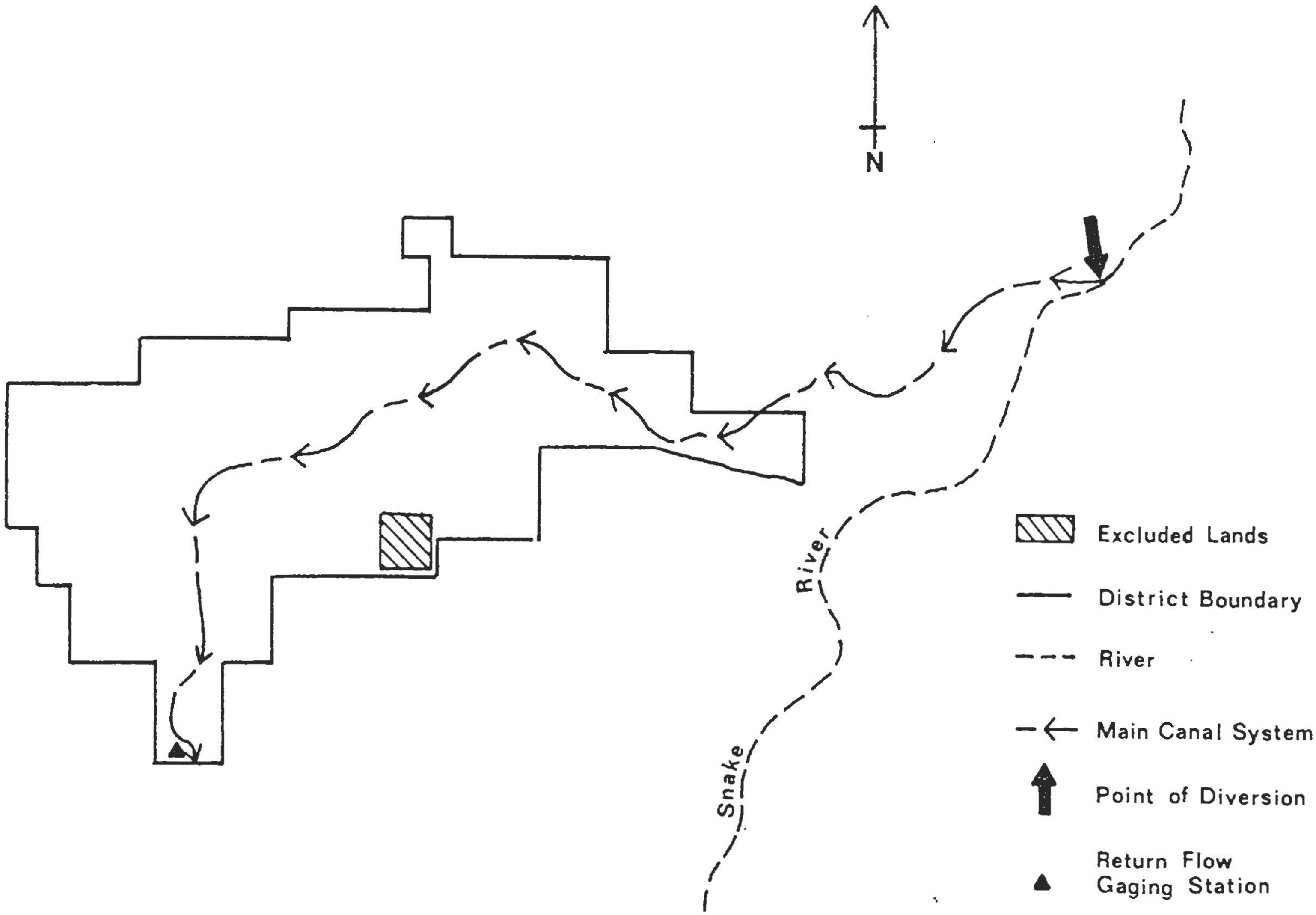


Figure 6. General Service Area of Irrigation District No. 4.

Irrigation District No. 5, Figure 7, page 49, is long and narrow in shape, beginning north of Idaho Falls running south and west through Bonneville and Bingham Counties, ending just north of the Blackfoot River. This system in addition to flood water received, diverts water out of the Snake River to irrigate about 33,597 acres through a distribution network of 143 miles and canals and laterals. A combination continuous flow-rotation farm delivery operation is employed on this tract. In other words, management of water deliveries are made on a continuous flow basis to farms on the main canals and by a rotation arrangement to those farms receiving water from the smaller distribution laterals. Water delivered to the distribution canals and laterals is measured and regulated by district personnel. An undetermined portion of the farm turnouts are regulated by the district, most are regulated by individual farmers. In conjunction with non-regulation of farm deliveries, most deliveries are not measured (41). Six stations shown on the district map were used for return flow measurements.

The Upper Sub-Area runs from north of Idaho Falls across the Snake River Fan into the Henry's Fork area near St. Anthony. Land in this area is supplied with irrigation water from the Snake River, the Henry's Fork of the Snake River, the Teton River, and the Fall River. These irrigated lands have historically had the largest per acre diversions

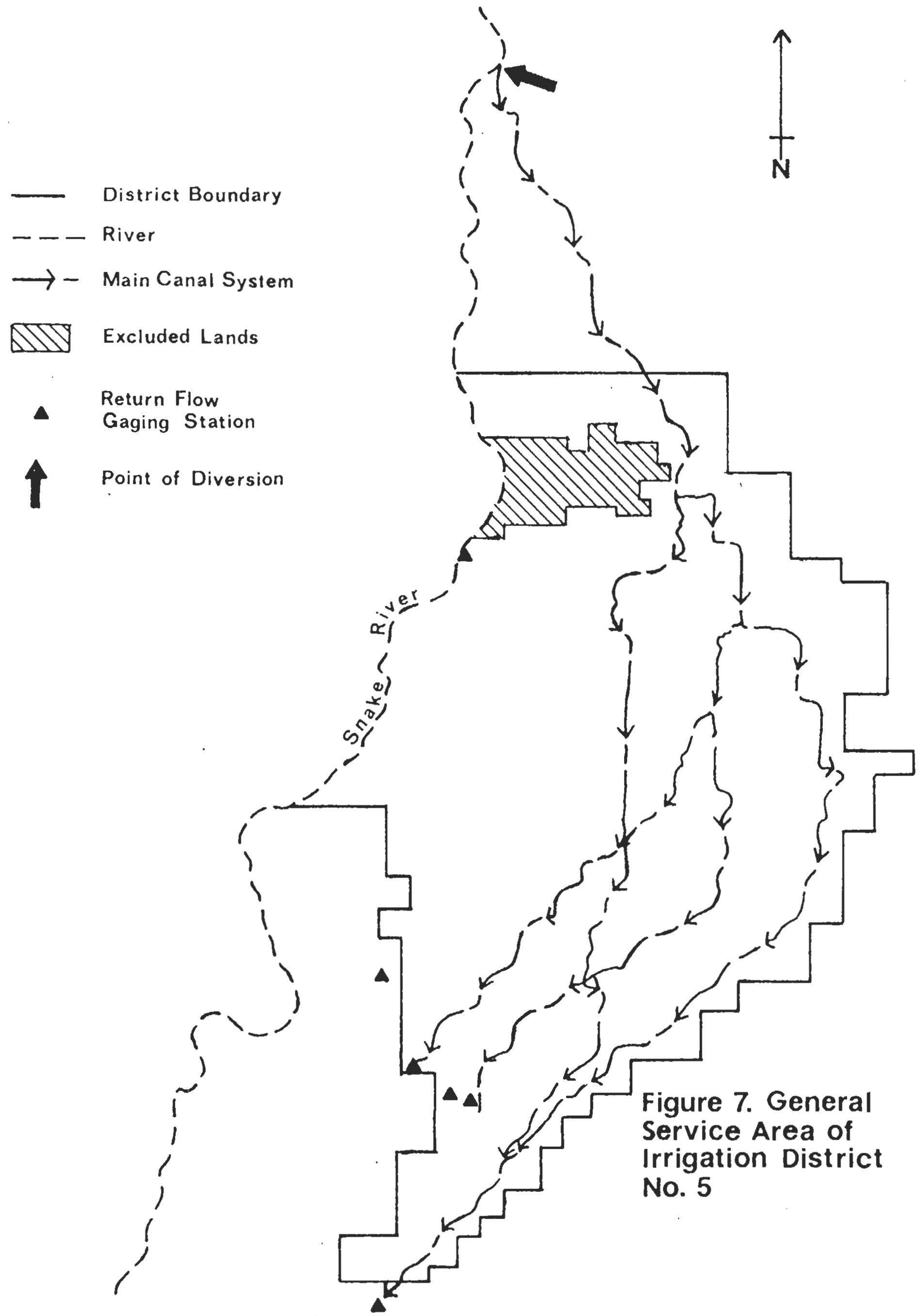


Figure 7. General Service Area of Irrigation District No. 5

of all the tracts in the Upper Snake River Region (20). Flat terrain, long irrigation runs coupled with high intake rate soils result in high irrigation water application rates (17,2). Sub-irrigation methods, in which underlying water tables are raised close to the land surface, are used in areas of this portion of the region. This form of irrigation requires extremely large diversions of water. Consequently, this region also furnishes large amounts of recharge to the Snake Plain Aquifer (13).

In this sub-area, elevations are higher and growing seasons are shorter than in the remaining region as shown by Table 1. Lands close to the river channels are flat with level to minimal slopes. Moving out of the river valleys toward the eastern foothills, undulating hills and larger land gradients are encountered. Soil conditions vary considerably from the loamy sands near the central river valleys to the silt loam soils, lying on the surrounding acres.

Since a considerable amount of field data has already been collected on irrigation efficiencies by Brockway (2) and Galinato (17) in this area, only one district was chosen for further study. The smallest district examined in this study was Irrigation District No. 6, which delivers water to about 5,375 acres. The general features of this district are shown in Figure 8, page 51. Rectangular in shape and oriented north to south; it is located in Fremont and Madison

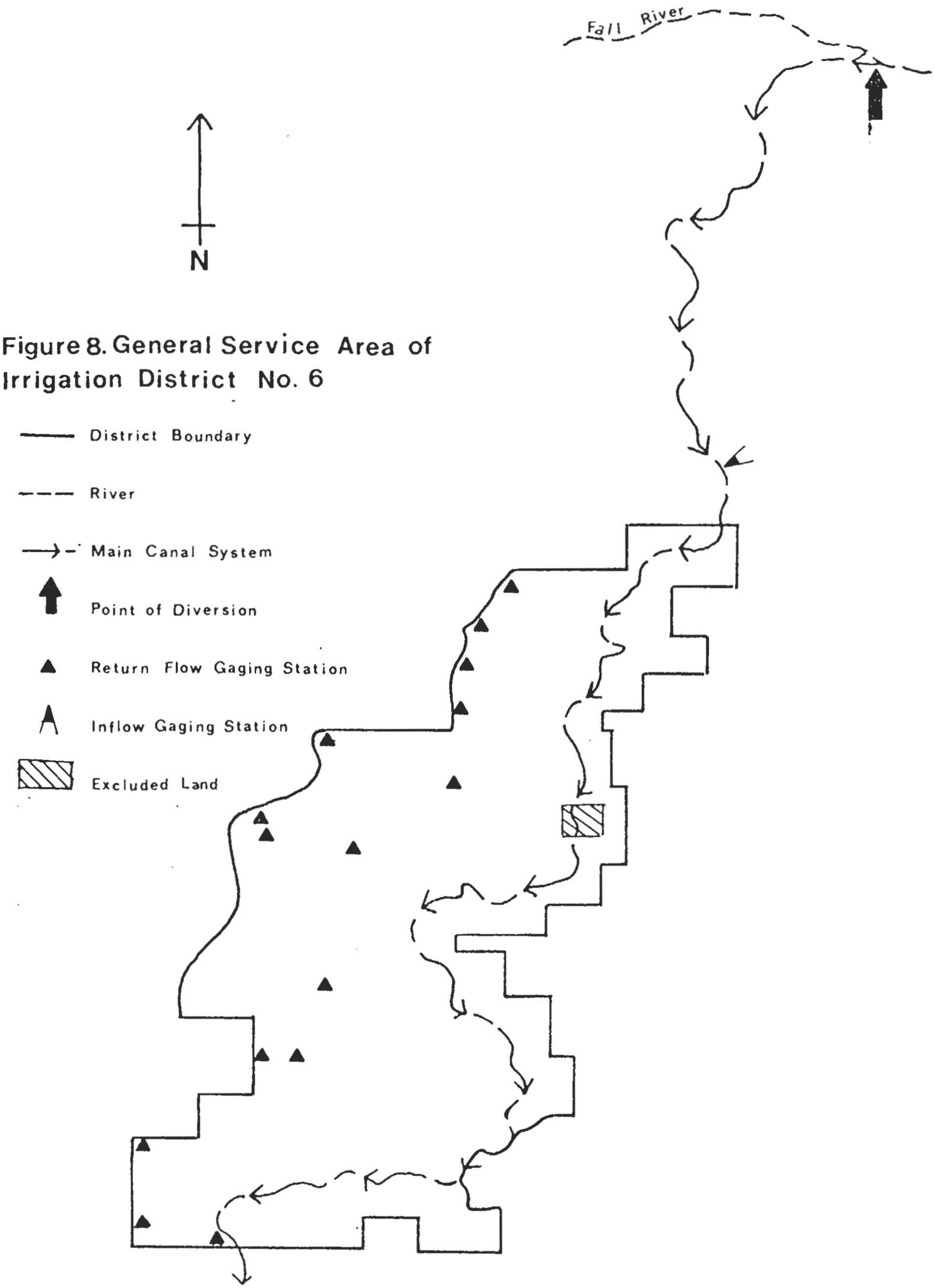


Figure 8. General Service Area of Irrigation District No. 6

Counties near Teton, Idaho. Unlike the five other systems, water supplied to this district is presently diverted out of Fall River near Chester, Idaho. However, upon completion of the Teton Dam Project, this district will abandon the present delivery canal and a wood stave inverted siphon section from Fall River. Water will then be supplied by the Teton River through new delivery works to the head end of the system (41). Fifteen points were established to measure return flow on this district.

This open channel system is somewhat unique to this study in that sprinkler irrigation accounts for the largest percentage of lands being irrigated on the tract, see Table 3. Most irrigated lands in District No. 6 have slopes greater than two to four percent. The silt loam soils are uniform throughout the district. Farm deliveries are not measured or regulated by district personnel whose primary responsibilities are to regulate flow and water level in the main canal (41).

Data Collection Techniques and Procedures

After determining what actual data would be required to compute a water balance throughout the irrigation season, methods of extracting and accumulating existing sources of data were examined. The suitability of each source or method was evaluated according to the objectives of the study. This examination and evaluation procedure is explained in the following discussion.

River Diversions and Supplementary Inflow

The first element of data required were quantities of water diverted for irrigation purposes by each district. Since all diversions of irrigation water during the irrigation season from the Snake River are measured daily by U.S. Geological Survey personnel and are reported annually, collecting these data was simplified to an extent on at least three of the six districts. Additional data collection efforts employed on the other three districts are discussed in the following paragraphs. Early season and late season flows, which are normally not recorded by Survey personnel, are recognized as possibly having potential influence upon total district water use. Before-season irrigation applications using these unmeasured diversions could be expected to alter actual water use patterns and subsequent efficiencies to a limited degree. This occurrence was not recognized as being potentially significant during the initial start-up of data collection activities.

Irrigation District No 2 also obtains a portion of its irrigation water from deep wells. In this case daily pumpage records from the district were secured to supplement data supplied by the U.S.G.S. District 5 receives substantial amounts of flood water particularly early in the irrigation season which it distributes for irrigation purposes. After flood waters recede, the district continues to receive a significant amount of supplementary inflow at two separate locations on the district perimeter. To measure these flows, a measuring device and rating section were established at each location. A gaging station was required at the point of inflow of the main canal on Irrigation District No. 6. A rating section was developed here to measure actual river diversion to the district. This eliminated concern for upstream unregulated wtihdrawals of irrigation water from this canal.

Early and late season frequency of measurements of river diversions is lower than the mid-season frequency, therefor the reliability of early and late season flows is considered to be lower.

Return Flows

Measuring District return flows or outflows required the greatest amount of resources and effort. Fifty-three separate point sources yielding significant return flow were located and inventoried on the six districts. Few of these point sources possessed any measuring device, which lead to determining an appropriate method for gauging discharges. Before most spring return flows began, rectangular contracted weirs, automatic stage recorders, and metal staff gages were installed at sixty point sources of return flow and three inflow gaging stations. ARS personnel from the Snake River Conservation Research Center, SRCRC, at Kimberly, Idaho assisted the writer in completing the installation of numerous gaging stations.

The next big step was to organize and arrange the logistics of the actual return flow data collection. Assistance of irrigation district personnel and part time help was employed to help this investigator collect return flow data. Flow readings were taken on a one to two day frequency at 49 stations. The remaining fourteen stations, equipped with stage recorders, were serviced and maintained by ARS personnel, the author, and several other individuals.

At various gaging stations, current meter flow measurements were conducted periodically to provide gage height versus discharge data for developing channel rating curves.

Field surveys of each district, made to inventory return flow point sources, substantiated the fact that measurement of 100 percent of the return flow from any one district is impractical, if not impossible. Therefore by enlisting assistance from personnel in each district, and maps when available, estimates of the portion of return flow being measured versus actual return flow were developed for each district. This factor denoted as the coefficient of return flow will be defined in Chapter VI. Return flow data was accumulated in this manner throughout the 1974 irrigation season on the six districts.

In this investigation the term "return flow" applies to all water leaving the designated irrigation district boundaries, whether it returned directly to the Snake river or to some other waterway. The portion of return flow directly discharging into the Snake River varied from 100 to 0 percent on the six districts.

Because farm surface runoff entering the conveyance system is considered to be operational waste, farm irrigation efficiencies computed are higher than actual.

Crop Consumptive Irrigation Requirement

The initial phase of determining crop water usage consisted to compiling crop distribution data for each irrigation district. Records from the Upper Snake River Office of the U.S. Bureau of Reclamation in Burley, Idaho supplied from two to five years of crop distribution data which were averaged to give reasonable mean crop distribution percentages. Gross acreages for each district were obtained from De Sonneville's date (12), Bureau of Reclamation records, and Soil Conservation Service data (32). These acreages were given previously on Table 2, page 38. The gross acreage given for District No. 1 is 4,500 acres less than that given by De Sonneville since that amount of land was excluded from this water balance analysis.

Several methods for determining evapotranspiration data were initially proposed including using De Sonneville's

Penman computer routine and using consumptive use data developed for Idaho by Sutter and Corey (34). Due to extensive additional data requirements and complications required by the Penman computer routine, the compiled data of Sutter and Corey was felt more suitable to this study.

Sutter and Corey combined the modified Blaney-Criddle method of calculating monthly crop consumptive use and average monthly rainfall data to compute consumptive irrigation requirements for 42 climatic areas in Idaho. The modified Blaney-Criddle formula they used is:

$$u = 00.1tpk_c(0.0173t - 0.314) \quad (7)$$

Where: u = monthly consumptive use, feet

t = mean monthly temperature, ^oF

p = monthly percentage of annual daylight hours

k_c= crop growth stage coefficient

The following three assumptions taken directly from Sutter and Corey must be made when using this formula: 1) seasonal or monthly consumptive use is proportional to the climatic factor, f, where f - 0.01tp; 2) crops are not limited by an inadequate water supply at any time during the growing season; 3) all factors other than temperature, percentage of daylight hours, and growing season are similar from location to location.

By totaling daily rainfall for each month and subtracting this amount from monthly consumptive use, they obtained values for consumptive irrigation requirement. The assumptions incurred here are that rainfall over all six districts in 1974 was not abnormal and all rainfall was considered effective. Sutter and Corey wrote a digital computer program inputting average daily weather data permitting a frequency analysis to be made on the input informatisn. Using a distribution-free statistical analysis method they ranked consumptive use and consumptive irrigation requirements in 20, 40, 50, 60 and 80 percentiles in addition to listing minimum, maximum, and mean values. To make their information universally applicable to all areas in Idaho, various crops were categorized as shown in Table 4, page 59. These mean monthly values for consumptive irrigation requirements for various crops were used to supply crop water use data to the water budget analysis.

Distribution Seepage Losses

Another essential component of the water budget is the amount of water lost through canal and lateral seepage. Since ponding or seepage meter determinations were not practicable or feasible on the hundreds of miles of canals and laterals in these six irrigation districts another indirect method was utilized to estimate seepage losses. This method consisted of inventorying and collecting dimensional data on all canals and laterals in each irrigation district. Aerial photos belonging to the local office of the Agricultural Stabilization and Conservation Service, U.S.D.A., in the

TABLE 4. Common Crops Grown in Idaho Grouped by Similar Consumptive Use Requirements (from Sutter and Corey, page 3)

Group Name	Crops Included
Sugar Beets	Sugar Beets
Dry Beans	Dry Beans
Corn Silage	Corn Silage
Field Corn	Field Corn
Spring Grain	Spring Wheat, Barley, Oats, Rye Dry Peas, Grain, Hay, Sweet Corn Seed, Mint, Other Grains, Other
Potatoes	Potatoes
Vegetables	Vegetables
Winter Grain	All Fall Seeded Grain
Alfalfa	Alfalfa, Alfalfa Seed, Other Legume Hay, Hops
Grass Pasture	Grass Pasture, Wild Hay, Other Grass Hay, Clover Seed, Other Legume Seed
Orchards	Deciduous Orchards (without cover)

appropriate counties were used to obtain this data. Using a microscope equipped with a calibrated micrometer lens and a map distance meter, topsidths and reach lengths were accumulated on each individual canal and lateral for the first five of the irrigation districts. Actual field measurements incorporated with a U.S. Geological Survey topographical map supplied similar data on Irrigation District No. 6.

General soil type information was then collected from Idaho Water Resource Board Special Soil Surveys (7,8,9,10,11) and Soil Conservation Service maps (42,45). Soil type information was initially correlated with seepage rate coefficients for general soil classifications developed by Worstell and Brockway (3). Computation of seepage losses is examined fully in Chapter VI.

Deep Percolation Losses

No direct data collection of measurements were made in determining this constituent of the water budget. Calculations of deep percolation losses is also examined in Chapter VI.

CHAPTER VI

Computer Programs Used for Data Processing

Two digital computer programs, written in Fortran IV for use on an IBM 370/145 computer, were used to compile and analyze water flow, crop irrigation requirement, and canal seepage data collected earlier in the study. Two other catalogued programs were also employed in the data processing phase. A catalogued polynomial regression program was used to develop channel rating curves for each flow gaging station. To compute and sum daily discharges throughout the irrigation season, a tape-stored program was used via a remote terminal at the Snake River Conservation Research Center (SRCRC). This chapter discusses the implementation and function of these four computer programs.

Polynomial Regression Program

Twenty-seven discharge rating curves were developed using a canned polynomial regression routine. This routine created ordinary second order correlation equations between pairs of simultaneous staff gage readings and discharges measured by current meter method. The number of data pairs used varied from three to six depending upon availability and reliability of field data. Values for the index of determination or the index of correlation ranged from about 0.90 to 1.0 for the twenty-seven equations.

Generated channel and control section rating curve equations, in addition to discharge equations from rectangular contracted and rectangular suppressed weirs are acceptable in coefficient form to the accumulative discharge program. Daily staff gage readings from all 63 gaging stations were compiled and converted into daily flows using this program. Twenty-four hour and accumulative discharge in units of cubic feet per second and acre-feet constitute the primary output of this discharge program. Figure 9, on page 63, is a sample of the output from this program.

Canal Seepage Analysis Program

Maximum, full channel (or base) daily seepage losses from each distribution system are calculated by the seepage program. Individual losses from each canal and total district losses are computed. Program input is composed of the following data elements: the irrigation district number, canal or lateral name, canal reach by township, range, and section number, calibrated lengths of canal reaches, scaled channel topwidths, and corresponding soil seepage coefficients for each canal reach. Since SCS scaled aerial photos were used, lengths and topwidths are calibrated at 8 inches = 5,280 feet and 1.0 unit = 25.0 feet respectively. The 2 different scale factors arose from using a map distance wheel to measure, in inches, canal reach lengths directly from the photos and the microscope equipped with a micrometer lens to measure channel topwidths in unspecified units. The dimensional units of the seepage coefficient are given as feet per day. Input data

#307

Time Interval = 1440
Previous Accumulation of Acre Ft. = 0

Equation of Rating Curve

A	B	C	Range	N	M
-2.91	5.32	1.20	0.0 - 3.0	1.0	2.0

Date	Ave. Daily Cfs.	Acc. Daily Cfs.	Acre Ft.	Acc. Acre Ft.
40506	0.046	0.046	0.091	0.091
40507	0.243	0.289	0.481	0.572
40508	0.441	0.730	0.875	1.448
40509	0.642	1.372	1.274	2.722
40510	0.845	2.218	1.677	4.399
40511	1.051	3.268	2.084	6.482
40512	1.258	4.526	2.495	8.978
40513	1.538	6.064	3.050	12.028
40514	1.750	7.814	3.472	15.500
40515	1.965	9.779	3.898	19.398
40516	2.182	11.961	4.328	23.725
40517	2.401	14.362	4.762	28.487
40518	2.622	16.984	5.200	33.687
40519	2.845	19.829	5.643	39.331
40520	3.071	22.899	6.090	45.421
40521	3.375	26.274	6.693	52.114
40522	3.605	29.879	7.151	59.265
40523	3.838	33.717	7.612	66.877
40524	6.540	40.256	12.971	79.848
40525	6.454	46.710	12.801	92.650
40526	3.368	53.079	12.632	105.281
40527	6.283	59.362	12.463	117.744
40528	6.198	65.560	12.294	130.038

Figure 9

Discharge Program Sample Output

specifications, the main seepage program, and an example of output are included in Appendix G.

Output data given by the seepage program includes the following components: the irrigation district identification number, canal or lateral name, canal reach location by township, range and section number, reach length, average width of the reach, reach seepage coefficient, reach seepage loss, and accumulated reach length and seepage loss. Township, range and section numbers appear in digital form. A simple four-digit code distinguishes directions by assigning the numbers 1, 2, 3, and 4 to north, east, south and west. The third township or range digit gives the corresponding direction. Reach length and average reach width are given in feet, but figures for accumulated reach length appear in terms of miles. The unit, feet per day, is again assigned to the reach soil seepage coefficient. Both reach and accumulated seepage losses are assigned units of acre feet per day.

Internally, this program computes average channel topwidths using two consecutive reach measurements at a time. Wetted perimeters are subsequently calculated by multiplying topwidths by a dimensionless topwidth coefficient varying from 1.05 to 1.30. Reference to Figure 10, page 67 will demonstrate why and how these coefficients were selected based upon common unlined earth channel shape and dimensional relationships. In short, as the width of a channel increases the amount of wetted perimeter contributed by side slopes diminishes. Table 5, page 66, gives the four topwidth coefficients and their corresponding channel topwidth intervals. The intervals at which the coefficients change value were approximated by trial and error calculations of the ratios of wetted perimeter to topwidth of some typical known channel dimensions.

Actual seepage losses are calcualted in the program from these two equations:

$$A_{wp} = L_r R_w C_t \tag{8}$$

Where: A_{wp} = wetted area of the canal reach, square feet

L_r = reach length, feet

T_w = average topwidth of reach, feet

C_t = topwidth coefficient

And $$S_p = \frac{A_{wp} C_s}{43{,}560} \tag{9}$$

Where: S_p = seepage loss in reach, acre-feet/day

C_s = soil seepage coefficient, feet/day

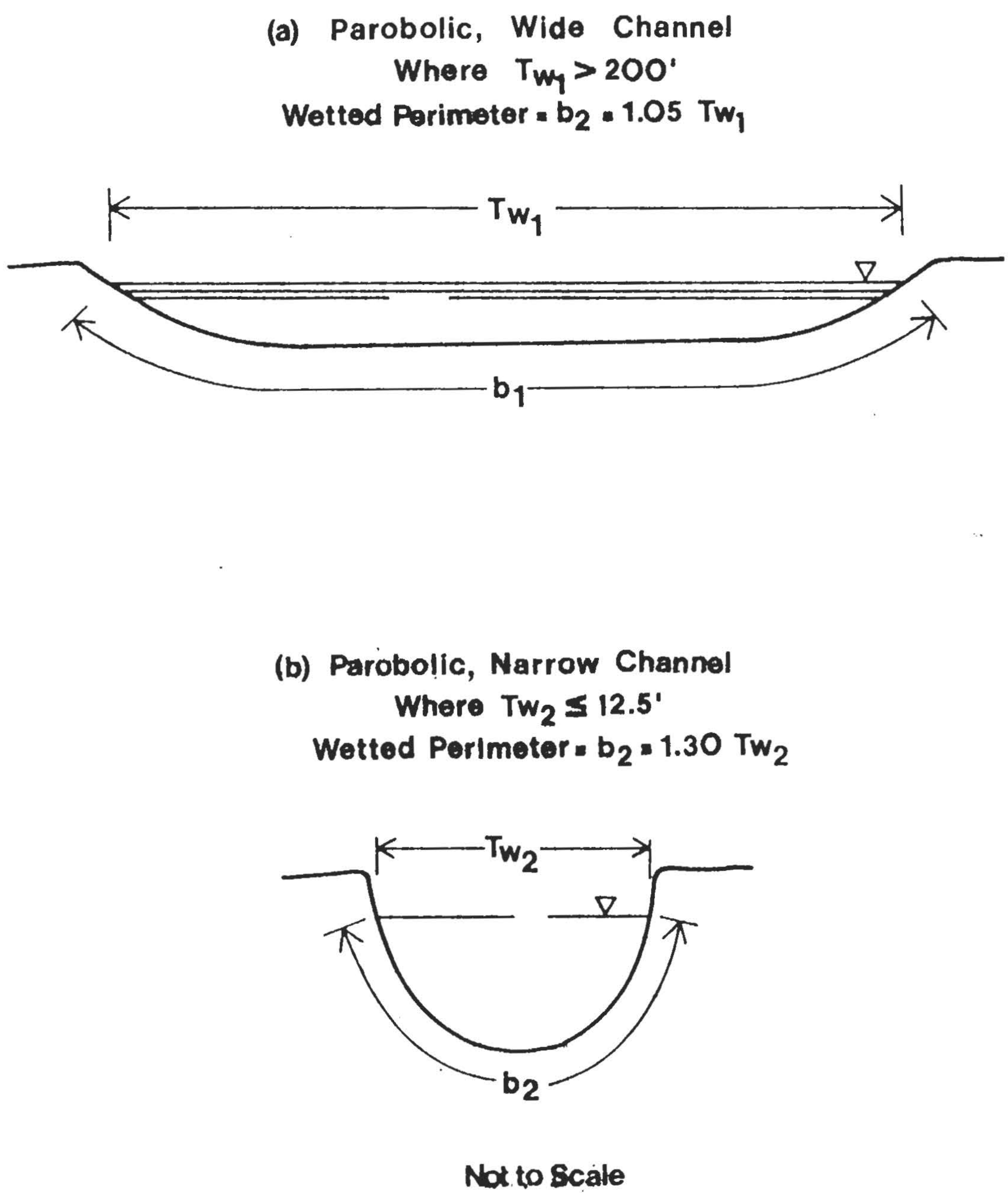
<u>Water Budget Program</u>

The water budget program listed in Appendix F, analyzes all components of total water use on each irrigation district using a two week or bi-monthly time interval throughout the irrigation season. The program was written to expedite analysis of irrigation efficiencies and various other water use paramaters from inflow-outflow data assembled for input. Thirty-six related water use components and three related irrigation efficiency variables are calculated for each district during

TABLE 5. Relationship Between Measured Channel Topwidths and Topwidth Coefficients

Average Channel Topwidth, Tw	Topwidth Coefficient, Ct
(feet)	
0 - 12.5	1.30
12.5 - 25.0	1.20
25.0 - 200.0	1.10
> 200.0	1.05

Figure 10. Dimensional Relationships Between a Wide Canal Channel and a Narrow Canal Channel



the 1974 irrigation season. Both program input and output elements are described and discussed individually below.

The following equation is fundamental to this analysis since this water budget approach is an inflow-outflow water balance for each irrigation district:

$$Q_{in} - Q_{out} + dS/dt = 0$$

Where Q_{in} = total system inflow

Q_{out} = total system use and outflow

dS/dt = change in system storage with time

The relative significance of changes in system storage, or net soil moisture content of a district, during the first one or two time intervals of the water balance can be obtained by examining data from the Bureau of Reclamation study done during 1964 to 1968 on the Minidoka Project, Northside Pumping Division Unit A (39). Three years of soil moisture data collected on fifteen different fields and crops were analyzed yielding an average soil moisture depletion (difference between field capacity and moisture content prior to the first spring irrigation), of about 3.4 inches per 3 foot soil horizon. Using District 2, with silt loam soils as an example:

$$dS/dt = \frac{3.4 \text{ inches}}{12 \text{ inches/foot}} \times (14{,}568 \text{ acres}) \qquad (11)$$

$$= 4{,}128 \text{ acre feet}$$

Since this figure is approximately equal to the first time interval total inflow for the district and amounts to about 7.8% of the river diversion for the entire water balance period, it appears to be a significant component. Similarly irrigation efficiencies could be affected during the initial time intervals if this storage term is meaningful. However, considering the following three factors reduced the consequence of this term to the seasonal water balance.

First, 4,128 acre feet should be recognized as an upper limit representing the extreme situation in which the entire soil profile of the irrigation district is raised to field capacity simultaneously; an unrealistic situation.

According to Table 6, page 70, only two of the six districts began diverting river water during the first time intervals of the water balance. Since diversion had already begun on four of the districts prior to the initial time interval some irrigation could be assumed to have occurred before the first time interval on these districts, reducing the total district soil moisture depletion.

As a third factor, an examination of soil types reveals that the probable average water holding capacity of soils on the other five districts is less than or equal to those found on District 2.

Considering these three factors allows omitting the storage term, dS/dt, from equation 10 for Districts 1, 4, and 5 during all periods of the water balance and certainly after the first time interval on all six districts. This assumption is realistic based upon these cited factors. During the remaining time intervals of the water balance, the net change in soil moisture for the entire districts was assumed to be negligible. Soil moisture measurements were beyond

TABLE 6. Starting Dates for River Diversion and the Water Balance Analysis

Irrigation District Number	Starting Date of Season Diversion	Starting and Ending Dates for Water Balance Analysis
1	March 25	April 15 to October 15
2	April 22	May 1 to September 15
3	April 17*	April 15 to October 15
4	May 9	May 15 to October 30
5	May 2	May 15 to September 30
6	June 2*	June 1 to September 30

* After Water Balance Starting Date.

the scope of this study and therefore, no adjustments were made on the appropriate water balance input data.

By substituting irrigation district water flow components for system inflow and outflow and omitting the dS/dt term, equation (10) becomes:

$$Q_{rd} + Q_{if} + Q_{p} - Q_{rf} - Q_{cu} - Q_{csl} - Q_{dpl} = 0 \qquad (12)$$

Where Q_{rd} = river diversion

Q_{if} = supplementary inflow to the district

Q_{rf} = return flow

Q_{cu} = consumptive use of crops

Q_{p} = amount of effective precipitation

Q_{csl} = canal and lateral seepage losses

Q_{dpl} = deep percolation losses

*all variables are in terms of acre feet

Combining the precipitation and consumptive use components in the new equation results in a single consumptive irrigation requirement term, Q_{cir}, defined by Sutter and Corey as:

$$Q_{cir} = Q_{cu} - Q_{p} \qquad (13)$$

In modified form the equation for a complete water balance under steady state conditions is:

$$Q_{rd} + Q_{if} - Q_{rf} - Q_{cir} - Q_{csl} - Q_{dpl} = 0 \qquad (14)$$

This equation defines the pertinent components of the water budget program.

The nineteen input components and terms for each district required by the water budget program are listed in Table 7, page 72. Except for those terms discussed in previous chapters, the remaining input terms are described in the

TABLE 7. Water Budget Program Input Variables

	Input Term	Program Variable Name	Units
1.	Irrigation District Number	DISTNO	-
2.	Total District Irrigated Acreage	DISTAC	acres
3.	Starting and Closing Dates of the Data Collection Period	DATE	-
4.	Number of Crops Grown	JCROP	-
5.	Specific Crop Percentage of Total Irrigated Acreage	CROP	%
6.	Number of Months in the Irrigated Season	JMONTH	-
7.	Inclusive Dates of Each 2-Week Time Interval	MONTH (I,K)	-
8.	Number of Days in Time Interval	TDD	-
9.	Number of Days in the Appropriate Month	TDM	days
10.	Monthly Consumptive Irrigation Requirement for Each Specific Crop	CONSUM	inches/month
11.	Coefficient of Return Flow	COFRTF	%
12.	Number of Return Flow Gaging Stations	JRF	-
13.	Accumulative Seasonal Return Flow for Each Gaging Station	RETFLW	acre feet
14.	Maximum Daily Canal Diversion	DIUMAX	cfs
15.	Canal Diversion at 50% Seepage Loss	DIUMIN	cfs
16.	Maximum Daily Seepage Rate	TOTSEP	acre feet/day
17.	Daily River Diversion	DAYDIV	cfs-day
18.	Number of Days of River Diversion	NUMDD	-
19.	Supplementary System Inflow During Time Interval	RINFLW	acre feet

following paragraphs.

Data collections periods approximated the beginning and ending dates of the normal irrigation seasons for all six districts. The specific dates are given along with the other data later in this chapter. In addition, the inclusive time intervals, spanning either fifteen or sixteen days, are also listed throughout each irrigation season. A variable giving the number of days in each month is read into the program to calculate correct proportions of bi-monthly consumptive irrigation requirements.

The approximate two week time interval was chosen for these subsequent reasons. First, half a month was the shortest practical period of time in which inflow-outflow conditions could be assumed to approach steady-state. Secondly, since monthly consumptive irrigation requirement data is utilized, a shorter than bi-monthly time step would increase the error probability involved with using such data. Third, because seasonal trends and average variations in irrigation efficiency are of interest to the study, shorter time steps would offer limited additional benefit. Finally, because the majority of return flow readings were taken on a once per day frequency, a 15 day period should tend to compensate for random fluctuations in the discharges.

The number of crops grown and their associated distribution percentages were derived by taking arithmetic averages of previous two to five years of crop distribution records collected as described in Chapter V. Corresponding monthly values for crop consumptive irrigation requirements were obtained directly from Sutter and Corey's publication.

Those variables directly relating to return flow computations in the program include: the number of return flow gaging stations, accumulative quantities of seasonal return flow, and the coefficient of return flow for the corresponding irrigation district. Separate return flow gaging stations ranged in number from one to fifteen on the irrigation districts. Accumulative values of seasonal return flow in acre feet are used since these values can be taken directly from the output generated by the SRCRC accumulative discharge program.

To estimate actual or theoretical total district return flow, the coefficient of return flow, C_{rf}, was incorporated into the program. This coefficient is defined by

$$C_{rf} = \frac{q_{rf}}{q_{act}} \tag{15}$$

Where: Q_{rf} = measured district return flow

Q_{act} = actual total district return flow

Consequently, actual total return flow, unmeasured plus measured, for any district is:

$$q_{act} = \frac{q_{rf}}{C_{rf}} \tag{16}$$

The return flow coefficient is employed in this manner in the water budget program. Actual total district return flow appears in program output rather than the value for measured return flow. Multiplying the return flow coefficient times the listed value of return flow gives the measured flow.

A linear correlation scheme was written into the main program to approximate changes in seepage losses arising from nonconstant canal and lateral wetted channel areas caused by fluctuating water levels and flows in the channels. This scheme was considered necessary since the maximum seepage loss occurs only at maximum river diversion for each irrigation district. Utilization of this daily seepage flow rate in the water budget analysis as a constant is unrealistic and could be expected to introduce a significant source of error. Hence, the seepage loss rate correlation scheme is designed to allocate maximum seepage loss only at maximum seasonal river diversion. When river diversions are equal to or less than 40 percent of their seasonal daily maximum, the seepage rate is reduced to one half its base daily value as computed by the seepage program. Consequently, when river diversions range between 40 and 100 percent of the season maximum daily level, twenty-four hour canal seepage losses are linearly interpolated between 50 and 100 percent of the calculated maximum or base daily rate. Examination of this water stage-seepage rate simulation scheme by the following equations should clarify its function and operation:

If $q_{rd} \leq q_{min}$

$$S = 0.50S_{max} \tag{17}$$

If $q_{rd} > q_{min}$

$$S - 0.50S_{max} \times \{1 + \frac{q_{rd} - q_{min}}{q_{max} - q_{min}}\} \tag{18}$$

Where:
q_{rd} = specific daily river diversion, cfs

q_{min} = 40% river diversion level, cfs

Q_{max} = maximum or 100% river diversion level, cfs

S = computed daily seepage rate, acre feet per day

S_{max} = base daily seepage rate computed by the seepage program, acre feet per day

The values of 50 percent of the base daily or maximum seepage rate at 40 percent of the daily maximum river diversion were selected based upon knowledge of the irrigation district's management of channel water levels throughout an irrigation season. No actual field data were used to directly develop these values. The seepage term, Q_{csl}, appearing as program output is computed using this method.

Quantities of daily river diversion in cubic feet per second-days are coded for input into the water budget program. Total district supplementary inflow discharged into the irrigation district during a time interval is intoduced as one total sum, in acre feet.

Output information including calculated data is presented for each irrigation district by four tables in the water budget program. The first tables, in Appendix A, list crop distribution data. Crop consumptive irrigation requirements are arranged by time interval in the second tables in Appendix B. The third table given in Appendix C catalogues eight functional water use components and values for three mathematically related, irrigation efficiency terms for each time interval throughout the specified irrigation season. Annual totals and seasonal averages of water use and efficiency terms are displayed in the last table in the program print-out, also Appendix C. The analytically significant figures included in the last three tables of output are discussed in the subsequent paragraphs. Table 8 on page 78 lists all output variables, program variable names, and their corresponding dimensional units.

Average crop distribution data is listed as both a percentage of net district irrigated acreage and as an acreage figure in program output tables numbered A-1 to A-6 in Appendix A. Net irrigated acreages for each district were obtained from the River Basin Study Unit of the Soil Conservation Service (32). These net acreages are gross acreages adjusted for farmsteads, waste ground, and right of ways, etc. The number of acres under any one crop is calculated as a product of the crop distribution percentages times the net irrigated acreage. Individual bi-monthly crop consumptive irrigation requirements are subsequently computed by the following equation in the program:

TABLE 8. Water Budget Program Output Variables for Each Irrigation District

Output Term	Program Variable Name	Units
Irrigation District Number	DISTNO	-
Total District Irrigated Acreage	DISTAC	acres
Data Collection Period	DATE	-
Dates of Each Time Interval	MONTH (I,K)	-
Number of Days in Each Time Interval	TDD	days
Crop Distribution by Percent	CROP (I)	%
Crop Distribution by Acres	ACCROP (J)	acres
Monthly Consumptive Irrigation Requirements	CONSUM (J,I)	inches
Bi-monthly Consumptive Irrigation Requirements	CRPCON (J,I)	acre feet
Bi-monthly River Diversions	TOTDIV	acre feet
Bi monthly Supplementary Inflow	RINFLW	acre feet
Bi-monthly Total District Inflow	TINFLW	acre feet
Bi-monthly Consumptive Irrigation Requirement	TOTCON (I)	acre feet
Bi-monthly Average Deep Percolation Loss	DEPERC	acre feet
Bi-monthly System Seepage Loss	TOTLOS	acre feet
Bi-monthly Total District Return Flow	TOTRTF	acre feet
Bi-monthly Net District Water Use	GDUSAG	acre feet
Bi-monthly District Conveyance Efficiency	DISEFF	%
Bi-monthly Farm Irrigation Efficiency	FRMEFF	%
Bi-monthly Project Irrigation Efficiency	TOUEFF	%
Total Annual District Return Flow	YRRTF	acre feet
Total Annual River Diversion	YRDIU	acre feet
Total Annual District Inflow	YRINFL	acre feet
Total Annual Consumptive Irrigation Requirement	YRCON	acre feet
Total Annual System Seepage Losses	YRSEP	acre feet
Total Annual Deep Percolation Losses	YRDEP	acre feet
Total Annual Net District Water Use	YRGDUS	acre feet
Average Annual District Return Flow	AVANRF	acre feet/acre
Average Annual River Diversion	AVANDV	acre feet/acre
Average Annual Consumptive Irrigation Requirement	AVANCR	acre feet/acre
Average Annual Total District Inflow	AVANIF	acre feet/acre
Average Annual Seepage Losses	AVANSP	acre feet/acre
Average Annual Deep Percolation Losses	AVANDP	acre feet/acre
Average Annual Net District Water Use	AVANGU	acre feet/acre
Average Annual District Conveyance Efficiency	AVANDE	%
Average Annual Farm Irrigation Efficiency	AVANFE	%
Average Annual Project Irrigation Efficiency	AVANDE	%

$$q_i = \frac{I_r \; a_i}{12} \frac{d}{m} \qquad (19)$$

Where: q_i = bi-monthly consumptive irrigation requirement for crop (i), in acre feet

I_r = monthly consumptive irrigation requirement for crop (i), inches

a_i = net acres of crop (i)

d = number of days in the bi-monthly period, days

m = number of days in the month in which this time period occurs

This equation accounts for the 15 or 16 day time period differences by the d/m factor. Crop consumptive irrigation requirements are summed for all crops during each time interval and are accumulated throughout the season to obtain an annual consumptive irrigation requirement total. These values constitute the Q_{cir} term in equation 14 on page 69. Accumulated daily and seasonal river diversions are compiled similarly to obtain the Q_{rd} term in the water budget equation, 13. This term is used in each time interval and at the end of an irrigation season for annual totals; its variables are either bi-monthly or seasonal totals.

Supplementary district inflow, Q_{if}, represents all inflow to the district used for irrigation purposes other that river diversion. Values are printed out in program output as single, time interval quantities and seasonal totals in acre feet. Not all districts receive water in addition to river diversions; in which case, zeros appear. Addition of river diversions and supplementary inflow yields total district inflow Q_{tf} for any time period where:

$$Q_{tf} = Q_{rd} + Q_{if} \tag{20}$$

Total district inflow therefore includes water from all sources flowing into the irrigation system.

Realizing that all but one component, deep percolation loss, Q_{dpl}, has been generated from external field data in the water budget program, equation 14 can be solved for this term of

$$Q_{dpl} = Q_{rd} + Q_{if} - Q_{rf} - Q_{cir} - Q_{csi} \tag{21}$$

Both bi-monthly and seasonal totals of deep percolation are computed in this fashion by the program.

Net district water use, Q_{net}, is defined as total inflow to the district minus total return flow, for either time period. Mathematically:

$$Q_{net} = Q_{rd} - Q_{rf} \tag{22}$$

This quantity represents all water consumed or lost during an irrigation season or period by an irrigation district.

Average annual totals for river diversion, return flow, consumptive irrigation requirement, total district inflow, net district water use, total distribution system seepage loss, and deep percolation loss on a per acre basis are computed for each irrigation district. These values are obtained by dividing season totals of water budget components by irrigated acreages of the appropriate district.

District return flow fraction, F_r, is computed in percent as a comparator of return flow for irrigation districts.

Expressed as an equation:

$$F_r = \frac{Q_{rf}}{Q_{rd} + Q_{if}} = \frac{Q_{rf}}{Q_{tf}} \times 100\% \qquad (23)$$

Return flow fraction is the ratio of seasonal return flow to seasonal total district inflow expressed as a percentage.

The three most useful and meaningful output components of the water budget program are the average annual figures for district water conveyance efficiency, farm irrigation efficiency and the composite project irrigation efficiency. Determination of these three functional parameters satisfies the second study objective.

Average annual district conveyance efficiency, E_c, is defined mathematically:

$$E_c = \frac{Q_{tf} - Q_{rf} - Q_{csl}}{Q_{tf}} \times 100\% \qquad (24)$$

Where: Q_{tf} = total district inflow

Q_{rf} = district return flow

Q_{csl} = canal and lateral seepage losses

District conveyance efficiency reflects the influence of system water management via return flow quantities and system seepage losses on district water use or river diversions to the system. This efficiency term is dependent upon both the physical characteristics of the distribution system and water management behavior of the district. To a degree, it is somewhat dependent also upon irrigation practices of farms in the district if return flow also includes water received as surface field runoff.

The ratio of the amount of water consumptively used by farm crops to the amount of water delivered to the farm is defined as average unit or farm irrigation efficiency, E_u, or algebraically:

$$E_u = \frac{Q_{cir}}{Q_{tf} - Q_{rf} - Q_{csl}} \times 100\% \qquad (25)$$

Where: Q_{cir} = consumptive irrigation requirement

Q_{tf} = total district inflow

Q_{rf} = district return flow

Q_{csl} = canal and lateral seepage losses

Farm irrigation efficiency is strictly dependent upon farm irrigation practices and irrigation water application management. Deep percolation rates are also reflected in this characteristic. Only district-wide averages of farm irrigation efficiency can be computed in this water budget program.

Because the objective of this study was to analyze irrigation efficiency from a total sytem or irrigation district concept, a total project irrigation efficiency term was considered appropriate. Project irrigation efficiency, E_p, in equation form is defined as:

$$E_p = E_u \times E_c \qquad (26)$$

$$= \frac{Q_{cir}}{Q_{tf} - Q_{rf} - Q_{csl}} \times \frac{Q_{tf} - Q_{rf} - Q_{csl}}{Q_{tf}} \times 100\% \qquad (27)$$

$$= \frac{Q_{cir}}{Q_{tf}} \times 100\% \qquad (28)$$

Where: E_u = average farm irrigation efficiency

E_c = district conveyance efficiency

Q_{cir} = consumptive irrigation requirement

Q_{tf} = total district inflow

Q_{rf} = district return flow

Q_{csl} = canal and lateral seepage losses

From equations 24, 25, 26, project efficiency is obviously a composite product of conveyance and farm irrigation efficiency. Jensen, in Chapter III, defined project irrigation efficiency in similar equations. This definition differs from the Jensen formulas by the ommission of the reservoir storage efficiency term. Project efficiency is an overall system operational index dependent upon all system parameters affecting irrigation efficiency.

Present levels of and reasonably attainable changes in these three numerically related irrigation efficiencies for each irrigation district are investigated in the following chapter. Other water use parameters are also examined to develop a complete irrigation water use analysis of present and future operating levels.

Chapter VII
PRESENTATION AND ANALYSIS OF DATA

Before present operating levels or reasonable predictions of changes in irrigation water use patterns and irrigation efficiencies could be evaluated, base daily system seepage losses were determined using the seepage program. Present (1974) levels and possible future reductions of canal system seepage losses are presented first in this chapter. Present irrigation water use patterns and irrigation efficiencies developed from 1974 data are then examined for each of the six districts. Expected reasonable changes in the conveyance and distribution systems and on-farm irrigation methods that could increase irrigation efficiencies are examined in Chapter VIII.

Distribution System Seepage Loss

Present, or 1974 level, daily base seepage rates were computed by the seepage program for each district. Because of different soil types found in the districts, various seepage coefficients were used. When justifiable, coefficients were modified to yield better reasonable estimates. Seepage coefficients used on canals and laterals in each district are listed in Table 9, page 86, along with the coefficients determined by Worstell and Brockway (3), which are denoted as SRCRC coefficients. These SRCRC coefficients

TABLE 9. Seepage Coefficients Used to Compute Present Distribution System Seepage Losses

Irrigation District	Soil Type			
	Clays (cfd)	Silts (cfd)	Loams (cfd)	Sands (cfd)
SRCRC Coefficients	0.31	0.81	0.95	1.33
1	0.35	0.67	0.95	1.33
2	-	0.67	-	-
3	-	-	0.95	1.33
4	-	-	0.95	1.33
5	-	-	0.95	1.33
6	-	-	0.97	-

were used as a guide and when better seepage coefficients could not be determined or estimated.

On District 2 all distribution channels were assigned an average seepage coefficient of 0.67 cfd based upon ponding test data developed by Brockway and Worstell (4) on this district.

Three general soil types were categorized for purposes of assigning seepage coefficients on Irrigation District 1. Because Districts 1 and 2 are adjacent to one another, soils classed as silts in both districts were assigned the same seepage coefficient, 0.67 cfd, rather than using the more generalized SRCRC seepage value of 0.95 cfs. Loam and sandy soils were assigned values corresponding to the SRCRC data. The seepage coefficient assigned to the re-regulating reservoir on the main canal system was estimated at 0.35 cfd, because of the known occurrence of fine particle deposition and accumulation which lowers permeabilities on the reservoir bottom.

Only two soil types, loams and sands, with corresponding seepage coefficients were categorized and assigned to distribution channel reaches in Districts 3, 4, and 5. No specific seepage tests were made on these districts, so a modification of these estimated seepage coefficients would not be warranted.

Brockway and Worstell in field studies found that ponded seepage rates could be estimated at 56 percent of the rate obtained from inflow-outflow analysis. The differences between the two methods is attributed to unavoidable system operational losses, such as headgate leakage. The gross seepage coefficient for the main canal system on District 6 was developed similarly from inflow-outflow data for a two week time interval after the end of the 1974 irrigation season. By assuming that all farm headgate diversion had ceased, that the conveyance channel was full, and by calculating the total wetted area of the main canal channel, an inflow-outflow seepage loss coefficient of 1.73 cfd was computed. The actual seepage rate was taken as 56 percent of the inflow-outflow value or 0.97 cfd. This estimate compares closely to the SRCRC value of .95 cfd for loam soils.

Combining the wetted areas obtained from photographic surveys and the estimated seepage coefficients for each district in the seepage program yielded present base daily seepage rates in acre-feet per day for each distribution system. Main canal seepage losses and the remaining distribution system or lateral losses are listed in Table 10, page 89. The total system figure, a sum of the two preceding losses, is also given in the table.

TABLE 10. Base Daily Seepage Rates Used to Calculate System Seepage Losses in the Water Budget Program

Irrigation Distict No.		Loss With Simulated Main Canal Linings				
	Present Base Seepage Rate (AF/DAY)	Unreinforced Concrete (AF/DAY)	Buried Plastic Membrane (AF/DAY)	Compacted Clay (AF/DAY)	Unreinforced Shotcrete (AF/DAY)
1. Main Canal	743.9	489.4	275.8	239.0	201.7
Remaining System	1642.5	1642.5	1642.5	1642.5	1642.5
Total System	2386.4	2131.9	1918.3	1881.5	1844.2
2. Main Canal	29.9	18.7	5.9	3.6	1.4
Remaining System	30.0	30.0	30.0	30.0	30.0
Total System	59.9	48.7	35.9	33.6	31.4
3. Main Canal	239.5	105.8	32.6	15.9	7.4
Remaining System	162.5	162.5	162.5	162.5	162.5
Total System	402.0	268.3	195.1	178.4	169.9
4. Main Canal	33.2	13.3	4.2	2.6	1.0
Remaining system	15.7	15.7	15.7	15.7	15.7
Total System	48.9	29.0	19.9	18.3	16.7
5. Main Canal	352.2	137.4	48.2	26.1	9.8
Remaining System	100.4	100.4	100.4	100.4	100.4
Total System	452.6	237.8	148.6	126.5	110.2
6. Main Canal	23.2	10.7	3.1	1.9	0.7
Remaining System	0.0	0.0	0.0	0.0	0.0
Total System	23.2	10.7	3.1	1.9	0.7

This first column is labeled "present base seepage" which are estimates of maximum daily losses for Irrigation Districts 1 through 6 during 1974. These values were used in computing present level water balances for each district as described in Chapter VI.

Simulated main canal lining projects to upgrade conveyance efficiencies were examined. The seepage loss reduction analysis was confined to lining only the main or largest canal systems in each irrigation district. Lining of the distribution laterals would be subject to stringent questions of economic feasibility, which is beyond the scope of this study.

Four commonly used canal lining materials were selected for use in the seepage reduction portion of this analysis. Table 11, page 92, lists each lining material and the associated range and average value of seepage coefficients of each material. These values were used to compute new base daily seepage rates. Seepage coefficient values for three of the lining materials were taken from Bureau of Reclamation studies (44,45). Coefficients for buried plastic membranes were taken from work done by Hickey for the Bureau of Reclamation (46). All coefficients were obtained from ponding tests of different lined irrigation canal sections in the Western U.S. No attempt has been made to select the most suitable type of liner for each channel.

Base daily seepage rates were then re-calculated by simulating the installation of each lining material in the main canals of Districts 1 through 6. The results of these computations occupy the last four columns of Table 10. The distribution lateral seepage losses remained constant while the seepage losses in the main canals were reduced by the simulated lining of the channels. Total system base daily seepage rates decreased accordingly. Pneumatically applied, unreinforced shotcrete is discussed because it offers the maximum reduction in permeability of the four seepage reducing materials. The use of the shotcrete liner in the following discussion does not imply that it would be the most suitable liner for any or all of the channels.

The seepage loss in the re-regulating reservoir of District 1 was not changed during the seepage reduction analysis. The section of main canal with simulated liners measured 54.7 miles in total length. Present seepage loss in the main canal amounts to about one-third of the total system loss in this district. Consequently the maximum simulated reduction in main canal seepage loss (unreinforced shotcrete) reduced the total system loss by just 23 percent.

The main canal system, for purposes of evaluation, in District 2 consists of four channel sections having a combined length of about 19.3 miles. Approximately half of the present total system loss occurs in these main canal

TABLE 11. Seepage Coefficients of Four Commonly Used Irrigation Canal Lining Materials

Lining Material	Range of Values (cfd)	Average Seepage Coefficient (cfd)
Unreinforced Concrete[1]	0.07 - 0.83	0.42
Buried Plastic Membrane[2]	0.05 - 0.22	0.13
Compacted Clay or Thick[1] Compacted Earth	0.05 - 0.13	0.08
Unreinforced (Pnuematically[1] Applied) 1½" Thick Shotcrete	0.03	0.03

[1]Reference 44 and 45.

[2]Reference 46

sections. Unreinforced shotcrete lining along this reach reduces the total system loss by about 48 percent.

A larger portion (about three-fifths) of the total system seepage loss in District 3 is attributed to 71.3 miles of main canal system. The present base daily system seepage loss is reduced by a maximum of 58 percent by the simulated shotcrete lining on the main canal system.

The present base seepage loss in the main canal of District 4 comprises almost seven-tenths of the present base total system loss. The simulated shotcrete lining of the entire 8.76 miles of main canal reduces the total system seepage loss by approximately 66 percent.

Four branching channels comprise the 79.0 miles of main canal system on District 5. The losses in the main canal system amount to more than three-fourths of the computed present base daily system seepage loss. Base daily system seepage losses could theoretically be reduced, using shotcrete lining, by approximately 76 percent.

The distribution system of District 6 is composed of only one main canal, 8.5 miles long (through the irrigation district only). As a result, total system seepage losses could be reduced with a shotcrete liner by about 97 percent on this system.

Present Irrigation Water Use Patterns and Irrigation Efficiencies

After completing the seepage analysis, irrigation water use patterns and irrigation efficiencies for the 1974 study season were compiled and evaluated using the water budget program. Water balances for each of the six districts, located in Appendix C, were developed for the 1974 irrigation season. Appendices A, B, D, and E are numbered consecutively beginning with District 1 through District 6. Appendix C is numbered consecutively similar to A, B, D, and E except that there are two tables per district.

The starting and ending dates for the water balances correspond to the normal irrigation seasons or primary water delivery periods of each district. Net district water use, total inflow minus return flow is given also in each district water balance table. The three irrigation efficiency terms are computed for each time period and for the entire seasons, appearing in both the district water balance and the summary water balance tables grouped in pairs in this appendix. The second table in each pair, "Summary Table", summarizes for the season data given in each preceding "District Water Balance" Table.

Graphs presenting additional information and data during the 1974 study period are located in Appendices D and E. Crop distribution tables for each district are presented in Appendix A. The crop consumptive irrigation requirement tables for each are located in Appendix B. The five major water use components of the district water balances, total district inflow, total consumptive irrigation requirements, average deep percolation losses, distribution system seepage losses and total district return flow, constitute the "seasonal irrigation water use patterns". These water use patterns are plotted in Graphs D-1 through D-6 and are found in Appendix D. Seasonal variation of the three irrigation efficiency terms is displayed on Graphs E-1 through E-6 in Appendix E.

For organizational purposes, the following section discussing present water use patterns and 1974 efficiencies, is broken up into six parts in which each district is discussed individually.

<u>Irrigation District No. 1</u>

The water balance for this district was evaluated from April 15 to October 15 or six months during 1974. Because approximately 4,500 acres were omitted from the district for this study, the river water diverted to that land appears as negative supplementary inflow. Net river diversions to the study area were 6.88 acre feet per irrigated acre during the study period. Total district return flow remained fairly constant throughout the study period reaching a minimum during the peak irrigation water use period in July. The time variation of the five major water balance components, total district inflow, total consumptive irrigation requirement, average deep percolation losses, distribution system seepage losses and total district return flow is shown clearly in Graph D-1 in Appendix D.

District conveyance efficiency, which is a function of both total district return flow and distribution system seepage loss, ranged from about 38 to 64 percent. Graph E-1, Appendix E, shows that conveyance efficiency peaked during July and fell to a minimum in October. The seasonal average conveyance efficiency was 59 percent.

Throughout the season farm irrigation efficiency ranged from about 6 to 62 percent, peaking during mid-irrigation season. The seasonal average farm irrigation efficiency for Irrigation District 1 was 39 percent. The project irrigation efficiency, the product of farm and conveyance efficiencies, followed a pattern similar to farm irrigation efficiency. Project efficiency ranged from about 2 to 40 percent and averaged 23 percent for the entire season. Average annual seepage losses were 2.39 acre feet per irrigated acre on this district. Seepage losses account for roughly 29% of all water diverted to this district. Consequently, the irrigation efficiencies in this district are heavily dependent upon the seepage term in the water balance.

Irrigation District No. 2

Four and one-half months, May 1 to September 15, were used as the water balance period on this district. River diversions, lowest of all six districts, totaled 3.61 acre-feet per acre during the study period. Because of late season data collection inconsistencies the study period terminates on September 15. River diversions after this time amounted to an additional 0.22 acre-feet/acre. The first time period shown (April 15-30) on Table C-3, Appendix C, is a pseudo time period used because the program functions with only an even number of time periods. All figures in the April 15-30 row are zero or meaningless in the district water balance.

The deep wells used to supply supplementary irrigation water were used only once during the season. As shown on the 1974 seasonal water use pattern graph, total district return flow peaked during mid-season and reached minimum values at the beginning and end of the season. Total return flow constitutes about 20 percent of the total district inflow on this tract. In the author's opinion this relatively high return flow rate is due more to topographical characteristics rather than the water management policies of the district. The location of the district centrally on a gently sloping mound about 6-8 miles in diameter causes return flow to leave in all four directions around the perimeter of the tract.

District conveyance efficiency ranged from 64 to 70.5 percent and averaged 68 percent during the season. Since return flow is a larger term in the water balance than is distribution system seepage loss, it effects conveyance efficiency to a greater degree.

Relatively high values of farm irrigation efficiency were computed throughout the irrigation season ranging from about 30 to 80 percent with a seasonal average of 62 percent. During July farm irrigation efficiency varied between 75 and 80 percent. The unique water pricing arrangement of this district economically discourages over-irrigation and therefore encourages higher irrigation efficiency at the farm level. This could be a possible contributing factor for District 2 achieving the highest farm irrigation and project efficiencies of the six districts studied. Also the earlier cutoff date for the water balance may have improved the average seasonal farm irrigation efficiency to a degree. Project efficiencies varied from 20 to about 54 percent with a seasonal mean of 41.7 percent. Graphs D-2 and E-2 in Appendices D and E show the seasonal water use patterns and the variations in irrigation efficiencies throughout the study period.

Irrigation District No. 3

The water balance on this district, Tables C-5 and C-6 in Appendix C, was compiled from April 15 to October 15 during 1974. Total river diversions during this period were 8.86 acre feet/acre. Two wasteways carrying return flow out of this district also contained base flows maintained by groundwater inflow. To estimate this groundwater contribution throughout the study interval, flow measurements were made prior to and immediately following the irrigation season. During the summer, groundwater inflows were linearly interpolated and subtracted from the total wasteway discharges. No alternative method for estimating actual groundwater inflow to these wasteways was available.

From the season totals it can be seen that canal seepage loss is a larger factor influencing conveyance efficiency than is total district return flow on this tract. Conveyance efficiency averaged 76 percent with a range of 58 to 82.5 percent.

Farm irrigation efficiency ranged from a minimum of about 3 percent to a maximum of 38 percent during the season. The seasonal mean value of farm irrigation efficiency on this district was 25 percent. This lower value of farm irrigation efficiency is attributed to the combination of moderately high intake rate soils, long field runs and flat field gradients. The combined project efficiency averaged 19 percent for the water balance period.

Irrigation District No. 4

Irrigation District 4 diverted 14.09 acre feet per irrigated acre of water from the Snake River between May 15 and October 31 of the 1974 irrigation season. The largest three intervals of diversion occurred during the beginning of this water balance period as shown on Table C-7 in Appendix C.

Consequently farm irrigation efficiencies were lower during this time. Farm irrigation efficiencies on this tract were the lowest of the six districts investigated, averaging about 11 percent throughout the irrigation season. During the season, farm irrigation efficiencies peaked at only 23 percent. Low irrigation efficiencies at the farm level can be attributed to the compounding factors of high intake rate soils, long field runs, and land slopes of near zero throughout this district. Only a small portion of the land in this district is sprinkler irrigated.

District conveyance efficiency averaged 85 percent during the irrigation season. Because of low mean farm irrigation efficiency the project efficiency averaged only 10 percent during the study period. The combined return flow and seepage losses accounted for only 2.06 acre-feet per irrigated acre of the initial river diversion or total district inflow. The largest portion of the river diversion was lost through deep percolation, calculated at an average of 10.65 acre-feet per irrigated acre during the irrigation season. This was the highest rate of deep percolation loss calculated for all the six districts.

Irrigation District No. 5

Between May 15 and September 30, 1974, this district diverted 8.85 acre-feet per irrigated acre of water from the Snake River in addition to distributing 0.65 acre feet per acre of supplementary inflow for a combined total district inflow of 9.50 acre feet per acre. How flow rates of supplementary inflow water from upstream flooding, and high return flow were observed at five locations on the district boundaries, approximately two weeks prior to the first time interval on the water balance table. However, no actual measurements of these flows were made at that time. Because of these flows it should be concluded that the season total system inflow and total return flow were higher than the quantities measured during this investigation period. An undetermined amount of irrigation took place prior to May 15 on the district using this flood water.

District 5 yielded the greatest return flow fraction of all districts in the study, almost 27 percent of the total system inflow left the district as return flow, Table 12, page 104. Only a small fraction of this return flow was discharged directly into the Snake River, most of this flow was received by adjacent downstream irrigation districts. The combined average seepage losses and return flow resulted in a district conveyance efficiency of 58 percent as a seasonal average.

Calculated farm efficiencies shown on Table C-9, Appendix C, averaged 25 percent in District 5, ranging between a low of 13 and a high of 40 percent throughout the season. The mean project irrigation efficiency computed was about 15 percent.

District 5 is somewhat unique in comparison to the other five districts since it receives high volumes of supplementary inflow while discharging correspondingly large quantities of return flow. Farms on this district have very long field runs with little, if any slope. The combination of these conditions with high intake rate soils would be expected to yield the somewhat lower irrigation efficiencies at the farm level.

Irrigation District No. 6

Irrigation District 6 used 4.34 acre feet per acre of water diverted from Fall River in the Henry's Fork Basin of the Snake River during the period June 1 to September 30, 1974. The district used the second lowest per acre amount of river water compared to the other five districts.

The summation of seepage and return flow losses was 1.31 acre feet per acre through the irrigation season and investigation period, Table C-12, Appendix C. As a result the district conveyance efficiency was computed to be 70 percent.

The farm irrigation efficiencies on this district averaged a little more than 42 percent but ranged from 17 to 62 percent during the water balance period shown by Table C-11, Appendix C. Since this district is nearly all under sprinkler irrigation, the seasonal farm average irrigation efficiency calculated was less than the value expected.

During July and August, however, the farm efficiencies were considerably higher varying from 54 to 62 percent. As described earlier an inflow gaging station was established on the district's boundary and main canal upstream from an old wood stave inverted siphon. This siphon carries the entire flow of the main canal into the district across the Teton River Canyon, a distance of approxiamtely 3/4 of a mile. In previous years, leakage through this siphon has been appreciable at certain times. Unfortunately no leakage measurements were made across the siphon during the 1974 season. Consequently the lower than expected values in irrigation efficiency may be partially attributed to this unknown siphon leakage.

Average annual project efficiencies averaged about 30 percent thoughout the investigation period.

The season average return flow fraction on this district was 20.4 percent, second highest in the study. This may be an indication that the predominance of sprinkler irrigation may not necessarily result in low return flow fractions occurring subsequently.

The variation in return flow throughout an irrigation season is an important component of any water budget. The bi-monthly return flow fractions, which are return flow as a percentage of the same period total district inflow are presented in Table 12, page 104,

Table 12. Bi-Monthly Return Flow Fractions (Percentages)

Time Period	Irrigation District Number					
	1	2	3	4	5	6
April 15-30	11.0	-	5.1	-	-	-
May 1-15	7.2	19.0	2.8	-	-	-
May 15-31	6.7	20.0	6.1	2.6	56.8	-
June 1-15	7.2	17.1	10.3	5.3	22.7	22.9
June 15-30	5.2	18.8	5.6	5.7	20.8	18.8
July 1-15	3.6	22.2	14.2	4.9	18.0	19.8
July 15-31	3.8	20.9	14.3	3.4	10.1	14.6
August 1-15	5.0	21.7	14.7	3.9	35.4	24.5
August 15-31	5.6	17.5	14.9	6.3	32.4	22.3
September 1-15	7.4	19.9	15.7	5.0	28.7	20.0
September 15-30	10.8	-	16.4	3.2	35.1	22.9
October 1-15	14.3	-	17.7	6.6	-	-
October 15-31	-	-	-	47.0	-	-
Season Averages	6.5	19.8	8.6	5.2	26.8	20.4

Season mean irrigation efficiencies for each district are summarized in Table 13, page 106.

Discussion of Sub-Areas

In the Lower Sub-Area of the Upper Snake River Region calculated irrigation efficiencies on the three districts ranged from 25 to 62 percent as shown in Table 13. Most districts in the sub-area could be expected to be operating close to or within this range of efficiencies since these three study districts are typical and representative of this area. District 2 with the highest farm efficiency represents perhaps the upper limit of farm irrigation efficiencies for gravity systems which the other districts in the sub-area could potentially approach in the future. This district, topographically and soil-wise, is not dissimilar from the other major districts in the sub-area. The irrigation efficiency of District 3 is probably indicative of the operating levels of irrigation districts located in the eastern portion of the Lower Sub-Area, except District 2. Those districts in the central and western portions of the Lower Sub-Area are probably achieving irrigation efficiencies comparable to those measured on District 1.

The lowest project irrigation efficiencies, 10 and 15 percent, in this investigation occurred on the two districts in the Central Sub-Area. This occurred primarily because farm irrigation efficiencies were lower on these two districts. District 4 had simultaneously the lowest

TABLE 13. Present Irrigation Efficiencies

Irrigation District	Farm Irrigation Efficiency (%)	District Conveyance Efficiency (%)	Project Irrigation Efficiency (%)
1	39	59	23
2	62	68	42
3	25	76	19
4	11	85	10
5	25	58	15
6	42	70	30

overall farm irrigation efficiency and the highest conveyance efficiency. Both farm irrigation and district conveyance efficiency were lower on District 5. The performance of District 5 is representative of those irrigation districts south of the Bonneville-Jefferson County line on either side of the Snake River to the Bingham County line. This district probably represents an average to upper operating limit of most districts in the Central Sub-Area. Those districts south of the Bonneville-Bingham County line to American Falls and those districts in the Snake River Fan Area are probably operating at or above the performance level of District 4.

Irrigation District 6 as pointed out in Chapter V is not representative of the districts lying on bottom lands in the Upper Sub-Area. Since very high rates of diversion and low irrigation efficiencies have been previously measured in portions of this area, District 6 should represent a potentially higher irrigation performance level for the sub-area. It is doubtful that more than one or two of the irrigation districts in this area are achieving anywhere near the 42 percent farm irrigation efficiency measured on District 6.

Conveyance efficiencies on all districts except District 2, peaked during the mid-irrigation season and were in general at their lowest during the beginning and end of the irrigation seasons. Return flows are the primary influence causing conveyance efficiencies to follow this trend.

Chapter VIII
Reasonably Attainable Irrigation Efficiencies

The analysis of reasonable and attainable changes in irrigation efficiencies was approached using four procedures involving manipulation of the water balances for each district. The third procedure consisted of combining two of the initial approaches. Changes in irrigation efficiency were examined by the following procedures:

1. Changing main canal system seepage losses
2. Simulated incremental reductions in river diversions
3. Combination (changing seepage losses and reducing diversions simultaneously)
4. Conversion to sprinkler irrigation

Each of the four simulated changes is discussed separately in the following text. The next section of this chapter examines estimates of maximum reasonably attainable irrigation efficiency levels for each district. Water control and management contributing to irrigation efficiency are discussed last in the chapter.

Reducing Main Canal System Seepage Losses

After new base daily seepage rates were calculated as described in Chapter VII, the water budget program was run with the original 1974 data files except for four new base daily seepage rates introduced for each district. These primary computer runs reduced the bi-monthly seepage loss component and the total district seepage losses were then subtracted from each corresponding 1974 equivalent to obtain actual reductions in the seepage component. To restore and hold farm irrigation efficiencies constant at their present (1974) levels, the differences between the bi-monthly seepage components were then subtracted from the appropriate bi-monthly supplementary inflow figures. The water budget program was run a second time with the new supplementary inflow values and the new base seepage rates for each lining material. The secondary run computed changes in conveyance and project efficiencies while holding farm irrigation efficiency constant at existing 1974 levels. Such a constraint is logical since changes in canal seepage losses would not necessarily mean a change in farm irrigation efficiency except on perhaps water deficient tracts. None of the irrigation districts investigated in this study fall into such a category.

The results of this analysis are given in Table 14, page 110. Some minor variation in farm irrigation efficiency appears in the table; however, it is relatively insignificant compared to the larger change observed in the conveyance efficiencies. This minor variation is due to the internal adjustments made in the water balance during the secondary computer runs.

TABLE 14. Effect of Lining Main Canals on Seasonal Average Irrigation Efficiencies and Seasonal River Diversions

Irrigation District No.	Efficiencies and Diversion	Unit	Present Operating Level	Operating Levels With: Unreinforced Concrete Lining	Buried Plastic Membrane Lining	Compacted Clay Lining	Unreinforced Shotcrete Lining
1	Farm Irrigation Efficiency	%	38.74	38.74	38.74	38.74	38.74
	Conveyance Efficiency	%	58.65	60.90	62.95	63.31	63.68
	Project Irrigation Efficiency	%	22.72	23.60	24.39	24.53	24.67
	Season River Diversion	AF	1,040,694	1,002,115	969,608	963,988	958,368
2	Farm Irrigation Efficiency	%	61.69	61.67	61.69	61.69	61.69
	Conveyance Efficiency	%	67.57	69.18	71.16	71.48	71.96
	Project Irrigation Efficiency	%	41.69	42.66	43.90	44.10	44.39
	Season River Diversions	AF	52,614	51,407	49,957	49,735	49,404
3	Farm Irrigation Efficiency	%	24.57	24.57	24.57	24.57	24.57
	Conveyance Efficiency	%	76.09	80.18	82.60	83.18	83.46
	Project Irrigation Efficiency	%	18.69	19.70	20.29	20.44	20.50
	Season River Diversion	AF	379,104	359,767	349,217	346,762	345,599
4	Farm Irrigation Efficiency	%	11.46	11.46	11.46	11.46	11.46
	Conveyance Efficiency	%	85.37	88.79	90.42	90.79	90.97
	Project Irrigation Efficiency	%	9.78	10.17	10.36	10.40	10.43
	Season River Diversion	AF	62,538	60,130	59,045	58,804	58,684
5	Farm Irrigation Efficiency	%	25.34	25.43	25.34	25.34	25.34
	Conveyance Efficiency	%	58.40	62.74	64.85	65.40	65.79
	Project Irrigation Efficiency	%	14.80	15.95	16.44	16.57	16.67
	Season River Diversion	AF	297,366	274,307	265,583	263,188	261,512
6	Farm Irrigation Efficiency	%	42.39	42.38	42,39	42.38	42.41
	Conveyance Efficiency	%	69.90	73.94	76.31	76.66	77.00
	Project Irrigation Efficiency	%	29.63	31.34	32.34	32.49	32.66
	Season River Diversion	AF	23,304	22,034	21,348	21,251	21,143

In general this table shows that the impact of lining the main canals in any of the districts did not change district conveyance efficiency more than about 7½ percent. The greatest percentage change was observed on District 5 with a 7.4 percent difference between the present and district conveyance efficiency obtained with the unreinforced shotcrete lining. Consequently the largest improvement in project irrigation efficiency occurred on this same district. River diversions would be reduced by about 12 percent under this simulated operating condition.

The important conclusion drawn from this table is that main canal seepage loss on any of the six districts is not a large component of the district water balances. Therefore, any canal lining action confined to the main canal systems will modify project irrigation efficiency up to about 7.4 percent and would not be an effective measure for large reductions in river diversion requirements.

Simulated Incremental Reductions in River Diversions

An analysis of the effect of changes in farm irrigation efficiency on river diversions throughout the irrigation season was made. The most convenient manner in which to study this response was to reduce river diversions by increments for each time interval and re-run the water budget program. The primary constraint controlling this procedure was to avoid invalidating the water balance for any time period by causing the deep percolation term to become negative. Therefore, a maximum reduction of 30 percent was observed by trial and error methods to satisy the constraint on all but two of the districts. Four increments of river diversion reduction, 5, 10, 20, and 30 percent, were selected. The results of this portion of the investigation are summarized in Table 15, page 113.

During this analysis, district return flows were left unchanged for each round of reduced river diversion computations. This was done because no valid criteria for reducing the return flow could be determined. With gradually increasing reductions in diversions it is recognized that changes in conveyance system operation would occur; thereby increasing the conveyance efficiency before farm irrigation efficiency reached unreasonable levels. As a result, as the total district inflow drops, district conveyance efficiency tends to decrease also since return flow is held constant. The decreases in system seepage only slightly offset the effect of declining total district inflows. This situation is not of great concern since the primary purpose here is to study the river diversion - farm irrigation efficiency relationship. From the table a specific change in farm irrigation efficiency can be observed

TABLE 15. Changes in Irrigation Efficiencies by Simulated Incremental Reductions in River Diversion

Irrigation District No.	Efficiencies and Diversion	Unit	Present Operating Levels	Percent Reduction in Diversion 5%	10%	20%	30%
1	Season River Diversion	(AF/YEAR)	1,040,694	988,659	936,625	832,555	728,486
	Farm Irrigation Efficiency	(%)	38.74	42.68	47.51	61.41	86.79*
	Conveyance Efficiency	(%)	58.65	56.28	53.63	47.22	38.77
	Project Irrigation Efficiency	(%)	22.72	24.02	25.48	29.00	33.64
2	Season River Diversion	(AF/YEAR)	52,614	49,983	47,352	42,091	36.830
	Farm Irrigation Efficiency	(%)	61.69	66.81	72.39	87.57*	>100.00*
	Conveyance Efficiency	(%)	67.57	65.87	63.98	59.48	--
	Project Irrigation Efficiency	(%)	41.69	43.88	46.31	52.09	--
3	Season River Diversion	(AF/YEAR)	379,104	360,149	341,194	303,283	265,373
	Farm Irrigation Efficiency	(%)	24.57	26.30	28.28	33.33	40.56
	Conveyance Efficiency	(%)	76.09	74.83	73.43	70.11	65.84
	Project Irrigation Efficiency	(%)	18.69	19.68	20.77	23.37	26.70
4	Season River Diversion	(AF/YEAR)	62,538	59,411	56,284	50,030	43,776
	Farm Irrigation Efficiency	(%)	11.46	12.17	12.98	14.97	17.67
	Conveyance Efficiency	(%)	85.37	84.60	83.74	81.71	79.10
	Project Irrigation Efficiency	(%)	9.78	10.30	10.87	12.23	13.98
5	Season River Diversion	(AF/YEAR)	297,366	282,498	267,629	237,893	208,156
	Farm Irrigation Efficiency	(%)	25.34	27.54	30.15	37.21	48.58
	Conveyance Efficiency	(%)	58.40	56.37	54.13	48.88	42.27
	Project Irrigation Efficiency	(%)	14.80	15.52	16.32	18.19	20.54
6	Season River Diversion	(AF/YEAR)	23,304	22,139	20,974	18,643	16,313
	Farm Irrigation Efficiency	(%)	42.39	45.65	49.46	59.38	74.26
	Conveyance Efficiency	(%)	69.90	68.32	66.56	62.38	57.00
	Project Irrigation Efficiency	(%)	29.63	31.19	32.92	37.04	42.33

* Some bi-monthly deep percolation values change sign at these levels.

in terms of the incremental reductions in river diversions for each district.

Negative deep percolation values were encountered at the 20 and 30 percent reduction levels for District 2 hence the first two levels are meaningful only. For the same reason, the 30 percent column for District 1 is not meaningful.

Combined Improved Irrigation Efficiency and Reduced Seepage Loss

The third approach consisted of looking at the combined effects of increased irrigation efficiency at the farm level and simultaneously reduced system seepage losses. Increased farm irrigation efficiencies were obtained by using the incremental reductions in river diversion procedure. Simultaneously, the corresponding seepage data developed using the simulated compacted clay lining on main canals was introduced into the water budget program. Running the program with the modified 1974 data files produced the results summarized in the last column of Table 16, page 115.

Because of the deep percolation non-negativity constraint, uniform levels of reduced river diversion could not be obtained for each of the six districts. The predicted river diversion figures reflect a combined reduction caused by the incremental decreases in river diversion and the supplementary inflow reductions calculated from changes in the seepage losses.

TABLE 16. Changes In Irrigation Efficiencies Caused by Combining Canal Seepage Loss Reductions with Reductions in River Diversion

Irrigation District No.	System Parameter	Units	Present Operating Level	Reduced River Diversion (%)	Main Canal Liner Used: Type	Main Canal Liner Used: Seepage Coefficient (cfd)	Predicted* Operating Level
1.	Seasonal River Diversion	(AF/YEAR)	1,040,694	20			738,741
	Farm Irrigation Efficiency	(%)	38.74	--	Compacted		61.41
	District Conveyance Efficiency	(%)	58.65	--	Clay	0.08	52.13
	Project Irrigation Efficiency	(%)	22.72	--			32.01
	Base Daily Seepage Rate	(AF/DAY)	2,386	--			1,881
2	Seasonal River Diversion	(AF/YEAR)	52,614	10			44,547
	Farm Irrigation Efficiency	(%)	61.69	--	Compacted		72.39
	District Conveyance Efficiency	(%)	67.57	--	Clay	0.08	68.11
	Project Irrigation Efficiency	(%)	41.69	--			49.30
	Base Daily Seepage Rate	(AF/DAY)	60	--			34
3	Seasonal River Diversion	(AF/YEAR)	379,104	30			233,031
	Farm Irrigation Efficiency	(%)	24.57	--	Compacted		40.56
	District Conveyance Efficiency	(%)	76.09	--	Clay	0.08	74.98
	Project Irrigation Efficiency	(%)	18.69	--			30.41
	Base Daily Seepage Rate	(AF/DAY)	402	--			178
4	Seasonal River Diversion	(AF/YEAR)	62,538	10			52,550
	Farm Irrigation Efficiency	(%)	11.46	--	Compacted		12.98
	District Conveyance Efficiency	(%)	85.37	--	Clay	0.08	89.69
	Project Irrigation Efficiency	(%)	9.78	--			11.64
	Base Daily Seepage Rate	(AF/DAY)	49	--			18
5	Seasonal River Diversion	(AF/YEAR)	297,366	20			225,671
	Farm Irrigation Efficiency	(%)	25.34	--	Compacted		37.21
	District Conveyance Efficiency	(%)	58.40	--	Clay	0.08	56.28
	Project Irrigation Efficiency	(%)	14.80	--			20.94
	Base Daily Seepage Rate	(AF/DAY)	452	--			126
6	Seasonal River Diversion	(AF/YEAR)	23,304	20			16,590
	Farm Irrigation Efficiency	(%)	42.39	--	Compacted		59.37
	District Conveyance Efficiency	(%)	69.90	--	Clay	0.08	70.10
	Project Irrigation Efficiency	(%)	29.63	--			41.62
	Base Daily Seepage Rate	(AF/DAY)	23	--			2

*Return Flow Levels held constant; Seepage Reductions Subtracted from river diversions

The primary purpose of this table is to exemplify the compounding effect of seepage reduction and improved farm irrigation efficiency upon project irrigation efficiencies and subsequently river diversions. For example on District 1, the compacted clay lining raises the project efficiency from 29 to about 32 percent at the 20 percent river reduction level (compare Tables 15 and 16). Various combinations of potential farm irrigation efficiency levels and canal liners which reduce system seepage losses could be investigated in detail, but to minimize confusion and maintain conciseness in this discussion, only one combination was investigated for each district. Because main canal seepage losses are small components of the water balances, extensive evaluation of various liners and diversion levels is not warranted.

Conversion to Sprinkler Irrigation

The last procedure, examining the impact of districts converting largely to sprinkler irrigation, is considered to be the practical upper limit of average farm irrigation efficiency attainable on the six districts in this study. To assume that sprinkler irrigation will replace surface irrigation as the major irrigation method implies that energy for pumping should not be a limiting factor. Such a presumption may not be realistic at the present time.

Sprinkler irrigation efficiencies fall normally between 60 and 70 percent on the type of soils found in the Upper Snake River Region. Hence, these two values were chosen as reasonable levels of potential average farm irrigation efficiency for the six districts. Most soils in the study area are adaptable to sprinkler irrigation, including soils on the six districts studied.

Table 17, page 118, presents the results of this portion of the predictive analysis. In this procedure, the assumption was made that no major changes occur in the operation and functioning of the irrigation distribution systems. For analytical purposes, sprinkler pumps would pump directly from the existing canals and laterals in each district. Based upon these assumptions, conveyance efficiencies would remain at 1974 levels.

These unchanged conveyance efficiencies appear in the third column of the table. Calculated project efficiency is the product of multiplying the second and third columns: similar to the previous manner in which it has been calculated. Column five lists the 1974 seasonal consumptive irrigation requirements for each district. The next to the last column is calculated by dividing the consumptive irrigation requirement in column five by the decimal fraction of the calculated project efficiency (column four). This new predicted river diversion (next to last column) is subtracted from the 1974 diversion (column six) to obtain the reduction

TABLE 17. Predicted River Diversions Due to Total District Conversion to Sprinkler Irrigation

Irrigation Dist. No.	Present Farm Efficiency (%)	Potential Farm Efficiency (%)	Present Conveyance Efficiency (%)	Calculated Project Efficiency (%)	Present Consumptive Irrigation Requirement (AF)	1974 River Diversion (AF)	1974 River Diversion (AF/ACRE)	Reduction in 1974 Diversion (AF)	Percent Reduction in 1974 Diversion (%)	Predicted River Diversion (AF)	Predicted River Diversion (AF/ACRE)
1	38.74	60.00	58.65	35.19	236,641	1040,694	6.88	368,739	35.4	671,955	4.44
	38.74	70.00	58.65	41.06	236,641	1040,694	6.88	464,803	44.7	575,891	3.80
2	61.69	60.00	67.57	40.54	21,964	52,614	3.61	0	0	52,614	3.61
	61.69	70.00	67.57	47.30	21,964	52,614	3.61	6,178	11.7	46,436	3.19
3	24.57	60.00	76.09	45.65	70,864	379,104	8.86	223,871	59.1	155,233	3.63
	24.57	70.00	76.09	53.26	70,864	379,104	8.86	246,051	64.9	133,053	3.11
4	11.46	60.00	85.39	51.22	6,118	62,538	14.09	50,593	80.9	11,945	2.69
	11.46	70.00	85.39	59.76	6,118	62,538	14.09	52,300	83.6	10,238	2.31
5	25.34	60.00	58.40	35.04	47,257	297,366	8.85	162,500	54.6	134,866	4.01
	25.34	70.00	58.40	40.88	47,257	297,366	8.85	181,767	61.1	115,599	3.44
6	42.39	60.00	69.90	41.94	6,905	23,304	4.34	6,840	29.4	16,464	3.06
	42.39	70.00	69.90	48.93	6,905	23,304	4.34	9,192	39.4	14,112	2.63

Total 1974 River Diversions (Acre-feet) - - - - - - - - - - - 1,855,620

Totals at 60% Farm Irrigation Efficiency (AF/YEAR) - - - - - - - - - - - - - - - - 812,543 - - - - - 1,043,077

Totals at 70% Farm Irrigation Efficiency (AF/YEAR) - - - - - - - - - - - - - - - - 960,291 - - - - - - 895,329 figures listed in column seven. The summation of reductions in river diversions for all districts at each operating level is given at the bottom of the table.

Significantly reduced river diversions and improvements in project irrigation efficiencies resulted on at least four of the districts. The predicted changes in irrigation efficiency are least on District 2. Because of the high percentage of measured return flow which is direct farm surface runoff on this district, the calculated farm irrigation efficiency under present conditions, 62 percent, is higher than actual. Therefore, it is believed that a 60 percent farm irrigation efficiency is a reasonably attainable farm irrigation efficiency for planning purposes. Since District 6 is 85 percent sprinkler irrigated by direct pumping from the main canal; changes in irrigation efficiencies and river diversions may, under actual conditions, be somewhat less than those figures shown on the table.

The largest reductions in river diversion and improvements in irrigation efficiencies were simulated on Districts 3, 4, and 5. As shown earlier, these districts have high deep percolation losses which would decline by converting to sprinkler irrigation.

The values in the first and third columns in Table 18, page 120, are estimated maximum reasonably attainable

TABLE 18. Maximum Reasonably Attainable Irrigation Efficiencies

Irrigation District	Potential Farm Irrigation Efficiency (%)	Present District Conveyance Efficiency (%)	Potential Project Irrigation Efficiency (%)
1	60	59	35
2	60	68	40
3	60	76	46
4	60	85	51
5	60	58	35
6	60	70	42

irrigation efficiencies that are achievable by each district in the study. No modifications in the existing distribution systems, which might alter seepage losses or district return flows are assumed. It has been observed that on districts now converting to sprinkler irrigation that either pumping from the canal is used or the canal water source is abandoned and groundwater sources are developed. The values are summarized from data given in Table 17. These attainable irrigation efficiencies are predicted if sprinkler irrigation evolved as the major irrigation method on each district. However, the attainment of such levels of irrigation efficiencies may be achieved with other than sprinkler irrigation methods.

Low existing distribution system efficiencies on Districts 1 and 5 cause potential project irrigation efficiencies to be lower relative to the other districts. District 4 which is presently operating at the lowest farm irrigation efficiency level, could attain the highest potential project irrigation efficiency as shown in Table 18.

Irrigation Districts in the Lower Sub-Area should be capable of attaining potential project efficiencies in the range of 35 to 46 percent. This is reasonable because the districts chosen in this study are representative of most irrigation districts found in this portion of the Upper Snake River Region.

Districts 4 and 5 are representative of most irrigation districts located in the Central Sub-Area. Therefore, districts in this sub-area could be expected to approach the 35 to 51 percent range in project irrigation efficiencies.

District 6 is not necessarily representative of most irrigation districts located in the Upper Sub-Area. However, it does serve as an example of the potential operating levels achieveable with sprinkler irrigation in this area. The predicted attainable project irrigation efficiencies for this area are estimated in the 42 percent range.

Control and Management of District Water Distribution

Proper management and responsible control of the diversion and distribution of irrigation water on a district can improve irrigation efficiencies and reduce river diversion requirements. Several means of improving irrigation efficiencies exist with current operational levels of irrigation districts in the Upper Snake River Region.

Measurement of water within a distribution system is essential to maximize conveyance efficiency. Adequate control and management of the distribution system can be achieved only when measuring devices are used effectively to monitor flows within the distribution system, A reduction in return flow and initial river diversions should occur in systems where water measurement is conscientiously employed. Water measuring devices are essential to insure uniform deliveries and flow regulation at the farm headgate. In the Central and Upper Sub-Areas of the Upper Snake River Region, water measurement after the initial river diversion is limited and irregular. Few measuring devices were observed on Districts 4, 5, and 6.

Chapter IX
CONCLUSIONS

A total system water balance is an effective tool for determining irrigation efficiencies and determining water use patterns on large irrigation districts. This method possesses the flexibility to analyze water use on any type or size of irrigation system or district. The impact of altering components on the total system can easily be investigated with this tool. A water balance technique is well adapted to determining average irrigation efficiencies at both present operating levels and future predicted levels.

Present water use patterns and irrigation efficiencies found on six typical irrigation districts in the Upper Snake River Region are variable. During the investigation periods, which approximated the normal irrigation seasons, river diversions ranged from 3.61 to 14.09 acre-feet per irrigated acre. Present farm irrigation efficiencies varied from 11 to 62 percent. Reasonably attainable farm irrigation efficiencies of 60 to 70 percent could be achieved on the same districts by fully implementing sprinkler irrigation and taking other measures to increase efficiencies.

With the exception of one irrigation district, farm irrigation efficiencies on districts in the study area are low. Three of the six districts investigated are operating at farm irrigation efficiency levels at or below 25 percent.

In five of the districts deep percolation losses were the largest outflow component in the 1974 water balances developed.

The unique pricing schedule for water delivery costs on District 2 may have been a contributing factor to the higher farm irrigation efficiencies measured.

Lining of main canal systems with various seepage reducing materials would have limited effect on decreasing river diversions on most of the districts. A 12 percent decrease in seasonal river diversions was the maximum simulated reduction computed, using the 1974 water year as a basis. Main canal seepage losses are not large components of the water balances in the six districts studied. The lower district conveyance efficiencies are constrained due to either high volumes of return flow or proportionally larger seepage losses in the distribution laterals in the systems. Total system seepage losses are appreciable components on three districts. Of all water balance components, the total system seepage losses inherently possess the largest probable error factor. This is a critical factor since farm irrigation efficiencies are sensitive to this component.

District return flow was a large component of the water balances on three districts in the investigation. The seasonal return flow fractions were less than 10 percent on the other three districts. According to data collected on

District 6, the conversion of a district to sprinkler irrigation may not reduce the amount of return flow leaving the district.

Substantial increases in flow measurement and regulation are needed to provide more control and management of irrigation water in Districts 4, 5 and 6. Additional measurement and control of flows on the other three districts would probably increase irrigation efficiency on these systems. Before uniform farm deliveries and better regulation of distribution system flows can be achieved, numerous measuring structures and devices are needed within all these systems.

Upgrading irrigation efficiencies on only these six districts, representing 252,142 acres, could potentially result in about 960,000 acre-feet of water remaining in the river for other uses. At a diversion rate of 3.5 acre-feet per acre per year, an additional 274,000 acres could be put into agricultural production on Upper Snake River lands. Simultaneously, non-beneficial over-irrigation would be reduced on presently irrigated lands on the six districts.

Before changes in irrigation systems or irrigation practices can be anticipated, stronger incentives to increase irrigation efficiency must become apparent to farm operators and the management of irrigation districts. Visible economic benefits from reducing over-irrigation would be expected to encourage farm operators to re-evaluate their irrigation programs and systems. Economic gains or benefits must outweigh costs before irrigation districts can justify taking action to increase their conveyance efficiencies. Presently, economic or other incentives provide farm operators and irrigation districts with little reason to alter their current practices and operating levels in the Upper Snake River Region of Idaho.

Chapter X
RECOMMENDATIONS

1. Seepage loss in distribution systems can be an important component of the water balance. More refined procedures for accurately assessing system seepage losses are needed. Additional data should be collected to identify the relationship between water levels in the channels or diversion rates and the actual seepage rates.

2. Additional research is needed to investigate the influence of water costs upon irrigation efficiencies in the Upper Snake River Region. Data collected in this study raised the question of the allotment water pricing policy being an effective incentive to increase farm irrigation efficiencies.

3. Irrigation efficiencies are now known only on a fraction of the districts in this region. Furthermore, the data collected in this study represents only one year of investigation. Additional studies of a similar nature are needed for periods exceeding one irrigation season to establish solid average values of irrigation efficiency.

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Appendix A

Crop Distribution Tables for each District

CROP DISTRIBUTION TABLE NO. A-1

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
3.94	21.94	4.81	14.07	11.33	5.78	0.0	24.60	13.33	0.0
5964.	33210.	7281.	21297.	17150.	8749.	0.	37539.	20177.	0.

CROP DISTRIBUTION TABLE NO. A-2

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
17.36	10.06	2.37	29.47	4.71	8.26	0.0	25.72	2.05	0.0
2529.	1466.	345.	4293.	686.	1203.	0.	3747.	299.	0.

CROP DISTRIBUTION TABLE NO. A-3

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
13.16	19.49	12.60	10.46	6.96	0.56	0.0	25.61	10.98	0.18
5632.	8341.	5392.	4476.	2978.	240.	0.	10960.	4699.	77.

CROP DISTRIBUTION TABLE NO. A-4

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
8.24	0.0	1.98	15.82	6.31	13.20	0.0	19.80	34.65	0.0
366.	0.	88.	702.	280.	585.	0.	879.	1538.	0.

CROP DISTRIBUTION TABLE NO. A-5

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
9.50	0.0	0.51	18.19	14.86	32.20	0.0	23.15	1.59	0.0
3192.	0.	171.	6111.	4993.	10818.	0.	7778.	534.	0.

CROP DISTRIBUTION TABLE NO. A-6

FIRST LINE OF FIGURES ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE
NEXT LINE OF FIGURES ARE ACRES

SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
0.0	0.0	0.05	14.64	15.51	52.74	0.0	12.16	4.90	0.0
0.	0.	3.	737.	834.	2835.	0.	654.	263.	0.

Appendix B

Crop Consumptive Irrigation Requirements Tables for each District

C R O P   C O N S U M P T I V E   U S E   T A B L E   N O .   B-1

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
APRIL	15-30	0.13	0.0	0.06	0.14	0.74	0.02	0.0	0.44	0.33	0.0
MAY	1-15	0.31	0.23	0.40	2.29	2.77	0.85	0.0	1.85	1.96	0.0
MAY	15-31	0.31	0.23	0.40	2.29	2.77	0.85	0.0	1.85	1.96	0.0
JUNE	1-15	3.14	3.32	2.27	5.90	6.43	4.15	0.0	4.95	4.09	0.0
JUNE	15-30	3.14	3.32	2.27	5.90	6.43	4.15	0.0	4.95	4.09	0.0
JULY	1-15	7.23	7.46	6.41	4.75	7.81	9.05	0.0	7.46	6.35	0.0
JULY	15-31	7.23	7.46	6.41	4.75	7.81	9.05	0.0	7.46	6.35	0.0
AUGUST	1-15	7.04	4.53	6.08	0.15	2.80	7.22	0.0	6.03	4.67	0.0
AUGUST	15-31	7.04	4.53	6.08	0.15	2.80	7.22	0.0	6.03	4.67	0.0
SEPTEMBER	1-15	3.26	0.06	1.67	0.0	0.0	0.0	0.0	2.71	1.21	0.0
SEPTEMBER	15-30	3.26	0.06	1.67	0.0	0.0	0.0	0.0	2.71	1.21	0.0
OCTOBER	1-15	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.55	0.0	0.0
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APRIL	15-30	32.3	0.0	18.2	124.2	528.8	7.3	0.0	688.2	277.4	0.0
MAY	1-15	194.8	303.0	117.4	1960.6	1915.5	299.9	0.0	2800.3	1594.7	0.0
MAY	15-31	207.8	324.5	125.3	2097.7	2043.2	319.9	0.0	2987.0	1701.0	0.0
JUNE	1-15	780.3	4594.1	688.6	5235.6	4594.8	1512.9	0.0	7742.5	3438.6	0.0
JUNE	15-30	780.3	4594.1	688.6	5235.6	4594.8	1512.9	0.0	7742.5	3438.6	0.0
JULY	1-15	1738.7	9987.8	1881.9	4079.2	5400.9	3192.7	0.0	11292.1	5166.4	0.0
JULY	15-31	1354.6	10655.8	2007.3	4351.1	5760.9	3405.6	0.0	12044.9	5510.8	0.0
AUGUST	1-15	1693.0	6066.2	1785.0	128.8	1936.3	2547.1	0.0	9127.5	3799.5	0.0
AUGUST	15-31	1805.8	6470.6	1904.0	137.4	2065.4	2716.9	0.0	9736.0	4052.8	0.0
SEPTEMBER	1-15	810.1	83.0	506.6	0.0	0.0	0.0	0.0	4238.8	1017.3	0.0
SEPTEMBER	15-30	810.1	83.0	506.6	0.0	0.0	0.0	0.0	4238.8	1017.3	0.0
OCTOBER	1-15	153.9	0.0	0.0	0.0	0.0	0.0	0.0	832.5	0.0	0.0

CROP CONSUMPTIVE USE TABLE NO. B-2

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
APRIL	15-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAY	1-15	1.12	0.16	0.79	3.21	3.41	0.38	0.0	2.38	2.28	0.0
MAY	15-31	1.12	0.16	0.79	3.21	3.41	0.38	0.0	2.38	2.28	0.0
JUNE	1-15	3.21	2.95	2.51	5.71	6.42	2.33	0.0	5.05	4.18	0.0
JUNE	15-30	3.21	2.95	2.51	5.71	6.42	2.33	0.0	5.05	4.18	0.0
JULY	1-15	7.39	7.65	6.81	3.31	7.42	8.08	0.0	7.73	6.59	0.0
JULY	15-31	7.39	7.65	6.81	3.31	7.42	8.08	0.0	7.73	6.59	0.0
AUGUST	1-15	7.15	5.12	6.19	0.0	2.47	8.02	0.0	6.15	4.76	0.0
AUGUST	15-31	7.15	5.12	6.19	0.0	2.47	8.02	0.0	6.15	4.76	0.0
SEPTEMBER	1-15	3.73	0.33	1.78	0.0	0.0	3.05	0.0	3.09	1.47	0.0
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APRIL	15-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAY	1-15	114.2	9.5	11.0	555.7	94.3	18.4	0.0	359.6	27.5	0.0
MAY	15-31	121.3	10.1	11.7	592.7	100.6	19.7	0.0	383.6	29.3	0.0
JUNE	1-15	338.3	180.1	36.1	1021.4	183.5	116.8	0.0	783.4	52.0	0.0
JUNE	15-30	338.3	180.1	36.1	1021.4	183.5	116.3	0.0	783.4	52.0	0.0
JULY	1-15	753.6	452.1	94.8	573.0	205.3	392.0	0.0	1167.9	79.4	0.0
JULY	15-31	803.8	482.2	101.1	611.2	219.0	418.2	0.0	1245.7	84.6	0.0
AUGUST	1-15	729.1	302.6	86.2	0.0	68.3	389.1	0.0	929.2	57.3	0.0
AUGUST	15-31	777.7	322.7	91.9	0.0	72.9	415.1	0.0	991.1	61.1	0.0
SEPTEMBER	1-15	393.0	20.2	25.5	0.0	0.0	152.9	0.0	482.4	19.3	0.0

CROP CONSUMPTIVE USE TABLE NO. B-3

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
APRIL	15 30	0.22	0.0	0.20	0.46	0.82	0.0	0.0	0.54	0.40	0.45
MAY	1 15	1.12	0.16	0.79	3.21	3.41	0.38	0.0	2.38	2.28	1.89
MAY	15 31	1.12	0.16	0.79	3.21	3.41	0.38	0.0	2.38	2.28	1.89
JUNE	1 15	3.21	2.95	2.51	5.71	6.42	2.33	0.0	5.05	4.18	3.97
JUNE	15 30	3.21	2.95	2.51	5.71	6.42	2.33	0.0	5.05	4.18	3.97
JULY	1 15	7.39	7.65	6.81	3.31	7.42	8.08	0.0	7.73	6.59	6.30
JULY	15 31	7.39	7.65	6.81	3.31	7.42	8.08	0.0	7.73	6.59	6.30
AUGUST	1 15	7.15	5.12	6.19	0.0	2.47	8.02	0.0	6.15	4.76	5.25
AUGUST	15 31	7.15	5.12	6.19	0.0	2.47	8.02	0.0	6.15	4.76	5.25
SEPTEMBER	1 15	3.73	0.33	1.78	0.0	0.0	3.05	0.0	3.09	1.47	2.66
SEPTEMBER	15 30	3.73	0.33	1.78	0.0	0.0	3.05	0.0	3.09	1.47	2.66
OCTOBER	1 15	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.56	0.0	0.44
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APRIL	15 30	51.6	0.0	44.9	85.8	101.8	0.0	0.0	246.6	78.3	1.4
MAY	1 15	254.3	53.8	171.8	579.4	409.5	3.7	0.0	1051.8	432.0	5.9
MAY	15 31	271.3	57.4	183.2	618.0	436.8	3.9	0.0	1121.9	460.8	6.3
JUNE	1 15	753.2	1025.2	563.9	1065.0	796.7	23.3	0.0	2306.1	818.4	12.7
JUNE	15 30	753.2	1025.2	563.9	1065.0	796.7	23.3	0.0	2306.1	818.4	12.7
JULY	1 15	1578.2	2572.8	1480.6	597.4	891.1	78.1	0.0	3416.0	1248.6	19.5
JULY	15 31	1790.0	2744.3	1579.3	637.3	950.5	83.3	0.0	3643.7	1331.8	20.9
AUGUST	1 15	1623.7	1721.9	1345.8	0.0	296.6	77.5	0.0	2717.8	901.9	16.3
AUGUST	15 31	1731.9	1836.7	1435.6	0.0	316.4	82.7	0.0	2899.0	962.0	17.4
SEPTEMBER	1 15	379.3	114.7	399.9	0.0	0.0	30.5	0.0	1411.0	237.8	8.5
SEPTEMBER	15 30	379.3	114.7	399.9	0.0	0.0	30.5	0.0	1411.0	237.3	8.5
OCTOBER	1 15	152.1	0.0	0.0	0.0	0.0	0.0	0.0	247.5	0.0	1.4

CROP CONSUMPTIVE USE TABLE NO. B-1

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
MAY	15-31	0.23	0.0	0.03	1.17	1.49	0.02	0.0	0.94	1.09	0.0
JUNE	1-15	2.44	0.0	1.94	5.17	5.94	1.96	0.0	4.47	3.68	0.0
JUNE	15-30	2.44	0.0	1.94	5.17	5.94	1.96	0.0	4.47	3.68	0.0
JULY	1-15	6.53	0.0	5.50	6.32	7.97	7.21	0.0	6.86	5.82	0.0
JULY	15-31	6.53	0.0	5.50	6.32	7.97	7.21	0.0	6.86	5.82	0.0
AUGUST	1-15	6.37	0.0	5.50	0.38	3.48	6.95	0.0	5.44	4.17	0.0
AUGUST	15-31	6.37	0.0	5.50	0.38	3.48	6.95	0.0	5.44	4.17	0.0
SEPTEMBER	1-15	2.41	0.0	1.53	0.0	0.05	1.77	0.0	2.06	0.99	0.0
SEPTEMBER	15-30	2.41	0.0	1.53	0.0	0.05	1.77	0.0	2.06	0.99	0.0
OCTOBER	1-15	0.48	0.0	0.0	0.0	0.0	0.0	0.0	0.37	0.0	0.0
OCTOBER	15-31	0.48	0.0	0.0	0.0	0.0	0.0	0.0	0.37	0.0	0.0
NOVEMBER	1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAY	15-31	3.6	0.0	0.1	35.3	18.0	0.5	0.0	35.5	72.1	0.0
JUNE	1-15	37.5	0.0	6.7	151.3	69.3	47.9	0.0	163.7	235.9	0.0
JUNE	15-30	37.5	0.0	6.7	151.3	69.3	47.9	0.0	163.7	235.9	0.0
JULY	1-15	96.3	0.0	19.5	179.0	90.0	170.4	0.0	243.2	361.0	0.0
JULY	15-31	102.9	0.0	20.8	193.9	96.0	181.7	0.0	259.4	385.1	0.0
AUGUST	1-15	94.0	0.0	19.5	24.9	39.3	164.2	0.0	192.8	258.7	0.0
AUGUST	15-31	100.2	0.0	20.8	26.6	41.9	175.2	0.0	205.7	275.9	0.0
SEPTEMBER	1-15	36.7	0.0	5.6	0.0	0.6	43.2	0.0	75.5	63.5	0.0
SEPTEMBER	15-30	36.7	0.0	5.6	0.0	0.6	43.2	0.0	75.5	63.5	0.0
OCTOBER	1-15	7.1	0.0	0.0	0.0	0.0	0.0	0.0	13.1	0.0	0.0
OCTOBER	15-31	7.6	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0
NOVEMBER	1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CROP CONSUMPTIVE USE TABLE NO. B-5

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
MAY	1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAY	15-31	0.62	0.0	0.13	1.59	1.68	0.06	0.0	1.09	1.61	0.0
JUNE	1-15	2.21	0.0	1.39	4.60	5.39	1.61	0.0	3.95	3.17	0.0
JUNE	15-30	2.21	0.0	1.39	4.60	5.39	1.61	0.0	3.95	3.17	0.0
JULY	1-15	6.40	0.0	5.52	6.18	7.59	7.11	0.0	6.69	5.68	0.0
JULY	15-31	6.40	0.0	5.52	6.18	7.69	7.11	0.0	6.69	5.68	0.0
AUGUST	1-15	6.13	0.0	5.27	0.50	2.85	6.85	0.0	5.21	3.96	0.0
AUGUST	15-31	6.13	0.0	5.27	0.50	2.55	6.85	0.0	5.21	3.96	0.0
SEPTEMBER	1-15	2.83	0.0	1.52	0.0	0.0	2.47	0.0	2.40	1.04	0.0
SEPTEMBER	15-30	2.88	0.0	1.52	0.0	0.0	2.47	0.0	2.40	1.04	0.0
MAY	1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAY	15-31	35.1	0.0	1.0	417.9	360.7	27.9	0.0	364.6	37.0	0.0
JUNE	1-15	293.9	0.0	9.9	1171.3	1121.2	725.7	0.0	1280.1	70.6	0.0
JUNE	15-30	293.9	0.0	9.9	1171.3	1121.2	725.7	0.0	1280.1	70.6	0.0
JULY	1-15	823.7	0.0	38.1	1522.9	1548.1	3101.5	0.0	2098.1	122.3	0.0
JULY	15-31	878.6	0.0	40.7	1624.4	1651.3	3308.3	0.0	2233.0	130.5	0.0
AUGUST	1-15	789.9	0.0	36.4	123.2	573.7	2988.1	0.0	1633.9	85.3	0.0
AUGUST	15-31	841.5	0.0	38.9	131.4	612.0	3187.3	0.0	1742.9	91.0	0.0
SEPTEMBER	1-15	383.0	0.0	10.9	0.0	0.0	1113.4	0.0	777.8	23.1	0.0
SEPTEMBER	15-30	383.0	0.0	10.9	0.0	0.0	1113.4	0.0	777.8	23.1	0.0

CROP CONSUMPTIVE USE TABLE NO. B-6

FIGURES SHOW MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS IN INCHES
AND BI-MONTHLY CONSUMPTIVE USE IN ACREFEET FOR THE DISTRICT
BELOW BROKEN LINE FOR EACH CROP GROWN

(MONTH)	(DAYS)	SUGAR BEETS	DRY BEANS	CORN SILAGE	SPRING GRAIN	WINTER GRAIN	POTATOES	SMALL VEGETABLES	ALFALFA	GRASS PASTURE	ORCHARDS
JUNE	1-15	0.0	0.0	0.75	3.02	4.59	0.95	0.0	3.21	2.45	0.0
JUNE	15-30	0.0	0.0	0.75	3.02	4.59	0.95	0.0	3.21	2.45	0.0
JULY	1-15	0.0	0.0	5.28	7.36	7.48	6.89	0.0	6.47	5.45	0.0
JULY	15-31	0.0	0.0	5.28	7.36	7.48	6.89	0.0	6.47	5.45	0.0
AUGUST	1-15	0.0	0.0	4.99	1.91	2.80	6.53	0.0	4.92	3.66	0.0
AUGUST	15-31	0.0	0.0	4.99	1.91	2.80	6.53	0.0	4.92	3.66	0.0
SEPTEMBER	1-15	0.0	0.0	1.36	0.0	0.0	2.08	0.0	2.03	0.80	0.0
SEPTEMBER	15-30	0.0	0.0	1.36	0.0	0.0	2.08	0.0	2.03	0.80	0.0
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JUNE	1-15	0.0	0.0	0.1	99.0	159.4	112.2	0.0	87.4	26.9	0.0
JUNE	15-30	0.0	0.0	0.1	99.0	159.4	112.2	0.0	87.4	26.9	0.0
JULY	1-15	0.0	0.0	0.6	233.5	251.4	787.6	0.0	170.5	57.9	0.0
JULY	15-31	0.0	0.0	0.6	249.1	268.2	840.1	0.0	181.9	61.7	0.0
AUGUST	1-15	0.0	0.0	0.5	60.6	94.1	746.4	0.0	129.7	38.9	0.0
AUGUST	15-31	0.0	0.0	0.6	64.6	100.4	796.2	0.0	138.3	41.5	0.0
SEPTEMBER	1-15	0.0	0.0	0.2	0.0	0.0	245.7	0.0	55.3	8.8	0.0
SEPTEMBER	15-30	0.0	0.0	0.2	0.0	0.0	245.7	0.0	55.3	8.8	0.0

Appendix C

Present Operating Level

Bi-monthly and Seasonal Water Balances for each District

Including Irrigation Efficiencies

(Tables are arranged in pairs; two for each district)

Table C-1

DISTRICT WATER BALANCE

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 1---
IRRIGATED ACREAGE IN THIS DISTRICT 151368.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLE-MENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
APRIL	15-30	47743.	-2637.	45106.	1676.5	18283.6	20195.9	4950.0	40156.	44.25	8.40	3.72
MAY	1-15	91893.	-4810.	87083.	9197.2	42332.6	29279.8	6273.3	80810.	59.17	17.85	10.56
MAY	15-31	108019.	-8416.	99603.	9810.3	49321.4	33758.9	6702.2	92901.	59.37	16.59	9.85
JUNE	1-15	104029.	-8920.	95109.	28587.2	27319.5	32359.0	6843.3	88266.	58.73	51.13	30.06
JUNE	15-30	109787.	-9237.	100550.	28587.2	32892.6	33819.7	5250.0	95300.	61.14	46.50	28.43
JULY	1-15	115505.	-7761.	107744.	42741.5	25832.6	35270.5	3898.9	103845.	63.65	62.33	39.67
JULY	15-31	123294.	-8075.	115219.	45590.9	27557.8	37644.4	4425.6	110793.	63.49	62.33	39.57
AUGUST	1-15	110197.	-7182.	103015.	27033.4	36812.4	33924.0	5195.6	97820.	62.03	42.39	26.29
AUGUST	15-31	107646.	-7683.	99953.	28883.9	31789.1	33674.3	5605.6	94352.	60.70	47.61	28.90
SEPTEMBER	1-15	92095.	-8095.	84000.	6655.8	41821.0	29331.2	6192.2	77808.	57.71	13.73	7.92
SEPTEMBER	15-30	69716.	-7573.	62143.	6655.8	25133.8	23653.1	6700.0	55443.	51.16	20.94	10.71
OCTOBER	1-15	46315.	-5149.	41166.	986.4	14770.2	19497.7	5911.1	35254.	38.23	6.26	2.40

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 3950.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 1590.
COEFFICIENT OF RETURNFLOW (%) = [illegible]
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 23[illegible]5.

DIVERSION REDUCTION FACTOR (%) = 100.00

SUMMARY TABLE NO. C-2

TOTAL ANNUAL RETURNFLOW	(AC-FT)	67948.
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	1126236.
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	1040694.
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	236461.
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	362413.
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	373966.
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	972746.
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)	0.45
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)	7.44
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)	1.56
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)	6.88
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)	2.39
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)	2.47
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)	6.43
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)	6.53
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)	58.65
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)	38.74
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)	22.72

Table C-3

DISTRICT WATER BALANCE

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 2---
IRRIGATED ACREAGE IN THIS DISTRICT 14568.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLE-MENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+ RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
APRIL	15-30	0.	0.	0.	0.0	0.0	0.0	0.0	0.	100.00	0.0	0.0
MAY	1-15	4123.	0.	4123.	1190.2	1571.1	577.7	783.7	3339.	66.98	43.10	28.87
MAY	15-31	6206.	0.	6206.	1269.5	2910.7	775.7	1250.0	4956.	67.36	30.37	20.46
JUNE	1-15	5769.	0.	5769.	2716.7	1354.0	722.5	976.2	4793.	70.56	66.74	47.09
JUNE	15-30	6896.	0.	6896.	2716.7	2049.7	832.4	1297.5	5599.	69.11	57.00	39.39
JULY	1-15	7418.	74.	7492.	3718.1	1224.5	883.4	1666.2	5826.	65.97	75.23	49.63
JULY	15-31	7365.	0.	7365.	3965.9	971.2	888.8	1538.7	5826.	67.04	80.33	53.85
AUGUST	1-15	6258.	0.	6258.	2561.8	1568.1	770.1	1357.5	4900.	66.00	62.03	40.94
AUGUST	15-31	5674.	0.	5674.	2732.6	1224.0	723.9	993.7	4680.	69.73	69.06	48.15
SEPTEMBER	1-15	2905.	0.	2905.	1092.4	766.5	468.2	577.5	2327.	64.00	58.77	37.61

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 255.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 100.
COEFFICIENT OF RETURNFLOW (%) = 0.80
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 60.

DIVERSION REDUCTION FACTOR (%) = 100.00

SUMMARY TABLE NO. C-4

TOTAL ANNUAL RETURNFLOW	(AC-FT)	10441.
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	52614.
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	52688.
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	21964.
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	6643.
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	13640.
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	42246.
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)	0.72
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)	3.61
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)	1.51
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)	3.62
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)	0.46
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)	0.94
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)	2.90
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)	19.82
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)	67.57
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)	61.69
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)	41.69

Table C-5

D I S T R I C T   W A T E R   B A L A N C E

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 3---
IRRIGATED ACREAGE IN THIS DISTRICT 42794.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLE-MENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+ RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
APRIL	15 30	7615.	0.	7615.	610.5	3777.5	2835.0	391.6	7223.	57.63	13.91	8.02
MAY	1 15	35603.	0.	35603.	2962.1	26415.2	5210.8	1014.7	34588.	82.51	10.08	8.32
MAY	15 31	33906.	0.	38906.	3159.6	27722.1	5667.7	2356.8	36549.	79.37	10.23	8.12
JUNE	1 15	33661.	0.	33661.	7364.5	17856.2	4982.0	3457.9	30203.	74.93	29.20	21.88
JUNE	15 30	40692.	0.	40692.	7364.5	25220.2	5810.3	2296.8	38395.	80.08	22.60	18.10
JULY	1 15	42041.	0.	42041.	11932.4	22099.9	5969.2	1989.5	40051.	81.07	35.16	28.50
JULY	15 31	43231.	0.	43231.	12781.2	20692.9	6177.2	3580.0	39651.	77.43	38.18	29.56
AUGUST	1 15	35295.	0.	35295.	8701.5	18066.7	5174.6	3352.6	31943.	75.84	32.51	24.65
AUGUST	15 31	35057.	0.	35057.	9281.6	16637.2	5214.3	3924.2	31133.	73.93	35.81	26.48
SEPTEMBER	1 15	25377.	0.	25877.	3127.7	14641.4	4065.1	4043.2	21834.	68.67	17.60	12.09
SEPTEMBER	15 30	22191.	0.	22191.	3127.7	12578.8	3630.9	2853.7	19337.	70.73	19.91	14.09
OCTOBER	1 15	18935.	0.	18935.	401.0	11877.3	3304.3	3352.6	15583.	64.84	3.27	2.12

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 1430.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 570.
COEFFICIENT OF RETURNFLOW (%) = 0.95
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 402.

DIVERSION REDUCTION FACTOR (%) = 100.00

SUMMARY TABLE NO. C-6

TOTAL ANNUAL RETURNFLOW	(AC-FT)	32614.	
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	379104.	
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	379104.	
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	70864.	
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	58041.	
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	217585.	
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	346491.	
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)		0.76
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)		8.86
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)		1.66
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)		8.86
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)		1.36
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)		5.08
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)		8.10
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)		9.50
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)		76.09
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)		24.57
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)		18.69

Table C-7

DISTRICT WATER BALANCE

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 4---
IRRIGATED ACREAGE IN THIS DISTRICT 4440.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLEMENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+ RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
MAY	15-31	8398.	0.	8398.	165.2	7305.5	705.1	222.4	8176.	88.96	2.21	1.97
JUNE	1-15	8311.	0.	8311.	712.4	6465.9	690.9	441.8	7869.	86.37	9.92	8.57
JUNE	15-30	8122.	0.	8122.	712.4	6264.7	678.0	467.3	7655.	85.90	10.21	8.77
JULY	1-15	5839.	0.	5839.	1159.5	3889.0	505.7	284.7	5554.	86.46	22.97	19.86
JULY	15-31	7341.	0.	7341.	1236.8	5225.2	632.9	245.9	7095.	88.03	19.14	16.25
AUGUST	1-15	5523.	0.	5523.	793.5	4011.9	500.7	217.3	5306.	87.00	16.51	14.37
AUGUST	15-31	5492.	0.	5492.	846.4	3793.7	506.8	344.9	5147.	84.49	18.24	15.41
SEPTEMBER	1-15	5164.	0.	5164.	225.1	4203.9	476.2	259.2	4905.	85.76	5.08	4.36
SEPTEMBER	15-30	4714.	0.	4714.	225.1	3890.4	445.5	153.1	4561.	87.30	5.47	4.77
OCTOBER	1-15	2712.	0.	2712.	20.2	2144.8	367.5	179.6	2533.	79.83	0.93	0.74
OCTOBER	15-31	921.	0.	921.	21.5	74.4	392.0	432.7	488.	10.42	22.45	2.34
NOVEMBER	1-15	0.	0.	0.	0.0	0.0	0.0	0.0	0.	100.00	0.0	0.0

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 301.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 120.
COEFFICIENT OF RETURNFLOW (%) = 0.98
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 49.

DIVERSION REDUCTION FACTOR (%) = 100.00

SUMMARY TABLE NO. C-8

TOTAL ANNUAL RETURNFLOW	(AC-FT)	3249.	
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	62538.	
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	62538.	
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	6118.	
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	5931.	
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	47269.	
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	59289.	
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)		0.73
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)		14.09
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)		1.38
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)		14.09
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)		1.33
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)		10.65
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)		13.35
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)		5.20
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)		85.37
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)		11.46
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)		9.78

Table C-9

D I S T R I C T   W A T E R   B A L A N C E

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 5---
IRRIGATED ACREAGE IN THIS DISTRICT 33597.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLE-MENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+ RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
MAY	1-15	0.	0.	0.	0.0	0.0	0.0	0.0	0.	100.00	0.0	0.0
MAY	15-31	27681.	3275.	25956.	1294.3	5810.5	4113.5	14737.8	11218.	27.37	18.22	4.99
JUNE	1-15	33960.	4694.	38654.	4672.7	19877.4	5344.0	8760.0	29894.	63.51	19.03	12.09
JUNE	15-30	39601.	2030.	41631.	4672.7	22246.2	6043.9	8667.8	32963.	64.66	17.36	11.22
JULY	1-15	39561.	2061.	41622.	9254.7	18837.2	6039.0	7491.1	34131.	67.49	32.94	22.24
JULY	15-31	44878.	1528.	46406.	9871.7	25045.8	6774.1	4714.4	41692.	75.24	28.27	21.27
AUGUST	1-15	33946.	2146.	36092.	6229.6	11752.6	5342.3	12767.8	23324.	49.82	34.64	17.26
AUGUST	15-31	29407.	2610.	32017.	6644.9	10143.2	4854.3	10374.4	21642.	52.44	39.58	20.75
SEPTEMBER	1-15	30248.	1742.	31990.	2308.2	15615.2	4883.4	9183.3	22807.	56.03	12.88	7.22
SEPTEMBER	15-30	23084.	1870.	24954.	2308.2	9899.1	3994.4	8752.2	16202.	48.92	18.91	9.25

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 1530.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 612.
COEFFICIENT OF RETURNFLOW (%) = 0.90
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 452.

DIVERSION REDUCTION FACTOR (%) = 100.00

SUMMARY TABLE NO. C-10

TOTAL ANNUAL RETURNFLOW	(AC-FT)	85449.	
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	297366.	
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	319322.	
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	47257.	
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	47389.	
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	139227.	
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	233873.	
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)		2.54
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)		8.85
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)		1.41
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)		9.50
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)		1.41
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)		4.14
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)		6.96
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)		26.76
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)		58.40
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)		25.34
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)		14.80

Table C-11

D I S T R I C T   W A T E R   B A L A N C E

IRRIGATION DISTRICT IDENTIFICATION NUMBER --- 6---
IRRIGATED ACREAGE IN THIS DISTRICT 5375.

TIME PERIOD (MON.)		RIVER DIVERSION (AC-FT)	SUPPLE-MENTARY INFLOW (AC-FT)	TOTAL INFLOW (SUPL.+ RIVDV.) (AC-FT)	TOTAL CONSUMPTIVE IRRIGATION REQUIREMENT (AC-FT)	AVERAGE DEEP PERCOLATION LOSSES (AC-FT)	DISTRIBUTION SYSTEM SEEPAGE LOSSES (AC-FT)	TOTAL DISTRICT RETURNFLOW (AC-FT)	NET DISTRICT WATERUSE (TINF-RET) (AC-FT)	DISTRICT CONVEYANCE EFFICIENCY (%)	FARM IRRIG. EFFIC. (%)	PROJECT IRRIG. EFFIC. (%)
JUNE	1-15	2170.	0.	2170.	485.1	970.0	217.4	498.0	1672.	67.04	33.33	22.35
JUNE	15-30	3377.	0.	3377.	485.1	1941.5	316.6	633.7	2743.	71.86	19.99	14.36
JULY	1-15	3403.	0.	3403.	1501.5	908.0	318.5	674.5	2728.	70.82	62.31	44.13
JULY	15-31	3488.	0.	3488.	1601.6	1047.1	329.0	510.2	2978.	75.94	60.47	45.92
AUGUST	1-15	3002.	0.	3002.	1070.2	907.9	288.0	735.7	2266.	65.90	54.10	35.65
AUGUST	15-31	2918.	0.	2918.	1141.6	840.3	285.5	651.0	2267.	67.91	57.60	39.12
SEPTEMBER	1-15	2536.	0.	2536.	309.9	1465.1	252.4	508.2	2027.	70.00	17.46	12.22
SEPTEMBER	15-30	2411.	0.	2411.	309.9	1304.7	242.9	553.1	1857.	66.98	19.19	12.86

RIVER DIVERSION LEVELS, COEFFICIENT OF RETURNFLOW, AND MAXIMUM SEEPAGE RATE:

MAXIMUM SEASONAL RIVER DIVERSION (CFS) = 126.
RIVER DIVERSION AT 50% SEEPAGE LOSS RATE (CFS) = 50.
COEFFICIENT OF RETURNFLOW (%) = 0.98
MAXIMUM INPUT SEEPAGE RATE (AF/DAY) = 23.

DIVERSION REDUCTION FACTOR (%) = 100.00

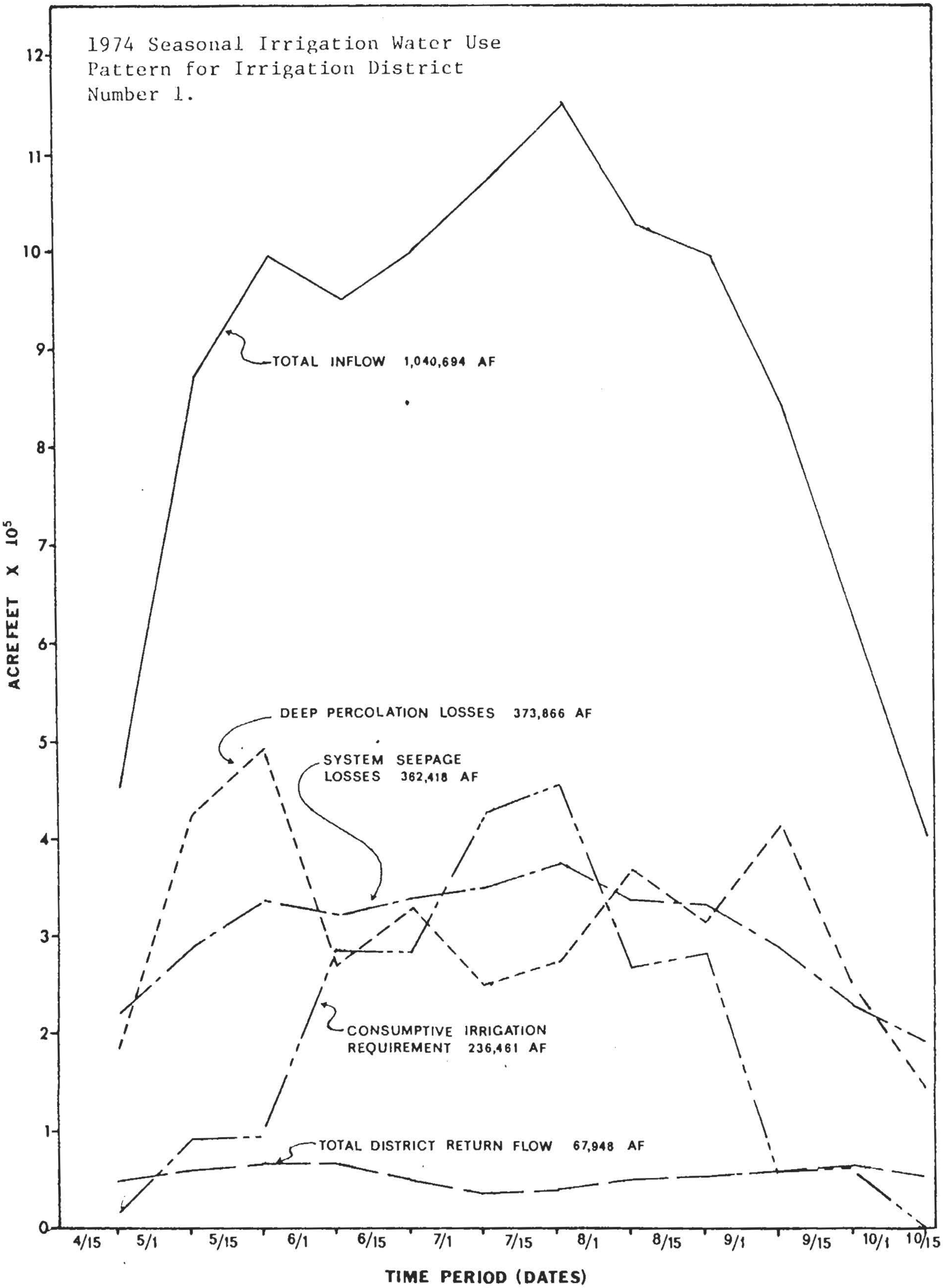
SUMMARY TABLE NO. C-12

TOTAL ANNUAL RETURNFLOW	(AC-FT)	4764.
TOTAL ANNUAL RIVER DIVERSION	(AC-FT)	23304.
TOTAL ANNUAL INFLOW (DIVERSIONS + SUPPLEMENTARY)	(AC-FT)	23304.
TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AC-FT)	6905.
TOTAL ANNUAL SYSTEM SEEPAGE LOSSES	(AC-FT)	2250.
TOTAL ANNUAL DEEP PERCOLATION LOSSES	(AC-FT)	9385.
TOTAL ANNUAL NET DISTRICT WATERUSE	(AC-FT)	18540.
AVERAGE ANNUAL RETURNFLOW PER ACRE	(AF/AC)	0.89
AVERAGE ANNUAL RIVER DIVERSION PER ACRE	(AF/AC)	4.34
AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT	(AF/AC)	1.28
AVERAGE ANNUAL TOTAL INFLOW TO DISTRICT PER ACRE	(AF/AC)	4.34
AVERAGE ANNUAL SEEPAGE LOSSES PER ACRE	(AF/AC)	0.42
AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE	(AF/AC)	1.75
AVERAGE ANNUAL NET DISTRICT WATER USE PER ACRE	(AF/AC)	3.45
AVERAGE ANNUAL DISTRICT RETURNFLOW FRACTION	(%)	20.44
AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY	(%)	67.90
AVERAGE ANNUAL FARM IRRIGATION EFFICIENCY	(%)	42.39
AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY	(%)	29.63

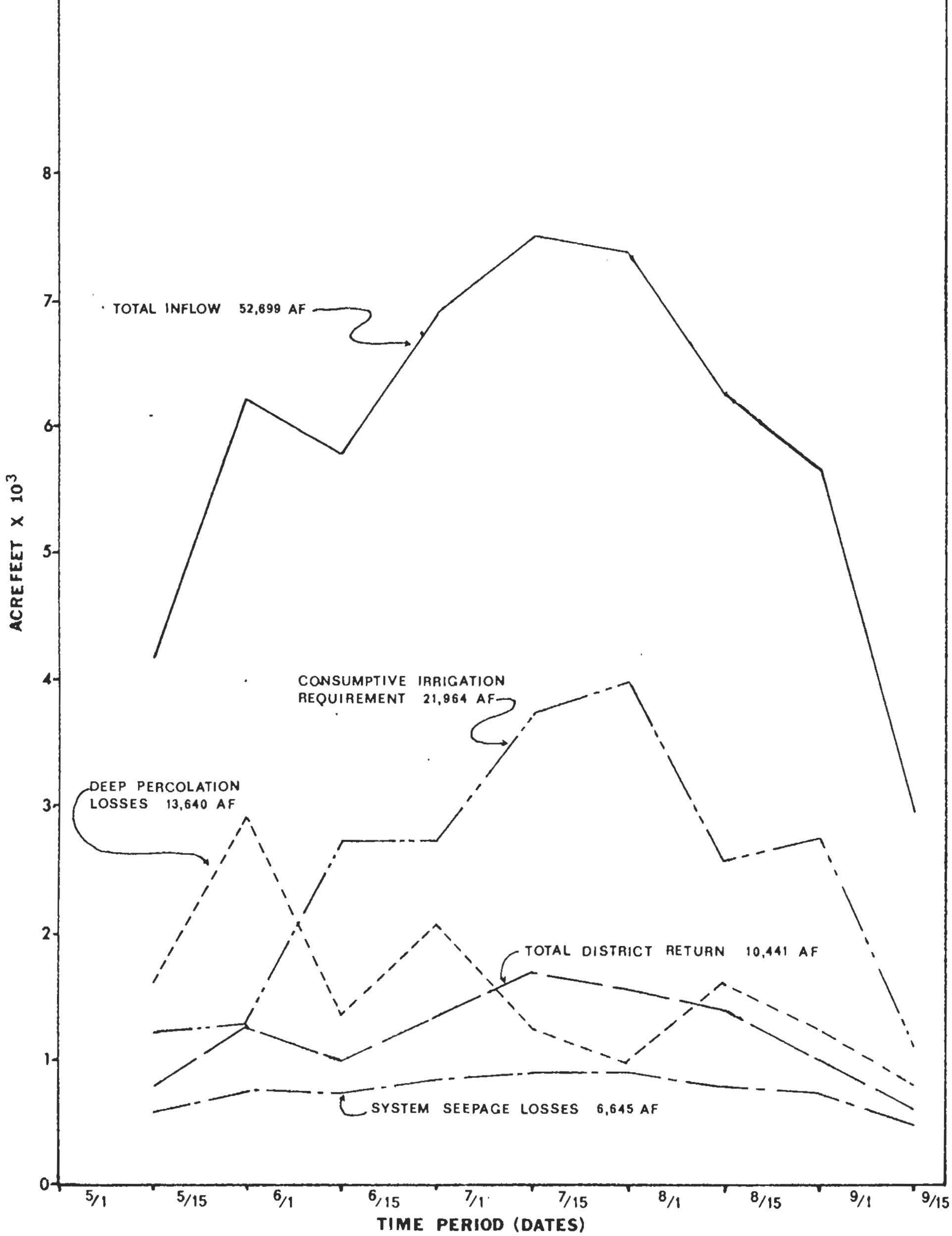
Appendix D

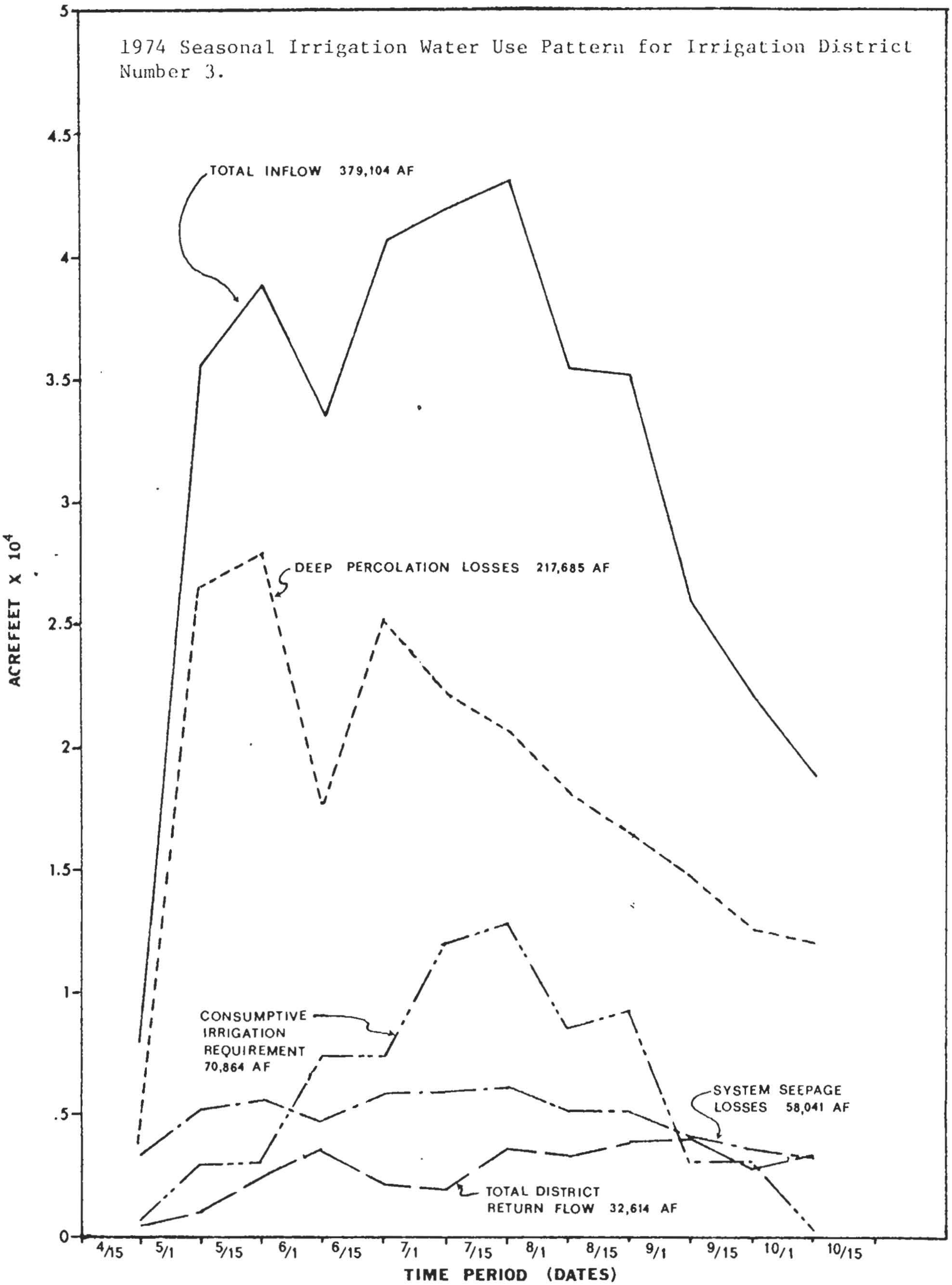
Seasonal Irrigation Water Use Patterns

for each District (Figures D1-D6)

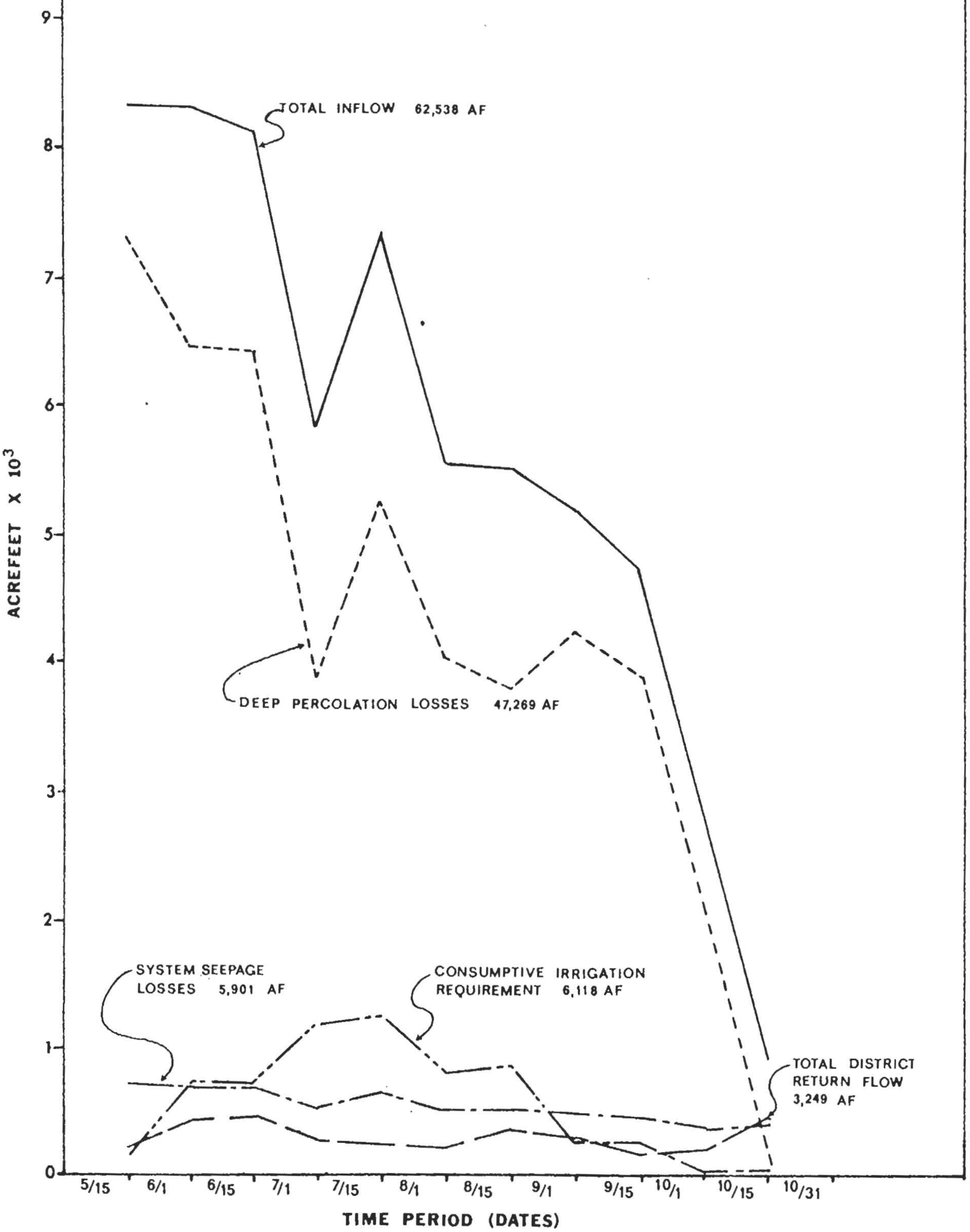

1974 Seasonal Irrigation Water Use Pattern for Irrigation District Number 1.
TOTAL INFLOW 1,040,694 AF
DEEP PERCOLATION LOSSES 373,866 AF
SYSTEM SEEPAGE LOSSES 362,418 AF
CONSUMPTIVE IRRIGATION REQUIREMENT 236,461 AF
TOTAL DISTRICT RETURN FLOW 67,948 AF
ACREFEET X 10^5
0
1
2
3
4
5
6
7
8
9
10
11
12
4/15
5/1
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
10/1
10/15
TIME PERIOD (DATES)

1974 Seasonal Irrigation Water Use Pattern for Irrigation District Number 2.




1974 Seasonal Irrigation Water Use Pattern for Irrigation District Number 3.
TOTAL INFLOW 379,104 AF
DEEP PERCOLATION LOSSES 217,685 AF
CONSUMPTIVE IRRIGATION REQUIREMENT 70,864 AF
SYSTEM SEEPAGE LOSSES 58,041 AF
TOTAL DISTRICT RETURN FLOW 32,614 AF
ACREFEET X 10^4
5
4.5
4
3.5
3
2.5
2
1.5
1
.5
0
4/15
5/1
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
10/1
10/15
TIME PERIOD (DATES)

1974 Seasonal Irrigation Water Use Pattern for Irrigation District Number 4.

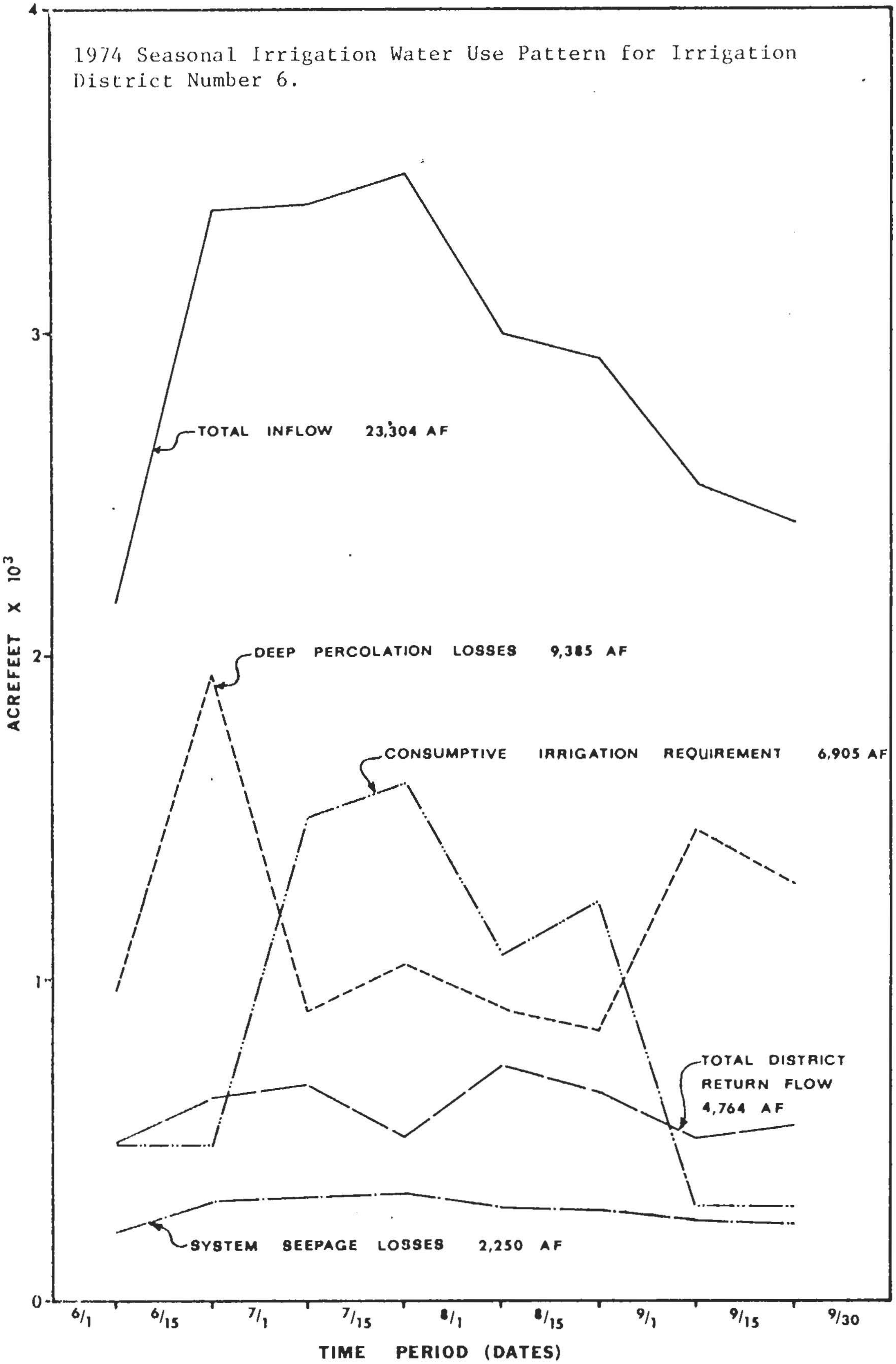


Appendix E

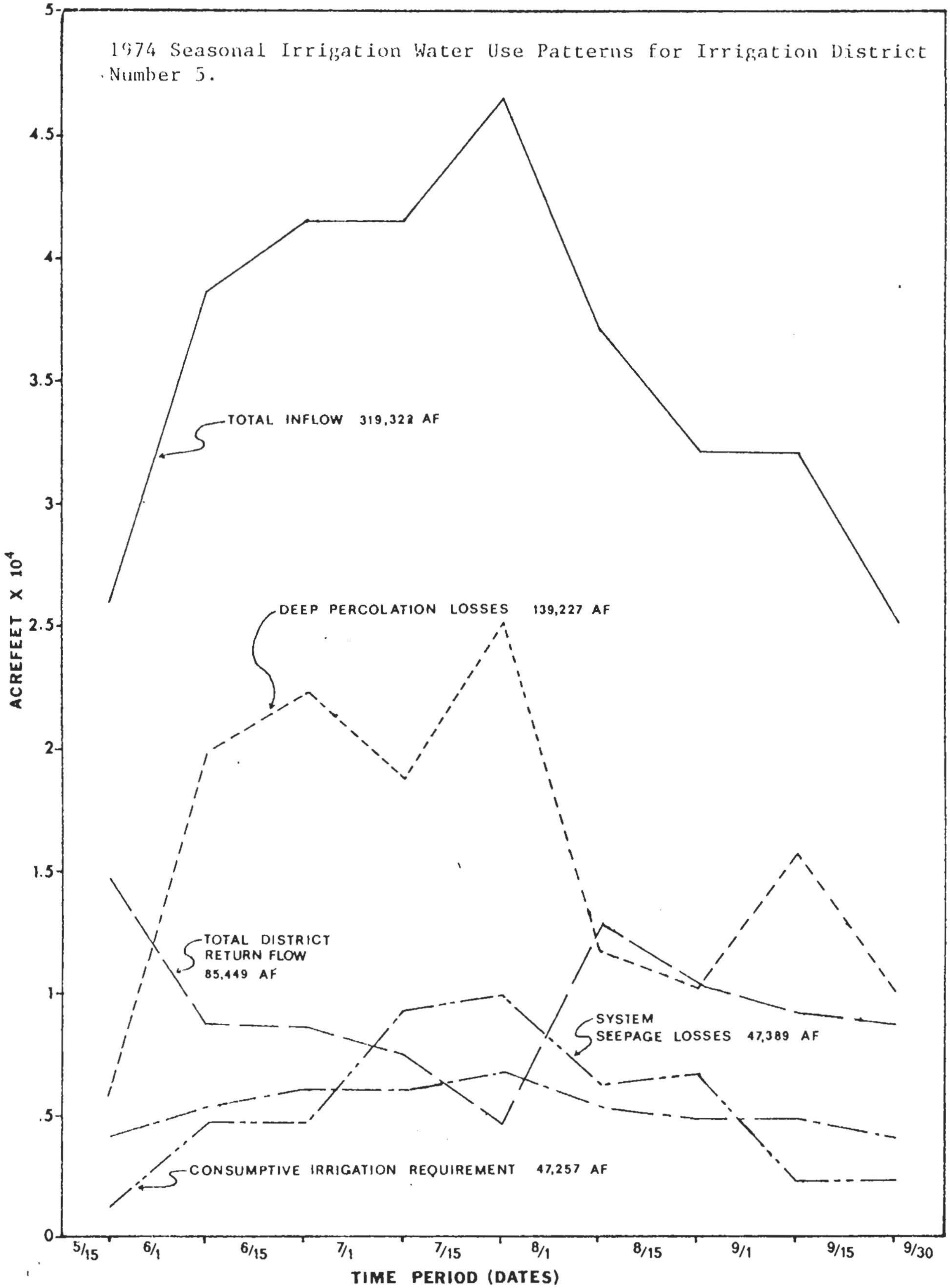
Seasonal Variations of Present

Irrigation Efficiencies for each District

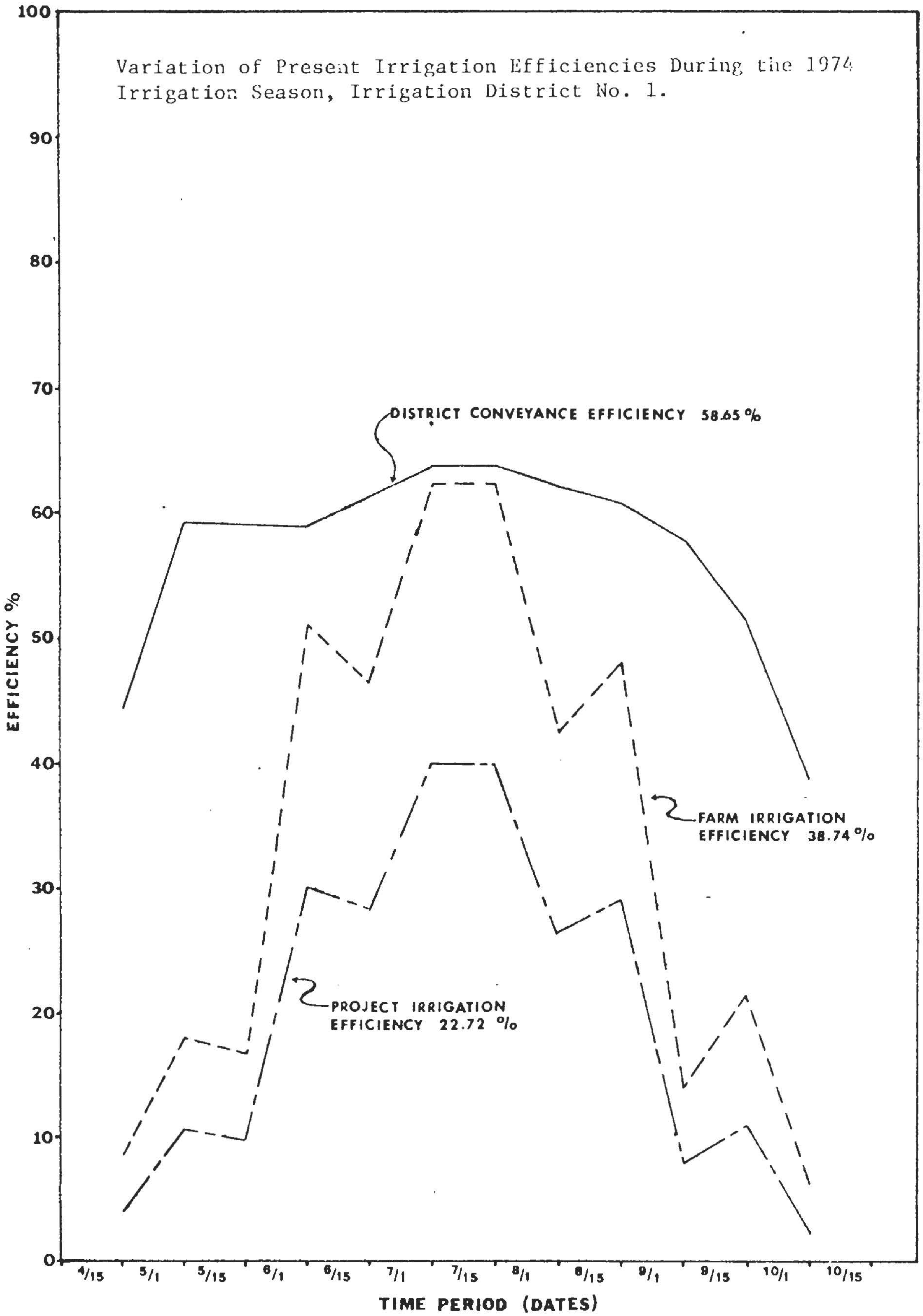
(Figures E1-E6)



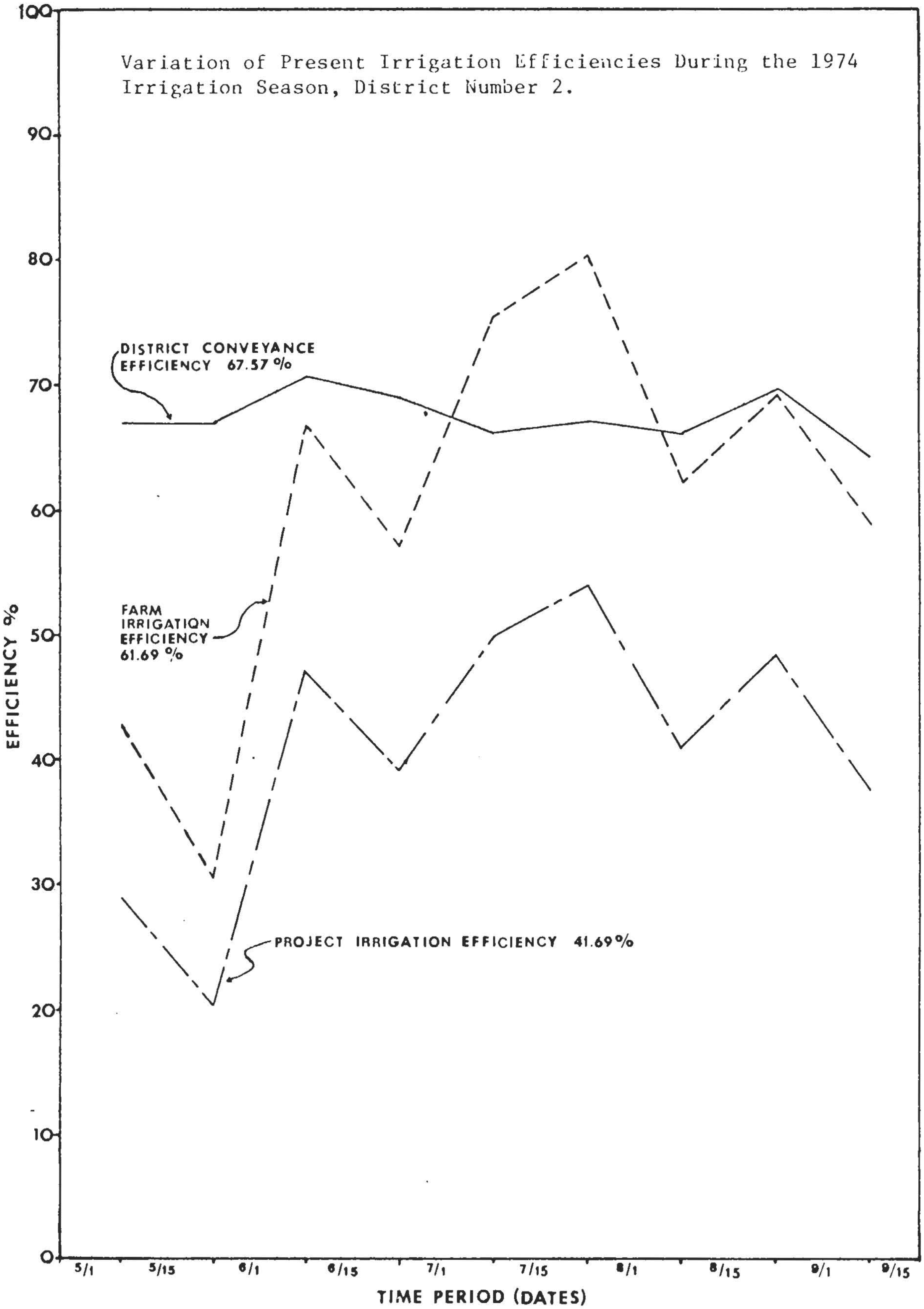
1974 Seasonal Irrigation Water Use Pattern for Irrigation District Number 6.



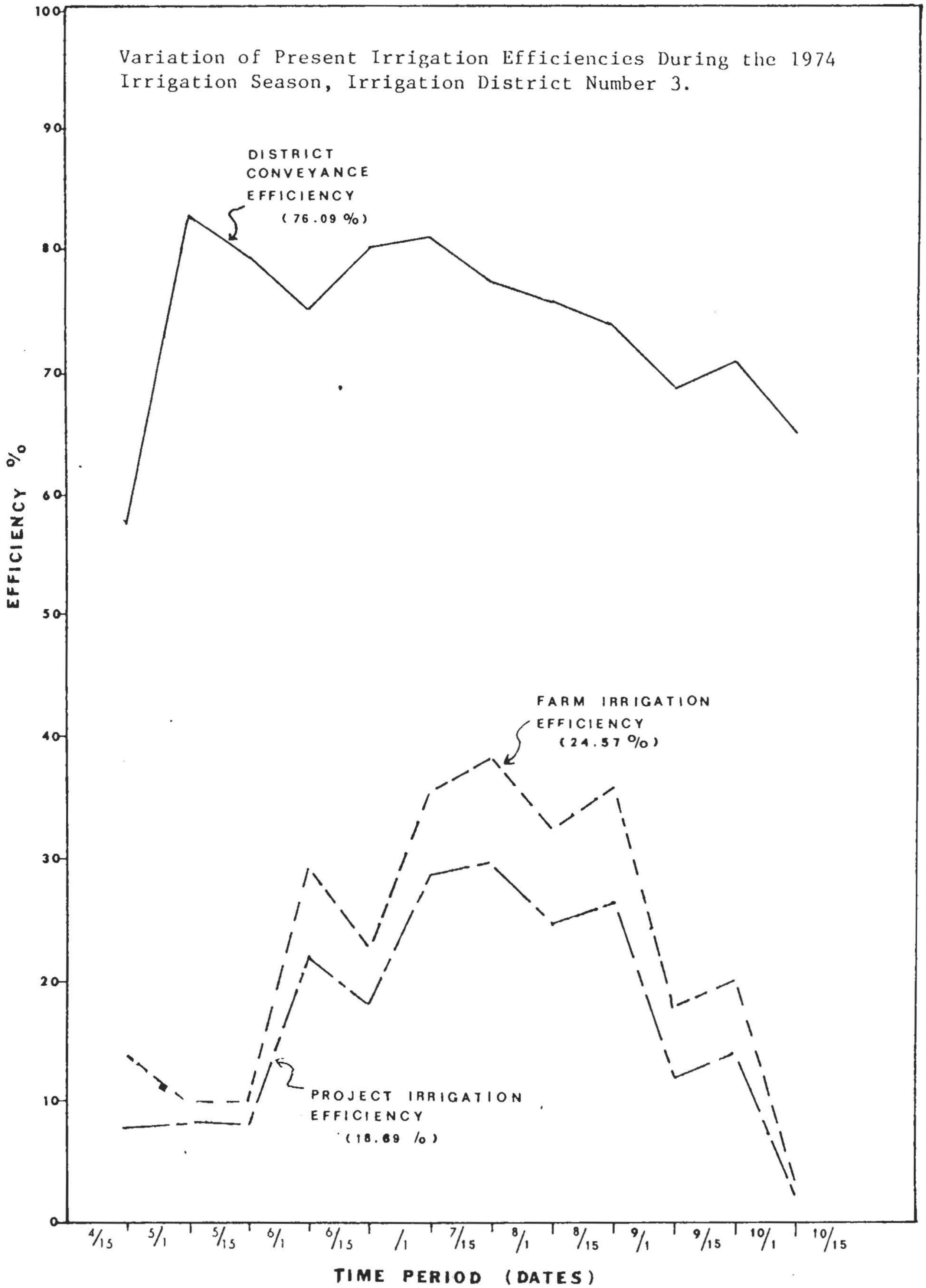
1974 Seasonal Irrigation Water Use Patterns for Irrigation District Number 5.



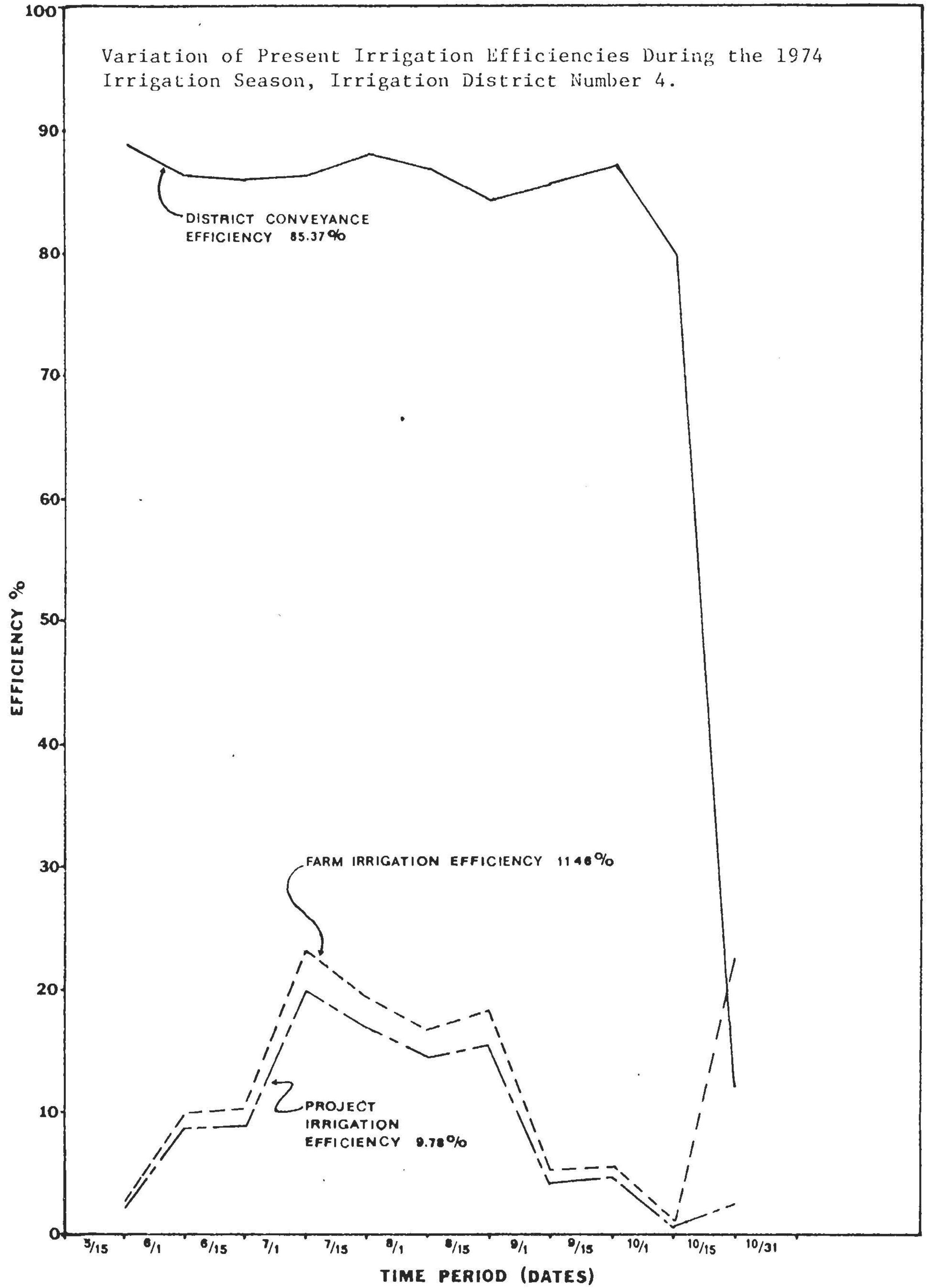
Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, Irrigation District No. 1.
DISTRICT CONVEYANCE EFFICIENCY 58.65 %
FARM IRRIGATION EFFICIENCY 38.74 %
PROJECT IRRIGATION EFFICIENCY 22.72 %
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
4/15
5/1
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
10/1
10/15
TIME PERIOD (DATES)



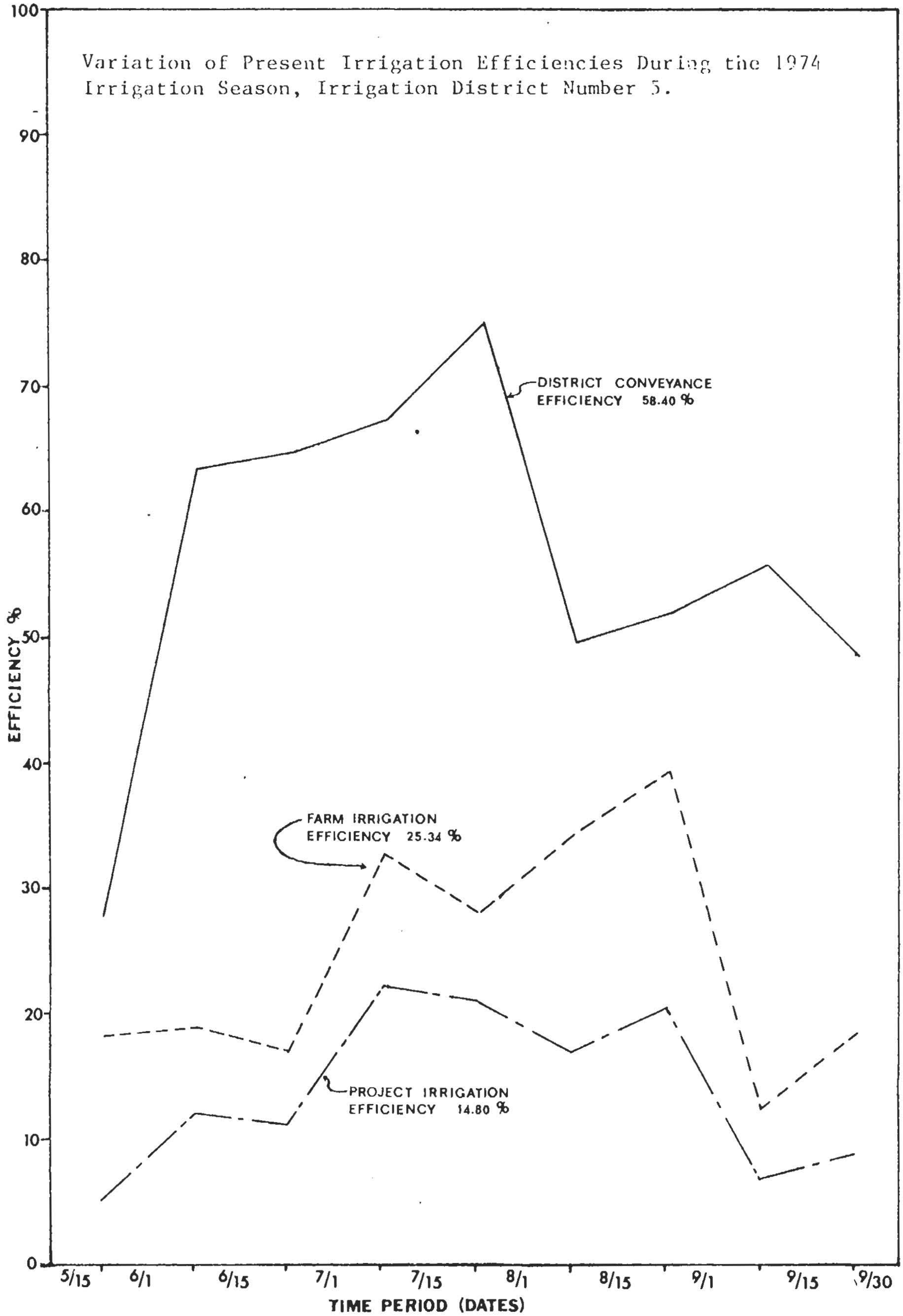
Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, District Number 2.
DISTRICT CONVEYANCE EFFICIENCY 67.57 %
FARM IRRIGATION EFFICIENCY 61.69 %
PROJECT IRRIGATION EFFICIENCY 41.69%
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
5/1
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
TIME PERIOD (DATES)



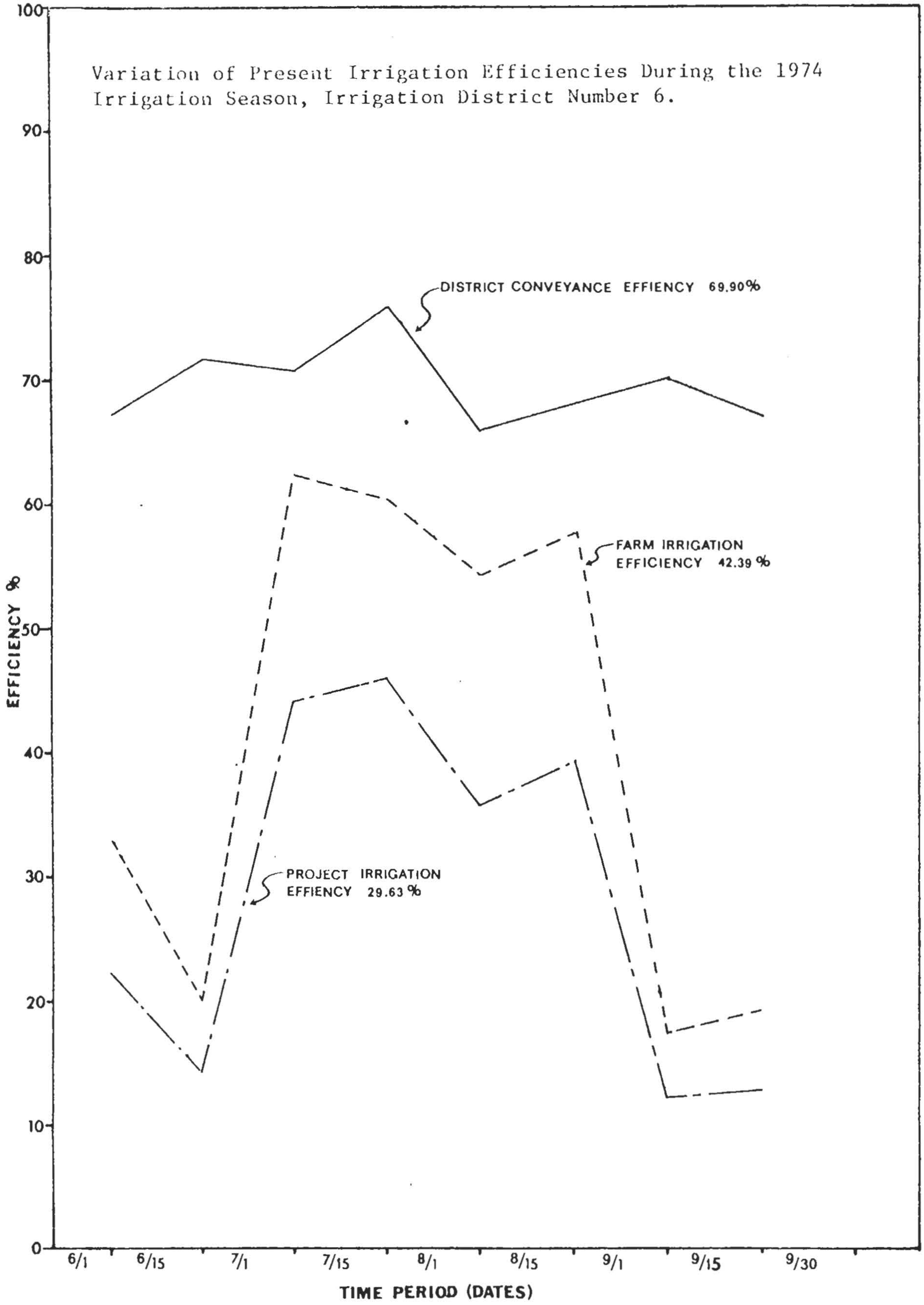
Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, Irrigation District Number 3.
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
DISTRICT CONVEYANCE EFFICIENCY (76.09 %)
FARM IRRIGATION EFFICIENCY (24.57 %)
PROJECT IRRIGATION EFFICIENCY (18.69 %)
4/15
5/1
5/15
6/1
6/15
/1
7/15
8/1
8/15
9/1
9/15
10/1
10/15
TIME PERIOD (DATES)



Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, Irrigation District Number 4.
DISTRICT CONVEYANCE EFFICIENCY 85.37%
FARM IRRIGATION EFFICIENCY 11.46%
PROJECT IRRIGATION EFFICIENCY 9.78%
EFFICIENCY %
TIME PERIOD (DATES)
100
90
80
70
60
50
40
30
20
10
0
5/15
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
10/1
10/15
10/31



Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, Irrigation District Number 5.



Variation of Present Irrigation Efficiencies During the 1974 Irrigation Season, Irrigation District Number 6.
DISTRICT CONVEYANCE EFFIENCY 69.90%
FARM IRRIGATION EFFICIENCY 42.39%
PROJECT IRRIGATION EFFIENCY 29.63%
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
6/1
6/15
7/1
7/15
8/1
8/15
9/1
9/15
9/30
TIME PERIOD (DATES)

Appendix F

Water Budget Program
With Sample Data Input File

```
C.......................................................................
C
C
C
C U P P E R   S N A K E   R I V E R   W A T E R   B U D G E T   P R O G R A M
C
C
C     COMMENT:      THIS PROGRAM COMPUTES A BI-MONTHLY AND TOTAL YEARLY
C                   IRRIGATION WATER BALANCE ON AN IRRIGATION DISTRICT.
C                   THE PROGRAM SUMS OR COMPUTES THE FOLLOWING IRRIGATION
C                   WATER COMPONENTS:
C                        GROSS RIVER DIVERSIONS
C                        SUPPLEMENTARY DISRICT INFLOW
C                        TOTAL DISTRICT INFLOW
C                        CROP CONSUMPTIVE IRRIGATION REQUIREMENTS
C                        AVERAGE DISTRICT DEEP PERCOLATION LOSSES
C                        DISTRIBUTION SYSTEM SEEPAGE LOSSES
C                        TOTAL DISTICT RETURN FLOWS
C                        NET DISTRICT WATER USE
C                        DISTRICT CONVEYANCE EFFICIENCY
C                        AVERAGE FARM IRRIGATION EFFICIENCY
C                        PROJECT IRRIGATION EFFICIENCY
C
C
C     VARIABLE:      DEFINITION:
C     AVANRF     =   AVERAGE ANNUAL RETURNFLOW PER ACRE, AF/AC.
C     AVANDV     =   AVERAGE ANNUAL RIVER DIVERSION PER ACRE, AF/AC.
C     AVANCR     =   AVERAGE ANNUAL CONSUMPTIVE IRRIGATION REQUIRE
C                    MENT,  AF/AC.
C     AVANIF     =   AVERAGE ANNUAL TOTAL DISTRICT INFLOW PER ACRE, AF/AF
C     AVANSP     =   AVERAGE ANNUAL DISTRIBUTION SEEPAGE LOSSES PER ACRE
C     AVANDP     =   AVERAGE ANNUAL DEEP PERCOLATION LOSSES PER ACRE,
C     AFANOR     =   AVERAGE ANNUAL RETURN FLOW AS A PERCENTAGE OF TOTAL
C                    DISTRICT INFLOW
C     AVANDE     =   AVERAGE ANNUAL DISTRICT CONVEYANCE EFFICIENCY, %
C     AVANFE     =   AVAERAGE ANNUAL FARM IRRIGATION EFFICIENCY, %
C     AVANPE     =   AVERAGE ANNUAL PROJECT IRRIGATION EFFICIENCY, %
```

```
C       AVANGU     =    AVERAGE ANNUAL NET DISTRICT WATER USE, AF/AC.
C
C       ACCROP(J)       ACREAGE OF A SPECIFIC CROP "J"
C       COFRTF     =    COEFFICIENT OF RETURNFLOW
C       CROP(J)    =    PERCENT OF TOTAL DISTRICT ACREAGE UNDER SPECIFIC
C                       CROP "J", WHERE "J" SUBSCRIPTS A PARTICULAR CROP
C       CONSUM(J,I)     CONSUMPTIVE IRRIGATION REQUIREMENT IN INCHES;
C                       WHERE "J" IDENTIFIES A PARTICULAR CROP AND "I"
C                       REFERS TO THE MONTH OR BI-MONTHLY TIME PERIOD
C       CRPCON(J,I)     CONSUMPTIVE IRRIGATION REQUIREMENT, FOR CROP = J,
C                       TIME PERIOD = I
C       DATE       =    BEGINNING AND ENDING DATES FOR THIS IRRIGATION
C                       SEASON FOR THIS DISTRICT
C       DAYDIV(I) =     DAILY RIVER DIVERSION IN CFS-DAYS FOR ANY "I" DAY
C       DEPERC     =    DEEP PERCOLATION WATER LOSS FOR THE DISTRICT IN AF.
C       DISTNO     =    IRRIGATION DISTRICT IDENTIFICATION NUMBER
C       DISTAC     =    IRRIGATED ACREAGE WITHIN A DISTRICT
C       DISEFF     =    DISTRICT CONVEYANCE EFFICIENCY BASED ON TINFLW, %
C       DIVMIN     =    LOWER LEVEL OF DAILY RIVER DIVERSIONS IN CFS-DAYS
C                       AT WHICH SEEPAGE LOSSES ARE EQUAL TO 50% OF THE
C                       BASE SEEPAGE RATE, TOTSEP
C       DIVMAX     =    UPPER LEVEL OF DAILY RIVER DIVERSIONS IN CFS-DAYS
C                       AT WHICH DAILY SEEPAGE LOSSES EQUAL 100% OF THE
C                       BASE SEEPAGE RATE, TOTSEP
C       DIVRED     =    DIVERSION REDUCTION FACTOR,  %
C       FRMEFF     =    AVERAGE FARM IRRIGATION APPLICATION EFFICIENCY, %
C       GDUSAG     =    NET DISTRICT WATER USE (TOTAL INFLOW - TOTAL RETURN
C                       FLOW)
C       JRF        =    NUMBER OF WASTEWAYS IN THIS DISTRICT
C       JCROP      =    NO. OF DIFFERENT CROPS GROWN IN THIS DISTRICT
C       JMONTH     =    NUMBER OF MONTHS IN THIS IRRIGATION SEASON
C       JBMNTT     =    NUMBER OF BI-MONTHLY TIME PERIODS, 15 TO 16 DAYS
C                       IN LENGTH
C       MONTH(I)   =    ANY PARTICULAR MONTH(I):  WHERE(I) IDENTIFIES A
C                       PARTICULAR MONTH
C       NUMDD      =    NUMBER OF DAYS OF DIVERSION IN THIS TIME PERIOD,
C                       (15 OR 16)
```

```
C      RETFLW(I,J)   ACCUMULATIVE RETURN FLOW IN ACREFEET FOR EACH "J"
C                    WASTEWAY. AT THE END OF TIME PERIOD "I".
C      RNUMOD     =  NUMOD, CONVERSION TO FLOATING POINT MODE
C      RINFLW     =  SUPPLEMENTARY INFLOW TO DISTRICT THAT IS ADDED TO
C                    THE RIVER DIVERSION TO OBTAIN TOTAL DISTRICT INFLOW
C                    IN AF.
C      TDC        =  NUMBER OF DAYS IN BI-MONTHLY TIME PERIOD
C      TDM        =  NUMBER OF DAYS PER MONTH
C      TOVEFF     =  AVERAGE TOTAL IRRIGATION EFFICIENCY BASED UPON TOTAL
C                    DISTRICT INFLOW. %
C      TOTLOS     =  TOTAL CANAL SEEPAGE LOSSES IN AF FOR THIS TIME
C                    PERIOD  (NUMOD DAYS)
C      TINFLW     =  TOTAL INFLOW TO IRRIGATION DISTRICT
C      TOTRTF     =  TOTAL ACTUAL RETURN FLOW IN AC-FT.
C      TOTCON(I)  =  TOTAL CROP CONSUMPTIVE IRRIGATION REQUIREMENT FOR
C                    TIME PERIOD = I
C      TOTFLW     =  ACCUMULATED RETURNFLOW OF ALL WASTEWAYS IN THIS
C                    DISTRICT IN ACRE-FEET, FOR ONE TIME STEP
C      TOTSEP     =  BASE DAILY SEEPAGE RATE IN AF/DAY FOR THIS
C                    DISTRICT (COMPUTED FROM THE SEEPAGE PROGRAM), FOR
C                    THE ENTIRE CANAL AND LATERAL DISRIBUTION SYSTEM
C      YRRTF      =  TOTAL ANNUAL RETURNFLOW FOR THIS DISTRICT , IN AF.
C      YRDIV      =  TOTAL ANNUAL RIVER DIVERSION IN AF.
C      YRCON      =  TOTAL ANNUAL CONSUMPTIVE IRRIGATION REQUIREMENT,AF.
C      YRINFL     =  TOTAL ANNUAL DISTRICT INFLOW, AF.
C      YRSEP      =  TOTAL ANNUAL DISTRICT  SEEPAGE LOSSES, AF.
C      YRDEP      =  TOTAL ANNUAL DISTRICT DEEP PERCOLATION LOSSES, AF.
C      YRGDUS     =  TOTAL ANNUAL DISTRICT GROSS WATER USE, AF.
C      WASTE      =  MEASURED RETURN FLOW IN A TIME PERIOD FOR A WASTE-
C                    WAY IN AC-FT.
C
C
C      ----------------------------------------------------------------------
C
C
       INTEGER DISTNO
       DIMENSION CROP(20),DAYDIV(50),ACCROP(20)
```

```
      DIMENSION CONSUM(50,50),CRPCON(10,12),TOTCON(50),DATE(10)
      DIMENSION RECORD(20),MONTH(12,4),RETFLW(30,30)
      M1=5
      M2=6
C                         <----------------------------READ CARD--------------
C     READ FIRST DATA CARD
C
15    READ(M1,16,END=300,ERR=410)DISTNO,DISTAC,DATE
      TOTRTF = 0.0
      YRRTF=0.0
      YRINFL=0.0
      YRCON=0.0
      YRSEP=0.0
      YRDIV=0.0
      YRDEP=0.0
      YRGDUS=0.0
C
C                         <----------------------------READ CARD--------------
C     READ CROP DISTRIBUTION DATA
20    READ(M1,21,ERR=410)JCROP,(CROP(J),J=1,JCROP)
C
C     COMPUTE INDIVIDUAL CROP ACREAGES (ACCROP(I), AND PRINT OUT CROP
C     DISTRIBUTIONS BY PERCENTAGE AND BY ACRES.
C
18    WRITE(M2,19)DATE,DISTNO,DISTAC
C
23    WRITE(M2,24)
C
      DO 40 J=1,JCROP
40    ACCROP(J)=CROP(J)*DISTAC*.01
C
C     PRINT OUT CROP DISTRIBUTION DATA
C
25    WRITE(M2,26)(CROP(J),J=1,JCROP)
27    WRITE(M2,28)(ACCROP(J),J=1,JCROP)
C
C     COMPUTE CONSUMPTIVE USE FOR EACH CROP FOR EACH TIME PERIOD
```

```
C
100   WRITE(M2,101)
C                         <-----------------------READ CARD-------------
C     READ NUMBER OF MONTHS IN THE IRRIGATION SEASON
C
90    READ(M1,91)JMONTH
      JBIMNT=2*JMONTH
      DO 92 I=1,50
92    TOTCON(I)=0.0
      DO 111 I=1,JBIMNT
C
C                         <-----------------------READ CARD-------------
C
C     READ BI-MONTHLY PERIOD DATE, NUMBER OF DAYS IN TIME PERIOD, NUMBER
C     OF DAYS IN MONTH, CROP CONSUMPTIVE IRRIGATION REQUIREMENT
C
105   READ(M1,106,ERR=410,END=408)(MONTH(I,K),K=1,4),TDD,TDM,
     1(CONSUM(J,I),J=1,JCROP)
      DO 110 J=1,JCROP
      CRPCON(J,I)=((CONSUM(J,I)*ACCROP(J)*TDD)/(TDM*12.))
110   TOTCON(I)=TOTCON(I)+CRPCON(J,I)
111   WRITE(M2,112)(MONTH(I,K),K=1,4),(CONSUM(J,I),J=1,JCROP)
C
C
95    WRITE(M2,96)
      DO 113 I=1,JBIMNT
113   WRITE(M2,114)(MONTH(I,K),K=1,4),(CRPCON(J,I),J=1,JCROP)
C
C                         <-----------------------READ CARD-------------
C     READ COEFFICIENT OF RETURN FLOW
C
33    READ(M1,34,ERR=410,END=408)COFRTF
      JBIM=JBIMNT+1
      DO 35 I=1,JBIM
C
C                         <-----------------------READ CARD-------------
C     READ NUMBER OF RETURN FLOW WASTEWAYS, ACCUMULATIVE RETURN FLOW
```

```
C     READINGS
C
35    READ(M1,36,ERR=410)JRF,(RETFLW(I,J),J=1,JRF)
C
240   WRITE(M2,241)DISTNO,DISTAC
C
C                           <-----------------------READ CARD--------------
C
C     READ IN MAXIMUM AND THE 40% LEVEL RIVER DIVERSIONS, BASE DAILY
C     SEEPAGE RATE, AND THE DIVERSION REDUCTION FACTOR.  RIVER DIVERSION
C     LEVELS ARE IN CFS-DAYS, BASE SEEPAGE RATE IS IN AF/DAY, AND THE
C     DIVERSION REDUCTION FACTOR IS IN %.  (REDUCTION IN DIVERSION = 0,
C     WHEN DIVRED = 100.00)
C
41    READ(M1,42,ERR=410)DIVMAX,DIVMIN,TOTSEP,DIVRED
63    DO 242 I=1,JBIMNT
      TOTLOS=0.0
      TOTDIV=0.0
      WASTE = 0.0
      TOTFLW=0.0
68    DO 55 J=1,JRF
C
C     SUM RETURNFLOW MEASUREMENTS
C
53    WASTE=RETFLW(I+1,J)-(RETFLW(I,J))
55    TOTFLW=TOTFLW+WASTE
      IF (TOTFLW.GT.0) GO TO 65
64    TOTRTF=0.0
      GO TO 56
65    CONTINUE
57    TOTRTF=TOTFLW/COFRTF
56    CONTINUE
C
C                           <-----------------------READ CARD--------------
C     READ IN DAILY RIVER DIVERSION
C
30    READ(M1,31,ERR=410)NUMDD,(DAYDIV(J),J=1,NUMDD)
```

```
C
C                        <----------------------READ CARD-------------
C
C     READ IN SUPPLEMENTARY INFLOW FOR THIS TIME PERIOD
66    READ(M1,67,ERR=410)RINFLW
C
C     COMPUTE TOTAL INFLOW OR DIVERSIONS TO DISTRICT FOR THIS TIME
C     PERIOD
C
      DO 50 J=1,NUMDD
      TOTDIV=TOTDIV+DAYDIV(J)
      IF (DAYDIV(J).EQ.0) GO TO 46
      IF (DAYDIV(J).GT.DIVMIN)GO TO 43
C
C
C     SEEPAGE IS CALCULATED AS 50% OF THE BASE DAILY SEEPAGE RATE
C     WHEN THE 40% LEVEL OF DIVERSION EXCEEDS THE DAILY DIVERSION.
C     WHEN THE MINIMUM DAILY DIVERSION IS EXCEEDED THE SEEPAGE IS PRO-
C     RATED FROM 50% TO 100% OF THE MAXIMUM SEEPAGE RATE (STATEMENT #43)
C
C
      DAYSEP=(0.50*TOTSEP)
      GO TO 44
43    DAYSEP=(0.50 + ((DAYDIV(J)-DIVMIN)/(DIVMAX-DIVMIN)*0.50))*TOTSEP
44    CONTINUE
45    TOTLOS=TOTLOS + DAYSEP
      GO TO 50
46    DAYSEP=0.0
47    TOTLOS=TOTLOS+DAYSEP
50    CONTINUE
C
C     CONVERT TOTDIV TO ACREFEET
C
51    TOTDIV = TOTDIV*1.984*(DIVPER/100.)
C
C     COMPUTE NET   DISTRICT USAGE (DIVERSIONS -.RETURNFLOWS), TOTAL
C     SEEPAGE LOSSES, DEEP PERCOLATION, DISTRICT EFFICIENCY, AND FARM
```

```
C      IRRIGATION EFFICIENCY FOR THIS TIME PERIOD
C
       TINFLW=TOTDIV+RINFLW
       IF (TOTDIV.EQ.0) GO TO 71
70     GO TO 75
71     TINFLW = 0.01
75     CONTINUE
       GDUSAG=TINFLW-TOTRTF
       DEPERC=GDUSAG-(TOTCON(I)+TOTLOS)
       DISEFF=((TINFLW-(TOTRTF+TOTLOS))/TINFLW)*100.
       FRMEFF=(TOTCON(I)/(GDUSAG-TOTLOS))*100.0
       TOVEFF=(TOTCON(I)/TINFLW)*100.0
       YRRTF=YRRTF+TOTRTF
       YRDIV=YRDIV+TOTDIV
       YRCON=YRCON+TOTCON(I)
       YRINFL=YRINFL+TINFLW
       YRSEP=YRSEP+TOTLOS
       YRDEP=YRDEP+DEPERC
       YRGDUS=YRGDUS+GDUSAG
C
242    WRITE(M2,243)(MONTH(I,K),K=1,4),TOTDIV,RINFLW,TINFLW,TOTCON(I),
      1DEPERC,TOTLOS,TOTRTF,GDUSAG,DISEFF,FRMEFF,TOVEFF
C
C      PRINT OUT SEEPAGE VARIABLES AND COEFFICIENTS
245    WRITE(M2,246)DIVMAX,DIVMIN,COFRTF,TOTSEP,DIVRED
C
C
C      COMPUTE AVERAGE ANNUAL (YEARLY) VALUES
C
       AVANRF=YRRTF/DISTAC
       AVANDV=YRDIV/DISTAC
       AVANCR = YRCON/DISTAC
       AVANIF=YRINFL/DISTAC
       AVANPR=(YRRTF/YRINFL)*100.0
       AVANSP=YRSEP/DISTAC
       AVANDP=YRDEP/DISTAC
       AVANGU=YRGDUS/DISTAC
```

```
      AVANDE=((YRINFL-(YRRTF+YRSEP))/YRINFL)*100.
      AVANFE=(YRCON/(YRGDUS-YRSEP))*100.
      AVANOE=(YRCON/YRINFL)*100.0
C
260   WRITE(M2,261)YRRTF,YRDIV,YRINFL,YRCON,YRSEP,YRDEP,YRGDUS,AVANRF
C
C
264   WRITE(M2,265)AVANDV,AVANCR,AVANIF,AVANSP
C
262   WRITE(M2,263)AVANOP,AVANGU,AVANDR,AVANDE,AVANFE,AVANOE
C
C
C     ERROR DIRECTORY OUTPUT SCHEME
C
C
      GO TO 250
408   BACKSPACE M1
410   BACKSPACE M1
412   READ(M1,415)RECORD
416   WRITE(M2,417)RECORD
C
C                             <----------------------READ CARD-------------
250   READ(M1,251)IMEND
C
      IF(IMEND.EQ.999)GO TO 15
C
C     IF A NEW DISTRICT FOLLOWS,  IMEND = 999,  THEN GO TO PROGRAM START
C
      IF(IMEND.EQ.888)GO TO 300
C
C     IF NO NEW DISTRICT FOLLOWS,  IMEND = 888,  GO TO THE END
C
16    FORMAT(T3,I2,T11,F6.0,T20,10A4)
21    FORMAT(I2,T6,10F5.2)
C
19    FORMAT(1H1,//////,T39,'WATER  BALANCE  ANALYSIS  OF  THE  IRRIGATI
     1ON  DISTRICT',/,T39,55('_'),//////,T15,'STARTING AND ENDING DATES
```

```
     1FOR THIS TIME PERIOD:',T85.10A4,///,T15,'IRRIGATION DISTRICT IDENT
     1IFICATION  NUMBER          =',T37,I2,///,T15,'TOTAL IRRIGATED ACREAG
     1E  WITHIN THIS DISTRICT       =',T85,F7.0)
C
24    FORMAT(1H1,///,1X,125('*'),////,T36,'C R O P     D I S T R I B U T
     1 I O N     T A B L E     N O .    1',/,T36,64('_'),/,
     1//,T36,                              'FIRST LINE OF FIGURE
     1S ARE UNITS OF PERCENT OF TOTAL DISTRICT ACREAGE',/,T36,'NEXT LINE
     1 OF FIGURES ARE ACRES',////,1X,'SUGAR',T14,'DRY ,T25,'CORN',T37,
     1'SPRING',T50,'WINTER',T62,'POTATOES',T76,'SMALL',T91,'ALFALFA',
     1T105,'GRASS',T118,'ORCHARDS',/,1X,'BEETS',T14,'BEANS',T25,'SILAGE'
     1,T37,'GRAIN',T50,'GRAIN',T76,'VEGETABLES',T105,'PASTURE',/,
     1132('_'))
C
26    FORMAT(//,1X,F5.2,T14,F5.2,T25,F5.2,T37,F5.2,T50,F5.2,T64,F5.2,
     1T76,F5.2,T91,F5.2,T105,F5.2,T118,F5.2)
C
28    FORMAT(////,F6.0,T13,F6.0,T25,F6.0,T37,F6.0,T50,F6.0,T64,F6.0,
     1T76,F6.0,T91,F6.0,T105,F6.0,T118,F6.0)
C
101   FORMAT(1H1,T32,'C R O P    C O N S U M P T I V E    U S E    T A B
     1 L E    N O .    2',/,T32,71('_'),/,
     1//,T32,                          'FIGURES SHOW MONTHLY CONSUMPTI
     1VE IRRIGATION REQUIREMENTS IN INCHES',/,T32,'AND BI-MONTHLY CONSUM
     1PTIVE USE IN ACREFEET FOR THE DISTRICT',/,T32,'BELOW BROKEN LINE
     1FOR EACH CROP GROWN',//,T21,'SUGAR',T31,'DRY',T40,'CORN',
     1T50,'SPRING',T62,'WINTER',T72,'POTATOES',T85,'SMALL',T98,
     1'ALFALFA',T111,'GRASS',T123,'ORCHARDS'
     1,/,T21,'BEETS',T31,'BEANS',T40,'SILAGE',T50,'GRAIN',T62,'GRAIN',
     1T85,'VEGETABLES',T111,'PASTURE',/,132('_'),/,T2,'(MONTH)',2X,
     1'(DAYS)')
C
91    FORMAT(I2)
106   FORMAT(4A4,T17,F2.0,F2.0,T21,10F5.2)
C
112   FORMAT(/,1X,4A4,T21,F5.2,T31,F5.2,T40,F5.2,T50,F5.2,T62,F5.2,
     1T74,F5.2,T85,F5.2,T98,F5.2,T111,F5.2,T123,F5.2)
```

```
76    FORMAT(/,43('  -'),1H1,/)
114   FORMAT(1X,4A4,T20,F7.1,T30,F7.1,T39,F7.1,T49,F7.1,T61,F7.1,
     1T73,F7.1,T84,F7.1,T97,F7.1,T110,F7.1,T122,F7.1,/)
34    FORMAT(F4.2)
36    FORMAT(I2,T11,6F10.0,/,6F10.0,/,6F10.0)
C
241   FORMAT(1H1,///,T40,'S U M M A R Y     T A B L E     N O .     3',
     1/,T40,43('_'),
     1//,T40,'IRRIGATION DISTRICT IDENTIFICATION NUMBER',5X,'---',I2,'--
     1-',/,T40,'IRRIGATED ACREAGE IN THIS DISTRICT',11X,F7.0,///,
     1T40,'TOTAL',T49,'TOTAL',T62,'AVERAGE',T75,'DISTRIBUTION',T96,
     1'NET  ',/,T31,'SUPPLE-',T40,'INFLOW',T49,'CONSUMPTIVE',T62,'DEEP',
     1T75,'SYSTEM',T84,'TOTAL',T96,'DISTRICT',T107,'DISTRICT',T118,
     1'FARM',T126,'PROJECT',/,T2,'TIME',T20,'RIVER',T31,'MENTARY',T40,
     1'(SUPL.+',T49,'IRRIGATION',T62,'PERCOLATION',T75,'SEEPAGE',T84,
     1'DISTRICT',T96,'WATERUSE',T107,'CONVEYANCE',T118,'IRRIG.',T126,
     1'IRRIG.',/,T2,'PERIOD',T20,'DIVERSION',T31,'INFLOW',T40,'RIVDV.)',
     1T49,'REQUIREMENT',T62,'LOSSES',T75,'LOSSES',T84,'RETURNFLOW',T96,
     1'(TINF-RET)',T107,'EFFICIENCY',T118,'EFFIC.',T126,'EFFIC.',/,
     1T2,'(MON.)',T20,'(AC-FT)',T31,'(AC-FT)',T40,'(AC-FT)',T49,'(AC-FT)
     1',T62,'(AC-FT)',T75,'(AC-FT)',T84,'(AC-FT)',T96,'(AC-FT)',T107,
     1'(%)',T118,'(%)',T126,'(%)',/,132('_'),//)
C
42    FORMAT(F10.0,F10.0,F10.0,F10.2)
31    FORMAT(I2,T11,6F10.0,/,T11,6F10.0,/,T11,6F10.0)
67    FORMAT(T12,F9.0)
C
243   FORMAT(T2,4A4,T20,F7.0,T29,F7.0,T40,F7.0,T51,F7.1,T62,F8.1,T74,
     1F7.1,T85,F7.1,T96,F7.0,T107,F6.2,T117,F6.2,T128,F5.2,/)
  246 FORMAT(//,132('_'),///,T40,'RIVER  DIVERSION LEVELS, COEFFICIENT O
     1F RETURNFLOW, AND MAXIMUM SEEPAGE RATE:',//,T40,'MAXIMUM SEASONAL
     1RIVER DIVERSION (CFS)   =',T95,F6.0,/,T40,'RIVER  DIVERSION AT 50%
     1SEEPAGE LOSS RATE (CFS)   =',T95,F6.0,/,T40,'COEFFICIENT OF RETURNF
     1LOW  (%)   =',T99,F4.2,/,T40,'MAXIMUM INPUT SEEPAGE RATE (AF/DAY)
     1=',T95,F6.0,///,T40,'DIVERSION REDUCTION FACTOR  (%) =',T93,F8.2)
261   FORMAT(1H1,///,T40,'S U M M A R Y     T A B L E     N O .     4',
     1/,T40,43('_'),///,
```

```
     1T10,'TOTAL  ANNUAL  RETURNFLOW',T67,'(AC-FT)',T80,F7.0,/,
     1T10,'TOTAL  ANNUAL  RIVER  DIVERSION',T67,'(AC-FT)',T79,F8.0,/,
     1T10,'TOTAL  ANNUAL  INFLOW  (DIVERSIONS + SUPPLEMENTARY)',
     1 T67,'(AC-FT)',T79,F8.0,/,
     1T10,'TOTAL  ANNUAL  CONSUMPTIVE  IRRIGATION  REQUIREMENT',
     1T67,'(AC-FT)',T80,F7.0,/,
     1T10,'TOTAL  ANNUAL  SYSTEM  SEEPAGE  LOSSES',T67,'(AC-FT)',T80,
     1F7.0,/,
     1T10,'TOTAL  ANNUAL  DEEP  PERCOLATION  LOSSES',T67,'(AC-FT)',T80,
     1F7.0,/,
     1T10,'TOTAL  ANNUAL  NET  DISTRICT  WATERUSE',T67,'(AC-FT)',T80,
     1F7.0,//,
     1T10,'AVERAGE  ANNUAL  RETURNFLOW  PER  ACRE',T67,'(AF/AC)',T90,
     1F4.2,/)
265   FORMAT(T10,'AVERAGE  ANNUAL  RIVER  DIVERSION  PER  ACRE',T67,
     1'(AF/AC)',T89,F5.2,/,
     1T10,'AVERAGE  ANNUAL  CONSUMPTIVE  IRRIGATION  REQUIREMENT',
     1T67,'(AF/AC)',T90,F4.2,/,
     1T10,'AVERAGE  ANNUAL  TOTAL  INFLOW  TO  DISTRICT  PER  ACRE',
     1T67,'(AF/AC)',T89,F5.2,/,
     1T10,'AVERAGE  ANNUAL  SEEPAGE  LOSSES  PER  ACRE',T67,'(AF/AC)',
     1T90,F4.2,/)
263   FORMAT(T10,'AVERAGE  ANNUAL  DEEP  PERCOLATION  LOSSES  PER  ACRE'
     1,T67,'(AF/AC)',T88,F6.2,/,
     1T10,'AVERAGE  ANNUAL  NET DISTRICT WATER USE  PER  ACRE',T67,'(AF/
     1AC)',T89,F5.2,/,
     1T10,'AVERAGE  ANNUAL  DISTRICT  RETURNFLOW  FRACTION',T67,'(%)',
     1T89,F5.2,/,
     1T10,'AVERAGE  ANNUAL  DISTRICT  CONVEYANCE  EFFICIENCY',T67,'(%)',
     1T89,F5.2,/,
```

```
     1T10,'AVERAGE  ANNUAL  FARM  IRRIGATION  EFFICIENCY',T67,'(%)',T88,
     1F6.2,/,
     1 T10,'AVERAGE  ANNUAL  PROJECT  IRRIGATION  EFFICIENCY',T67,'(%)'
     1,T89,F5.2)
415   FORMAT(20A4)
417   FORMAT(1H1,'XXXXXXXXXX    ERROR   IN   RECORD    ',///,1H1,20A4)
251   FORMAT(I3)
      DEBUG SUBCHK
300   STOP
      END
```

```
 01       151368   APRIL 15  TO  OCTOBER 15, 1974                     1
10     394 2194  481 1407 1133  578    0 2480 1333    0               2
06                                                                    3
APRIL      15-30 1530   13    0    6   14   74    2    0   44   33    0    4
MAY         1-15 1531   81   23   40  229  277   85    0  185  196    0    5
MAY        15-31 1631   81   23   40  229  277   85    0  185  196    0    6
JUNE        1-15 1530  314  332  227  590  643  415    0  495  409    0    7
JUNE       15-30 1530  314  332  227  590  643  415    0  495  409    0    8
JULY        1-15 1531  723  746  641  475  781  905    0  746  635    0    9
JULY       15-31 1631  723  746  641  475  781  905    0  746  635    0   10
AUGUST      1-15 1531  704  453  608   15  280  722    0  603  467    0   11
AUGUST     15-31 1631  704  453  608   15  280  722    0  603  467  . 0   12
SEPTEMBER   1-15 1530  326    6  167    0    0    0    0  271  121    0 . 13
SEPTEMBER  15-30 1530  326    6  167    0    0    0    0  271  121    0   14
OCTOBER     1-15 1531   64    0    0    0    0    0    0   55    0    0   15
  90                                                                  16
12                  0          0          0          0        238          0   17
           0        0          0          0          0          0              18

12                 74         93        199         66        782        539   19
         282     2181        221         11        210         35              20

12                271        352        398        159       1031       1335   21
         586     4532        536        440        606         93              22

12                588       1058        542        305       1530       2391   23
         939     6350        799        709        924        236              24

12                928       1622        626        387       2008       3759   25
        1280     8227        985       1020       1284        404              26

12               1133       2206        815        432       2261       4859   27
        1500     9597       1078       1347       1526 [illegible]01              28

12               1413       2939        870        433       2366       5507   29
        1722    10329       1131       1797       1704        553              30
```

12		1713	3879	929	450	2582	6164	31
	1963	11203	1199	2068	1951	646		32
12		1963	4783	1039	475	3152	6681	33
	2183	12131	1315	2499	2461	741		34
12		2179	5541	1142	536	3942	7376	35
	2479	13184	1452	2872	2920	845		36
12		2569	6175	1307	639	4637	8173	37
	2703	14721	1604	3312	3287	915		38
12		2964	6701	1480	787	5611	9019	39
	2928	16311	1886	3672	3749	963		40
12		3310	6882	1574	937	6411	10140	41
	3005	17784	2296	3877	4162	1013		42
	3950	1580	2386	10000				43
16		701	944	1050	1080	1110	1285	44
		1473	1694	1773	1768	1759	1779	45
		1800	1889	1975	1984			46
		-2637						47
15		2254	2446	2830	3100	3167	3164	48
		3167	3177	3182	3263	3353	3257	49
		3317	3313	3327				50
		-4810						51
16		3343	3320	3340	3343	3330	3355	52
		3338	3328	3335	3331	3331	3421	53
		3495	3565	3630	3640			54
		-8416						55
15		3630	2734	3614	3610	3577	3626	56
		3623	3616	3532	3486	3475	3459	57
		3455	3462	3535				58
		-3920						59
15		3565	3673	3636	3636	3648	3663	60
		3658	3651	3628	3715	3778	3775	61

	3770	3753	3777				62
	-9237						63
15	3820	3820	3910	3864	3864	3857	64
	3899	3873	3843	3869	3925	3908	65
	3902	3924	3940				66
	-7761						67
16	3950	3943	3924	3875	3858	3876	68
	3901	3921	3922	3917	3927	3937	69
	3757	3734	3851	3851			70
	-8075						71
15	3824	3839	3825	3806	3807	3762	72
	3751	.3701	3683	3670	3664	3592	73
	3529	3543	3547				74
	-7182						75
16	3547	3534	3524	3498	3508	3548	76
	3515	3399	3352	3338	3278	3248	77
	3248	3251	3241	3228			78
	-7688						79
15	3237	3240	3240	3217	3210	3153	80
	3136	3110	3110	3110	3072	3032	81
	2940	2824	2788				82
	-8095						83
15	2638	2571	2511	2381	2338	2255	84
	2195	2255	2303	2299	2269	2253	85
	2335	2338	2198				86
	-7573						87
15	2151	2071	2023	1956	1852	1783	88
	1779	1876	1913	1140	1050	1050	89
	950	900	850				895
	-5149						90
999							91

Appendix G

Canal Seepage Program With Examples of a Sample Input Data File and Sample Program Output

```
C     ***********************************************************************
C     *                                                                     *
C     *                                                                     *
C     *    .............................................                   *
C     *    .                                           .                   *
C     *    .   C A N A L   S E E P A G E   P R O G R A M   .                *
C     *    .                                           .                   *
C     *    .............................................                   *
C     *                                                                     *
C     *                                                                     *
C     * THIS PROGRAM WILL CALCULATE CANAL SEEPAGE LOSSES FROM THE FOLLO    *
C     * ING DATA:   TOWNSHIP NO.,  TWN                                      *
C     *             RANGE NO.,  RAN                                         *
C     *             SECTION NO.,  SEC                                       *
C     *             SEEPAGE COEFFICIENT,  FT/DAY,  SPC                      *
C     *             LENGTH OF CANAL REACH, (SCALE:  8"  =  5280'),  SCL     *
C     *             TOPWIDTH, (SCALE:  1.0 =25'),X(N),  WHERE N IS > 5      *
C     *                                                                     *
C     * VARIABLE:      DEFINITION:                                          *
C     * ACRLEN  -      ACCUMULATIVE REACH LENGTHS FOR EACH CHANNEL, MILES   *
C     * ACSEEP  -      ACCUMULATIVE SEEPAGE LOSS  FOR  EACH CHANNEL, AC-FT  *
C     * AVG     -      AVERAGE TOPWIDTH OF THE WATER SURFACE BETWEEN TWO    *
C     *                CONSECUTIVE REACH MEASUREMENTS                       *
C     * LINENO  -      ACCUMULATIVE DO-LOOP COUNTER                         *
C     * NAMCAN  -      NAME OF CANAL OR LATERAL                             *
C     * NAMDST  -      IRRIGATION DISTRICT NUMBER                           *
C     * PAN     -      RANGE NUMBER AND DIRECTION CODE NUMBER               *
C     * RLEN    -      REACH LENGTH, FEET                                   *
C     * D       -      NUMBER OF CROSS-SECTIONAL MEASUREMENTS PER SQUARE    *
C     *                MILE SECTION                                         *
C     * SEEP    -      SEEPAGE LOSS, IN ACREFEET PER DAY, FOR A REACH       *
C     * SEC     -      SECTION NUMBER  AND DIRECTION CODE NUMBER            *
C     * SPC     -      SEEPAGE COEFFICIENT,CFD, OR FT/DAY                   *
C     * SCL     -      CALIBRATED LENGTH OF CHANNEL PER SQUARE MILE SECTION *
C     *                IN TENTHS OF INCHES                                  *
C     * WPA     -      WETTED AREA OF A REACH, SQ. FT.                      *
C     * TC      -      TOPWIDTH COEFFICIENT                                 *
```

```
C    * TOTLEN  -     TOTAL LENGTH IN MILES OF ALL CHANNELS IN A DISTRICT    *
C    * TOTSEP  -     TOTAL SEEPAGE LOSS IN ACREFEET PER DAY OF ALL CHAN-    *
C    *               NELS IN A DISTRICT                                      *
C    * TWN     -     TOWNSHIP NUMBER AND DIRECTION CODE NUMBER               *
C    * TOTWPA  -     TOTAL WETTED AREA IN SQ.FT. FOR ALL CHANNELS IN A
C    *               DISTRICT                                                *
C    * X(N)    -     UN-FORMATTED INPUT VARIABLE FOR DATA                    *
C    *                                                                       *
C    *                                                                       *
C    ************************************************************************
      DIMENSION X(50),NAMDST(50),NAMCAN(35)
      INTEGER TWN,RAN,SEC
      LINENO=0
    3 CONTINUE
      TOTLEN=0.00
    4 TOTWPA = 0.0
      TOTSEP=0.0
   16 WRITE(6,18)
C                              <----------------------READ CARD-------------
   14 READ(5,13)NAMDST
   12 WRITE(6,15)NAMDST
C
   17 WRITE(6,19)
   25 CONTINUE
      ACRLEN=0.0
       ACSEEP=0.0
C                              <----------------------READ CARD-------------
   22 READ(5,23)NAMCAN
   27 WRITE(6,28)NAMCAN
C
C
C     X  -  ELEMENT OF THE N-ARRAY
C
C     N  -  NO. OF VALUES ON CARD,
C
C
C                              <----------------------READ CARD-------------
```

```
      CALL INPUT (X,N)
      SAVE=X(6)
      GO TO 51
    6 SAVE=X(N)
    5 CONTINUE
C                        <----------------------READ CARD-------------
      CALL INPUT(X,N)
   51 TWN=X(1)
      RAN=X(2)
      SEC=X(3)
      SPC=X(4)*0.01
      SCL=X(5)
C
C     END OF THIS IRRIGATION DISTRICT
      IF(TWN.EQ.999)GO TO 100
C
   10 NN=(N-2)
      X(5)=SAVE
C
C     END OF CANAL OR LATERAL;  START NEW CANAL
   20 IF(TWN.EQ.99)GO TO 25
C
      NX=(NN+1)
      DO 7 I=5,NX
C
C     END OF DATA;   OPTIONAL
   21 IF(TWN.EQ.95)GO TO 150
C
      AVG=((X(I)+X(I+1))*2.50)*0.5
C
C
C     AVG  =  THE AVERAGE TOPWIDTH OF THE WATER SURFACE, USING TWO
C     CONSECUTIVE REACH MEASUREMENTS
C
C
      IF(AVG.LE.12.5)GO TO 42
      IF(AVG.LE.25.0)GO TO 43
```

```
      IF(AVG.LE.200.)GO TO 44
      IF(AVG.GT.200.)GO TO 45
42    TC=1.3
      GO TO 46
43    TC=1.2
      GO TO 46
44    TC=1.1
      GO TO 46
45    TC=1.05
46    CONTINUE
C
C
C
C     THE PROGRAM USES 4 SEPARATE COEFFICIENTS (1.05,1.10,1.20,1.30) TO
C     CONVERT TOPWIDTH TO WETTED PERIMETER.  CROSS-SECTION TOPWIDTHS ARE
C     AVERAGED CONSECUTIVELY FOR EACH ENTIRE CANAL REACH.
C
C
C
      D=N-5
      IF(D.GT.0.0)GO TO 35
   30 RLEN=(SCL*5280.0)/(80.0)
      GO TO 38
C
C
C     RLEN = REACH LENGTH OF CANAL,FEET
C
C
   35 RLEN=(SCL*5280.0)/(80.0*D)
   38 CONTINUE
C
      WPA=(RLEN*AVG*TC)
C
C
C     WPA = WETTED PERIMETER AREA OF THE REACH OF THE CANAL
C     THE DIVISOR IN THE FOLLOWING SEEPAGE EQUATION ACCOUNTS FOR THE
C     FORMAT OF SPC READ IN WITH ITS DECIMAL DISPLACED 2 POSITIONS
```

```
C     TO THE RIGHT.
C
C
      SEEP=(WPA*SPC)/(43560.)
C
C
C     SEEP = SEEPAGE, IN ACREFEET PER DAY
C
C
      ACRLEN= ACRLEN+(RLEN/5280.)
   39 TOTWPA = TOTWPA + WPA
C
C
C     ACRLEN = ACCUMULATED RLEN IN MILES
C
C
      ACSEEP=(ACSEEP+SEEP)
C
C
C     ACSEEP = ACCUMULATED SEEPAGE
C
C
      LINENO=(LINENO + 1)
      TOTLEN=TOTLEN+(RLEN/5280.)
      TOTSEP=TOTSEP+SEEP
    7 WRITE(6,40)TWN,RAN,SEC,RLEN,AVG,SPC,SEEP,ACRLEN,ACSEEP
      IF(LINENO.LE.65)GO TO 55
   52 WRITE(6,59)
      LINENO=0
      GO TO 6
   55 CONTINUE
C
C
C     TOTSEP = TOTAL SEEPAGE LOSSES FOR THE ENTIRE DISTRICT
C
C
      GO TO 6
```

```
100 WRITE(6,65)TOTSEP,TOTLEN,TOTWPA
    LINENO=0
    GO TO 3
150 CONTINUE
 18 FORMAT(1H1,40X,'C A N A L     S E E P A G E      A N A L Y S I S',
   1////,48X,'DIRECTION  COORDINATES:',4X,'1 - NORTH',/,
   175X,'2 - EAST',/,75X,'3 - SOUTH',/,75X,'4 - WEST')
 13 FORMAT(5X,50A1)
 15 FORMAT(//,1X,132('*'),//,55X,50A1,//,1X,132('*'),//)
 19 FORMAT(1X,'TOWNSHIP',T18,'RANGE',T32,'SECTION',T48,'REACH',
   1T62,'AVE.',T75,'REACH',T89,'REACH',T115,'ACCUMULATED',/,1X,
   1T3,'(NO.)',T18,'(NO.)',T33,'(NO.)',T48,'LENGTH',T62,'REACH',
   1T75,'SEEPAGE',T89,'SEEPAGE',T112,'REACH',T122,'SEEPAGE',/,1X,
   1T48,'(FEET)',T62,'WIDTH',T75,'COEFF.',T89,'LOSSES',T112,'LENGTH',
   1T122,'LOSSES',/,1X,T62,'(FEET)',T75,'(FT/DAY)',T89,'(AF/DAY)',
   1T112,'(MILES)',T122,'(AF/DAY)',/,132('_'),//)
 23 FORMAT(5X,35A1)
 28 FORMAT(/,4X,35A1)
 40 FORMAT(T4,I3,T19,I3,T35,I2,T48,F5.0,T62,F6.1,T77,F4.2,T90,F6.2,
   1T112,F5.2,T122,F7.2)
 59 FORMAT('1','TOWNSHIP',T18,'RANGE',T32,'SECTION',T48,'REACH',
   1T62,'AVE.',T75,'REACH',T89,'REACH',T115,'ACCUMULATED',/,1X,
   1T3,'(NO.)',T18,'(NO.)',T33,'(NO.)',T48,'LENGTH',T62,'REACH',
   1T75,'SEEPAGE',T89,'SEEPAGE',T112,'REACH',T122,'SEEPAGE',/,1X,
   1T48,'(FEET)', T62,'WIDTH',T75,'COEFF.',T89,'LOSSES',T112,'LENGTH',
   1T122,'LOSSES',/,1X,T62,'(FEET)',T75,'(FT/DAY)',T89,'(AF/DAY)',
   1T112,'(MILES)',T122,'(AF/DAY)',/,132('_'),//)
 65 FORMAT(/////////,5X,'TOTAL DISTRICT CANAL SEEPAGE LOSSES   (AF/DAY)
   1        =',F16.2,//,5X,'TOTAL LENGTH OF ALL  CHANNELS   (MILES)
   1  =',T69,F7.2,//,
   15X,'TOTAL WETTED AREA OF ALL CHANNELS  (SQ.FT.)  =',T64,F12.0)
    STOP
    END
```

198

```
IBM204I  'ONCODE'=0084  'UNDEFINEDFILE' CONDITION RAISED
  NO DD STATEMENT ('ONFILE'= CARDS)
  IN STATEMENT 9 AT OFFSET +000156 IN PROCEDURE WITH ENTRY PAGLST
```