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9. ABSTRACT
This doctoral dissertation demonstrates that large water losses through evaporation can be reduced by compartmentalizing shallow impervious reservoirs and in flat terrain concentrating water by pumping ti from one compartment to another. This method reduces the surface-area-to-water-volume ratio to a minimum, thus decreasing evaporation losses by reducing both termperature and exposure of the water to the atmosphere. There is a need for low cost, efficient water storage in semi-arid and arid lands. An examination of storage reservoirs in Arizona, northern Mexico and West Africa revealed the average depth at less than the average annual water evaporation rate. This report includes a discussion of the potential of the compartmental reservoir, a literature review, a description of the compartmental reservoir optimization program (CROP-76), a demonstration of the compartmental reservoir using the CROP-76 model, detailed appendices on pumping methods, required embankment materials, and the Fortran IV listing of CROP-76, and many illustrative tables and figures. It is concluded that the rate of increase of efficiency of storage decreases as the number of compartments increase; there was no significant difference in evaporation loss by varying the relative size of compartments provided the side slope depth, total number of compartments and the total combined volume remained constant; the increase in efficiency due to the use of the compartmented system decreases as the depth of the reservoir increases, becoming insignificant for depths of 20 or more meters; and the use of a compartmented reservoir provides efficient storage for a water harvesting agri-system. The evaporation savings as determined by CROP-76 are based on a reduction of surface area only. There should also be a significant reduction by decreasing the temperature by increasing the average depth.

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DISSERTATION

THE COMPARTMENTED RESERVOIR: A METHOD OF EFFICIENT WATER STORAGE

Submitted by

Carwin Brent Cluff

In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

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ABSTRACT OF DISSERTATION

THE COMPARTMENTED RESERVOIR: A METHOD OF EFFICIENT WATER STORAGE

The compartmented reservoir is introduced as an efficient method of storing water in areas having a relatively flat terrain where there is a significant water loss through evaporation. The flat terrain makes it difficult to avoid large surface-area-to-water-volume ratios when using a conventional reservoir.

This study demonstrates that large water losses through evaporation can be reduced by compartmentalizing shallow impervious reservoirs and in flat terrain concentrating water by pumping it from one compartment to another. Concentrating the water reduces the surface-area-to-water-volume ratio to a minimum, thus decreasing evaporation losses by reducing both the temperature and exposure of the water to the atmosphere. Portable, high-capacity pumps make the method economical for small reservoirs as well as for relatively large reservoirs. Further, the amount of water available for beneficial consumption is usually more than the amount of water pumped for concentration.

A Compartmented Reservoir Optimization Program (CROP-76) was developed for selecting the optimal design configuration. The program was utilized in designing several systems. Through the use of the model, the interrelationship of the parameters have been eludicated. These parameters are volume, area, depth, and slope of the embankment around each compartment. These parameters interface with the parameters describing rainfall and hydrologic characteristics of the watershed.

The water-yield model used in CROP-76 requires inputs of watershed area, daily precipitation, daily and maximum depletion. In addition, three sets of seasonal modifying coefficients are required either through calibration or estimated by an experienced hydrologist. The model can determine runoff from two types of watersheds, a natural and/or treated catchment. Additional inputs of CROP-76 are the surface water evaporation rate and the amount and type of consumptive use.

Because of the large number of parameters it was found that repeated runs of the model are necessary to determine a near optimum design in a reasonable amount of time. The model computation time for the CDC 6400 computer for a 45 years length of record is less than ten seconds per run for the usual design. Usually no more than four or five computer runs were needed for design purposes. CROP-76 was used on several typical systems including a water harvesting agrisystem. The following general observations were made: (1) The rate of increase of efficiency of storage decreases as the number of compartments increase; (2) there was no significant difference in evaporation loss by varying the relative size of compartments provided the side slope, depth, total number of compartments and the total combined volume remained constant; (3) the increase in efficiency due to the use of the compartmented system decreases as the depth of the reservoir increases, becoming insignificant for depths of 20 or more meters; and (4) the use of a compartmented reservoir provides efficient storage for a water harvesting agrisystem.

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LIST OF SYMBOLS

af	Acre-feet.
A	Area of the watershed.
AB	Area of the bottom of the reservoir.
AS	Water surface area of the reservoir.
AWAP	Area of the planted portion of the water harvesting agrisystem.
CDC	Control Data Corporation.
C.R.	Compartmented reservoir.
CROP-76	Compartmented reservoir optimization program developed in 1976.
C.U.	Consumptive use.
d	Depth of reservoir.
d_A	Depth of compartment A.
D	A selected daily watershed depletion.
E	Evaporation loss.
ET	Cumulative evaporation loss from the compartmented reservoir system.
ft	Foot.
F	The fetch of water surface in miles.
H	Wave height in feet.
IW	Weekly counter.
km	Kilometer.
km^2	Square kilometer.
K_1, K_2	Constants in the "runon" equation.

L	A maximum upper limit on the total depletion.
m	Meter.
m^2	Square meters.
m^3	Cubic meters.
mcm	Million cubic meters.
mm	Millimeter.
mo	Month.
M	The runoff modifier that is a function of P_d.
NRTM	Number of layers of soil used for storage in the water harvesting agrisystem.
P_d	Daily precipitation.
Q	Daily runoff.
QTWW	Weekly runoff total from the water harvesting carchment.
r	Correlation coefficient.
RCROSS	Y-axis intercept of the root function.
RSLOPE	Rate of root growth of plants in the water harvesting agrisystem.
RUNON	Amount of runoff going into the soil below the planted area in the water harvesting agrisystem.
S	Side slope of the embankment.
S_D	A seasonal modifier of D.
S_L	A seasonal modifier of L.
S_M	A seasonal modifier of M.
Δt	Time in days between rainfall events.
tcm	Thousand cubic meters.
T	Wind duration in hours.
U	Effective wind velocity.

V	Water volume in a reservoir.
V_A	Water volume in compartment A.
V_T	Remaining water volume in the compartmented reservoir system.
$	United States dollar sign.

CHAPTER 1

INTRODUCTION

The need for a low-cost, efficient method of water storage in semi-arid and arid lands has long been recognized. The high evaporation loss coupled with flat terrain has prevented economical water storage except in rare instances where favorable reservoir sites are available. These favorable sites in most parts of the world have been utilized but the demand for water is far from satisfied and will continue to increase in the future.

Importance of Improved Storage of Water

The importance of improved water storage can be verified easily by aerial flights over dry areas prior to the onset of the rainy season. These flights reveal that most small storage reservoirs are dry or close to it. An examination of many of these reservoirs by the author in Arizona and northern Mexico, as well as West Africa, has revealed that the average depth generally is less than the average annual water evaporation rate. This condition prevents withdrawal of water on a constant-rate basis and any chance of carry-over storage from one year to the next.

The importance of constructing deep reservoirs has long been known but there are several constraints which normally have prevented the construction of deep reservoirs. These are:

1. The grade of the bed of the contributing stream. Any conventional storage must be below the bed.

2. Shallow soils. These make excavation difficult.
3. Construction equipment. The equipment has constraints which restricts the depth.
4. Seepage control. This becomes more difficult in deeper reservoirs.
5. Erosion control on the steep banks. The problem increases with deeper reservoirs.
6. Safety constraint. Unless excavated, deeper reservoirs pose more danger to downstream occupants than shallow reservoirs.
7. Financial constraints. Deep reservoirs usually cost more money per unit-volume of storage than shallow reservoirs.

The dozer tractor commonly is used for constructing small reservoirs. The deeper a dozer excavates into the ground the greater is the unit cost. It has been the author's experience, when using a 1:2 embankment slope, that building a reservoir deeper than six meters is very expensive. This six-meter depth is usually accomplished with a three-meter cut combined with a three-meter embankment. Due to the constraint imposed by the grade of the stream the upper bank generally serves no useful purpose other than as a spoil area; hence, the effective depth is three meters or less.

The efficiency of storage is defined as the percent of water going into storage that is available for a desired beneficial use on a fixed demand basis. This efficiency can be increased by reducing evaporation loss. As indicated in the literature review in the next section, some research has been done on evaporation control which indicates that the costs of such control in general are prohibitive for use in some major applications such as conventional agriculture.

This study shows the advantages of controlling evaporation loss through the use of the compartmented reservoir. Using this system, the surface area to depth ratio is reduced by keeping the water concentrated. The increase in average depth reduces the amount of solar energy input into the reservoir as well as the exposure to the atmosphere thus reducing evaporation loss.

Figure 1-1 illustrates a three-compartmented reservoir. The tank consists of a receiving compartment which is called A. This compartment is located below the stream grade and therefore is usually shallow. Compartments B and C are shown as being smaller in surface area but deeper in depth. This reservoir is operated as follows: As runoff occurs during the rainy season, water is pumped from compartment A to fill compartments B and C. Water is first withdrawn for consumptive use from compartment A until the evaporation and seepage losses from B and C are equal to the remaining water in A. At this time, the pump is used to move the remaining water in A to fill the unused capacity of B and C. This eliminates further evaporation and seepage losses from A. Water is then withdrawn as needed for consumptive use from B until the water remaining in B is equal to the unused capacity in C. At this time, the pump is used again to move the remaining water from B into C. This eliminates further evaporation and seepage losses from B. At this point, C is filled and A and B are empty. A spillway would be needed from compartment A to protect the safety of the system. All inner dikes would have to be built higher than the maximum water level determined by the elevation of the spillway.

The compartmented reservoir concept can be applied to existing reservoirs or new ones. Since a pump will be used in flat terrain, all

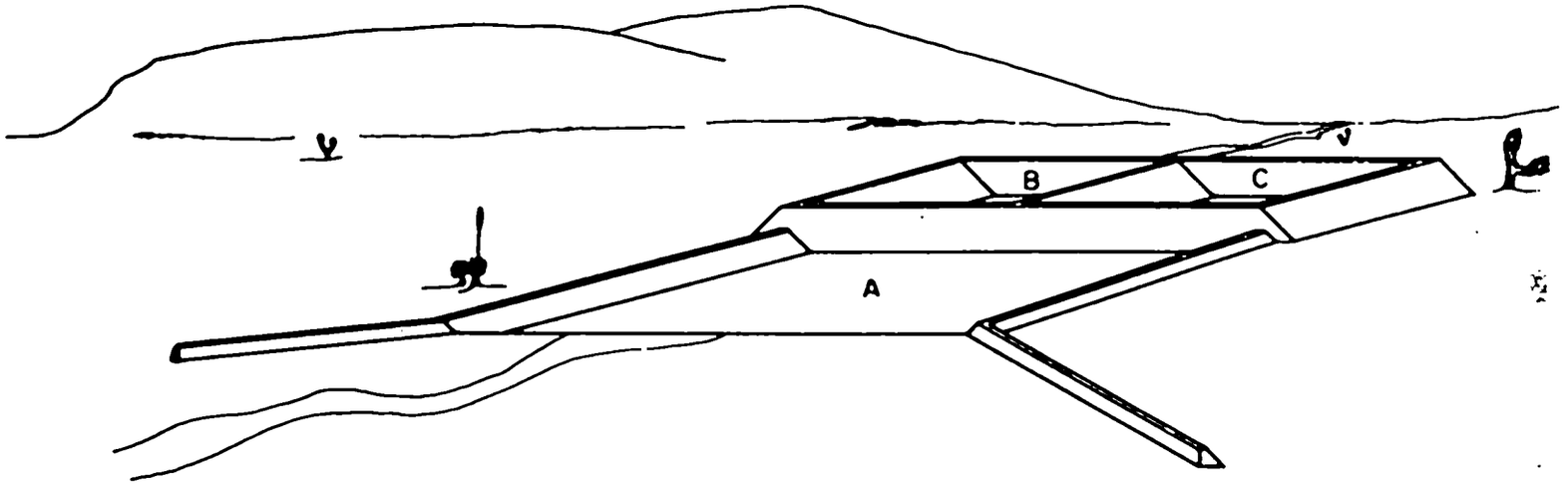

Figure I-1. A Schematic Drawing of the Compartmented Reservoir.

compartments other than the receiving compartment can be made deeper by building the embankments above the stream grade.

The recent development of portable, low-lift, high-capacity, tractor-operated pumps makes the compartmented reservoir system economically attractive. These pumps are available in capacities of up to 5000 cubic meters per hour. One pump can service several small reservoirs. These pumps, as well as other pumping schemes, are described in more detail in Appendix A.

If the general slope of the topography is greater than three or four percent, the concept of a gravity-fed compartmented reservoir can be used. The compartments of this reservoir are separated by a sufficient distance to develop enough hydraulic head so that one compartment can be completely drained by a gravity pipeline or an elevated canal into the second and succeeding compartments. This reservoir system could be operated as before but without a pump.

Surface storage reservoirs in semiarid regions are usually fed by intermittent flood flows. However, in some cases, there may be a base flow going into compartment A. In this case, the base flow would be used to satisfy consumptive demands. The remainder, if any, could be pumped into storage on a continuous basis.

The Potential of the Compartmented Reservoir

The potential of the compartmented reservoir can be demonstrated in a series of figures using idealized conditions.

Figure 1-2 illustrates the use of compartments of equal sizes in a reservoir of depth equal to the evaporation loss. The reservoir is assumed to be filled by runoff only once a year, with no additional

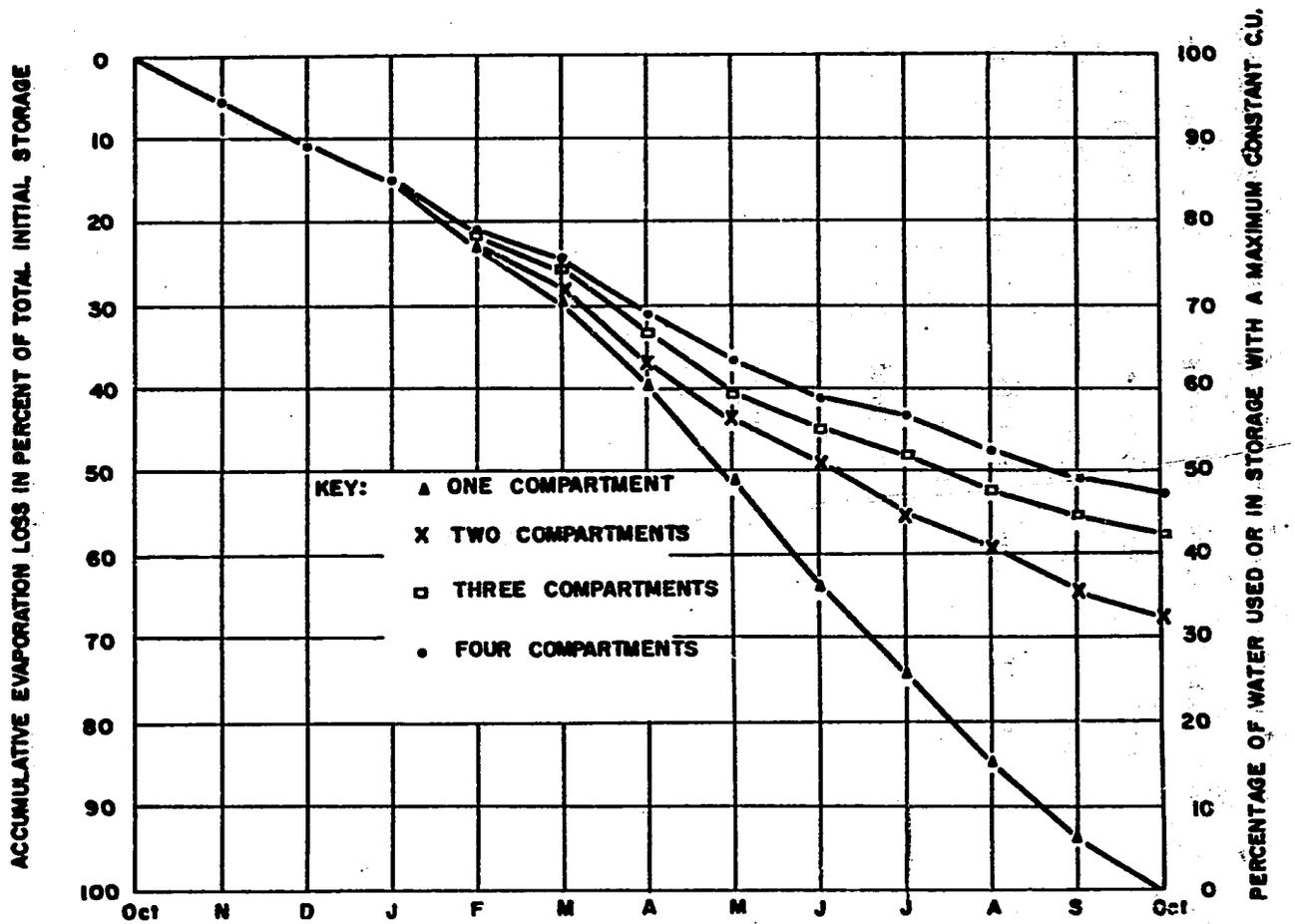

Figure I-2. Evaporation Loss for Compartmented (but undeepened) Reservoirs with a Constant Volume and Area, a Maximum Constant Consumptive Use and a Depth Equal to Annual Evaporation Loss.

input. In this figure and other figures in this chapter, an annual evaporation depth (ΣE) of 1.636 meter (m) is used. This is the average reservoir evaporation for Parras, Coahuilla, Mexico, and is close to the evaporation loss in Tucson, Arizona. A constant consumptive use that would be withdrawn each month is selected so that there would be no water remaining in the reservoir at the end of the year. This value is determined by trial and error. It is called the maximum constant consumptive use. For the single compartment (the typical reservoir), this consumptive use value is zero. When the depth of the reservoir is equivalent to the annual evaporation loss, it is impossible to withdraw any water on a continuous basis since all the water would be consumed by evaporation.

Using two compartments, the efficiency of utilization is increased by 32.6 percent. With three compartments, 42.5 percent of the water initially stored can be beneficially used. For the four-compartmented reservoir, 47.4 percent can be used on a continuous basis.

Figure 1-3 indicates the evaporation savings obtained by using deeper compartments. As indicated earlier, this can be done utilizing the storage created by the excavated material since the constraint of gravity flow has been removed through use of the low-head pump.

In this figure, the total volume was kept constant as well as the volume of each compartment. The depth of compartments B and C was doubled so that it is twice the evaporation loss, ($2\Sigma E$) in one curve and quadrupled to $4\Sigma E$ in another.

The ΣE used in this and the other figures was 1.636 m. The $2\Sigma E$ and $4\Sigma E$ depths correspond to 3.272 m and 6.544 m, respectively. As

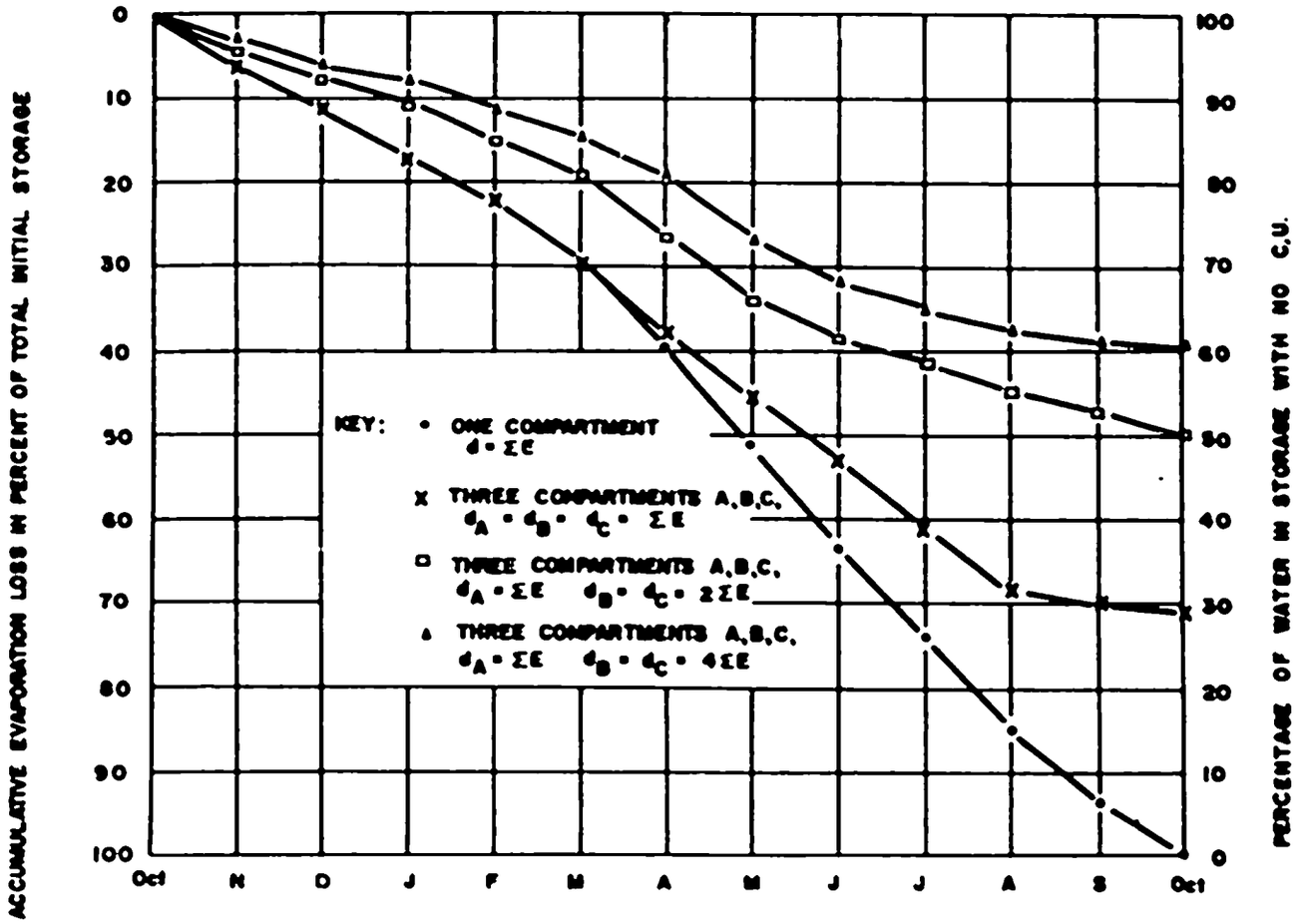

Figure I-3. Evaporation Loss for Compartmented Reservoirs with a Constant Volume and Varying Depth with no Consumptive Use.

indicated earlier, the six-meter depth can be rather easily obtained if an embankment is used for the upper three meters.

The surface of B and C was reduced to correspond to an increase in depth. Under a no-consumptive-use regimen, 27.8, 50.0 and 61.6 percent of water remains for the reservoirs with compartment depths of ΣE, $2\Sigma E$ and $4\Sigma E$, respectively.

Figure 1-4 illustrates what happens to the same reservoir when maximum consumptive use is applied. Under this method of operation the percent of water available for beneficial consumptive use on a constant basis is 42.5 percent, 67.1 percent and 80.2 percent for the three reservoir systems, respectively. This can be compared with zero percent water available on a constant basis in the single compartment reservoir when the depth is equal to the summation of the evaporation losses.

The above illustrations are idealized in that the reservoirs are filled once a year with no additional input. If seepage is controlled, the same savings would apply regardless of the total size of the reservoir system. It is readily apparent that the compartmented reservoir concept can be applied to reservoirs of all sizes, from small, livestock watering tanks to large reservoirs for agricultural use. See Figure 1-5 for a pictorial illustration of the range in sizes over which compartmented reservoirs will work effectively.

The amount of pumping required in a compartmented reservoir is relatively low compared to the water savings effected. For instance, a three-compartmented reservoir, with all compartments equal in depth to the evaporation loss, requires pumping of 20.8 percent of the initial storage to obtain a 42.5 percent efficiency when used on a constant basis. This amounts to pumping 48.9 percent of the water utilized.

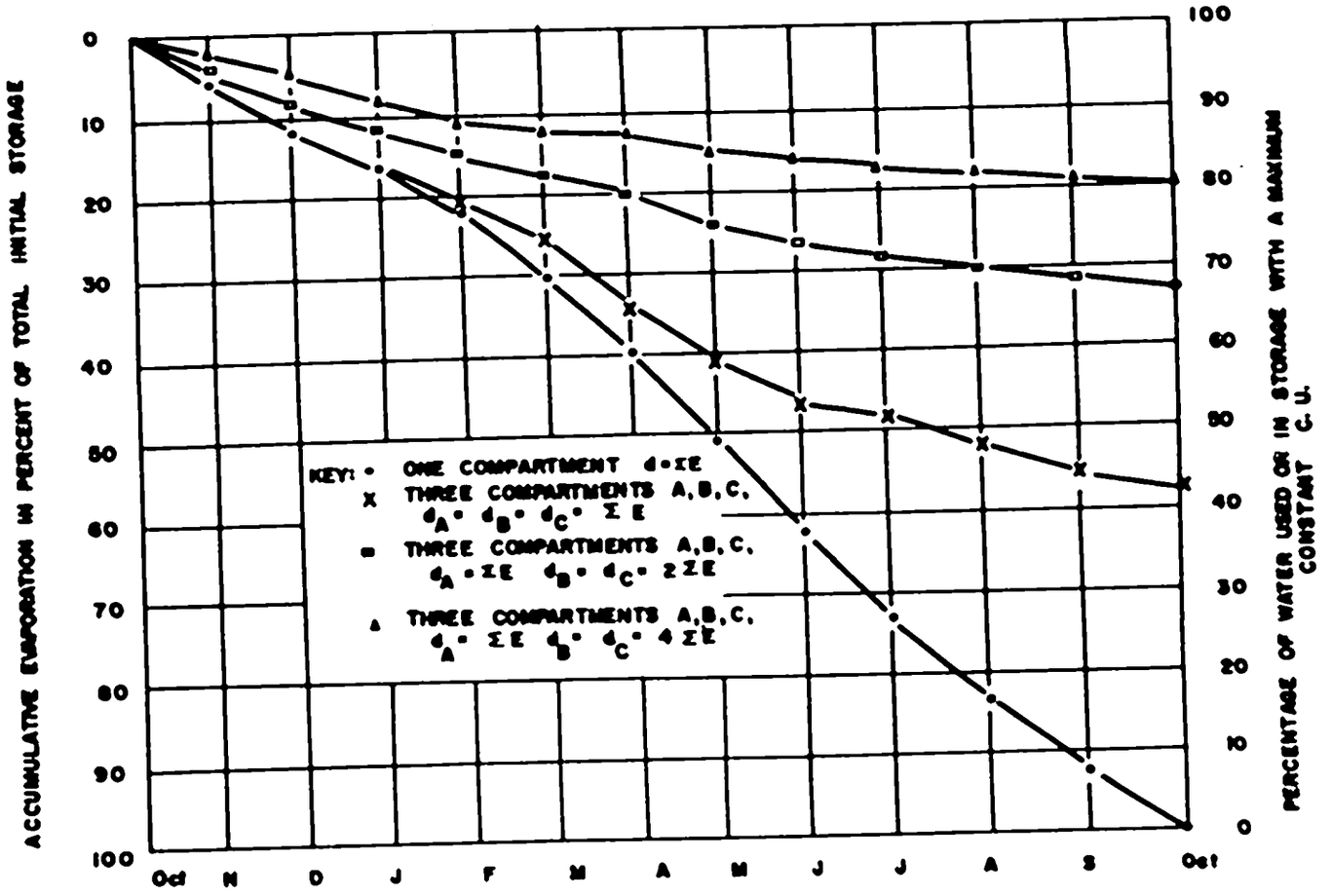

Figure I-4. Evaporation Loss in Percent of Total Initial Storage for Compartmented Reservoirs with a Constant Volume, Varying Depth and a Maximum Constant Consumptive Use.

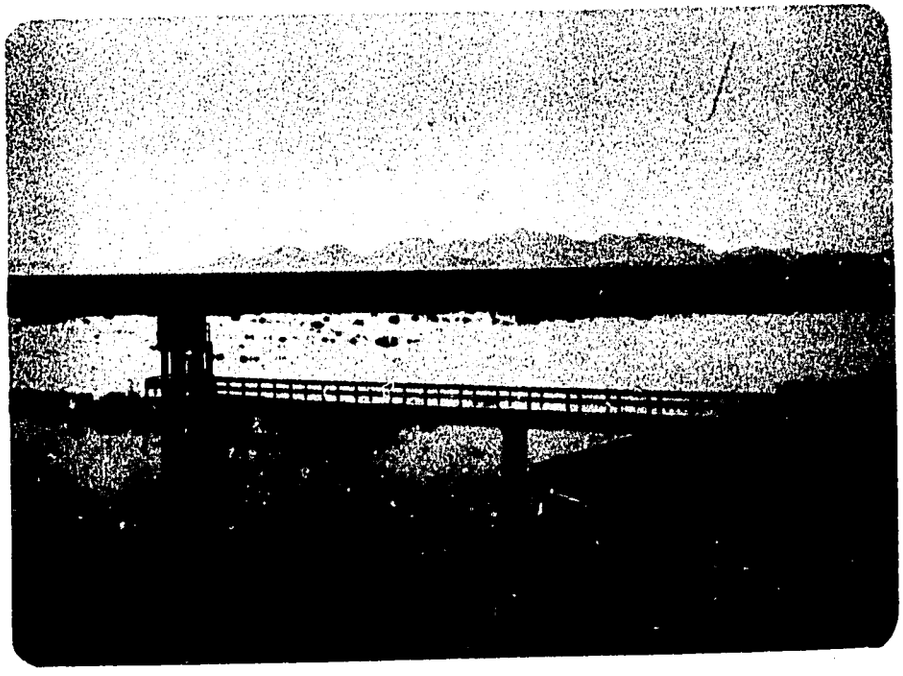

Figure 1-5. Examples on the Papago Indian Reservation, Arizona, of the Size Range of Reservoirs for which a Compartmented Reservoir Is Suited. -- Above: Stock Tank in January. Below: Multipurpose Reservoir on Santa Rosa Wash.

This pumping is all low-lift and costs much less than the average cost of pumping ground water. Table 1-1 contains the dates of pumping and amounts for this and the other types of compartmented reservoirs that are illustrated in Figures 1-3 and 1-4.

The concept of the compartmented reservoir was conceived by the author in the summer of 1975 while serving as a consultant in the Sahel Region of Mali in West Africa. The concept evolved as an attempt to help solve a critical water storage problem. Ten different sites were surveyed and recommended designs were made using a small programmable calculator (Cluff, 1975). Following his return from Africa, the author spent six months in Mexico working for the Food and Agricultural Organization (FAO) of the United Nations (Cluff, 1976) in support of the Fundo Candelillero, an action agency of the Mexican Government. Eleven compartmented reservoirs were built by the above agencies in the state of Coahuilla, Mexico, during the six-month period the author served as a consultant. More have been built since that time. These reservoirs range in size from a 8100 m^3 two-compartmented livestock reservoir dug by mules, to a 200,000 m^3 four-compartmented reservoir constructed using D-7 dozers. This largest reservoir which is used for agricultural purposes is shown in Figure 1-6. One small gravity-fed separated compartmented reservoir also was constructed.

The use of the compartmented reservoirs introduces additional design parameters for effectively using and storing water from any given watershed. The number of compartments and their depth and size relative to each other must be considered in order to maximize production of water from any given watershed. These parameters are a function of the seepage and evaporation losses. However, in this study it is assumed

Table 1-1. Compartmented Reservoir Pumping Schedule[1]. -- Constant initial volume.

Type of Tank	Water Available for Use[2]		Dates of Pumping		Amount of Water Pumped	
	No C.U.[3]	Max. C.U.[4]	No C.U.	Max. C.U.	No. C.U.	Max. C.U.
One Compartment ($d = \Sigma E$)	0.0	0.0	-	-	0.0	0.0
Three Compartments A, B, C ($d_A = d_B = d_C = \Sigma E$)	27.8	42.5	Mar. 12 July 28	Jan. 19 May 2	22.2 16.6 38.8	13.6 7.2 20.8
Three Compartments A, B, C ($d_A = \Sigma E$, $d_B = d_C = 2\Sigma E$)	50.0	67.1	Initial[5] April 27	Initial[5] Jan. 18 May 13	33.3 16.7 - 50.0	33.3 6.7 6.1 46.1
Three Compartments A, B, C ($d_A = \Sigma E$, $d_B = d_C = 4\Sigma E$)	61.1	80.2	Initial[5] June 9	Initial[5] Jan. 16 May 18	50.0 11.1 - 61.1	50.0 3.3 4.8 58.1

[1]Based on a 1.6 m annual evaporation loss.
[2]Percent of initial storage.
[3]No water withdrawn for consumptive use (C.U.) during the year. Percentage indicates the water available for use at the end of the year (see Figure 1-3).
[4]Water used at a constant rate so there was no water left in the reservoir at the end of the year. Percentage indicates the total amount of water withdrawn at a constant rate (see Figure 1-4).
[5]Initial pumping is the amount of water required to fill the storage above the depth of compartment A.

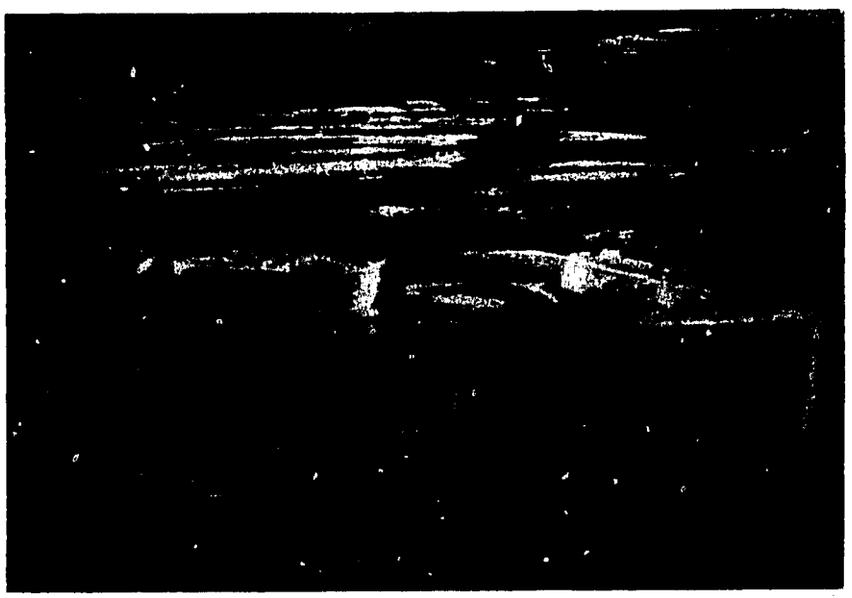

Figure 1-6. Four Compartmented Reservoir System near Parras, Coahuilla, Mexico, with a 200,000 m^3 Capacity. -- Above: Under Construction. Below: Completed System.

that seepage is controlled, thus eliminating it as a parameter to be considered. The use of a floating cover in conjunction with the compartmented reservoir is explored.

The objective of this study was to develop a computer model to study the parameters involved in the compartmented system and their relationship to each other using historical data. This model is described in Chapter 3 with examples of its use in three different climatic regions given in Chapter 4.

CHAPTER 2

LITERATURE REVIEW

This review includes literature about evaporation and seepage as well as about reservoir embankment design and construction. The literature about hydrologic models is briefly reviewed in addition to that which has been written in the area of water harvesting system in general and water harvesting agrisystems in particular. The review of the latter subject is included since a water harvesting agrisystem example was used in conjunction with a compartmented reservoir in this study.

Evaporation and Its Control

The major function of the compartmented reservoir is to reduce water losses through evaporation. These losses in the United States range up to 2.0 m along the lower Colorado River (Kohler et al., 1959) but go over 2.0 m per year in many parts of the world, as is the case in some parts of the Sahel Region of West Africa (Thomas and Whittington, 1970; UNESCO, 1971).

A study conducted by the staff of Senate Committee on Interior and Insular Affairs summarizes the need for evaporation control with the statement: "In the future large quantities of water will have to be stored at relatively shallow depths and up to the present this has meant that high evaporation losses have been unavoidable" (Eaton, 1958).

For evaporation to occur there must be a source of energy to vaporize the water. In addition, there must be a transfer mechanism, a greater vapor pressure at the water surface compared to that of the air

above. The evaporation process is accelerated by wind. The various methods of evaporation control reported by Veihmeyer (1964) are:

1. Surface-area reduction.
   a. Constructing reservoirs with a minimum ratio of area to storage volume.
   b. Storing water "in one large reservoir instead of several small ones."
   c. Proper selection of reservoir sites.
2. Mechanical covers. (Roofs, floating rafts and windbreaks.)
3. Surface films. (Oil and long-chain fatty alcohols.)

On first reading, item 1b could be interpreted as the direct opposite of the compartmented reservoir concept. However, Veihmeyer bases his summary in part on an article by Beadle and Cruse (1957) in which "concentration of water into single reservoirs" is said to be a method of retarding evaporation. Another method listed by Beadle and Cruse is "elimination of shallow water areas." The compartmented reservoir concept provides a systematic method of concentrating water, thus eliminating shallow water areas. The other reference used by Veihmeyer is Freese (1956) who also stresses concentration of water and indicates that this might be done by selecting a good site. Freese gives an example of the operation of three reservoirs in Abilene, Texas, where the water was concentrated in a lower lake. In essence, this is a gravity-fed separated-compartmented reservoir system described in Chapter 1. Freese also gives an example of the savings that could result in filling in the shallow areas of a lake near Fort Worth, Texas. He determines that saving water worth \$0.05/1000 gallons (\$0.19/m^3) would justify filling in the shallow areas in the lake up to a depth of

3.22 feet (0.98 m) even though the fill would cost $0.25 per cubic yard ($0.33/m^3). Fort Worth is in a four-foot (1220 mm) net annual evaporation area.

Garstka (1962) indicated that elimination of the shallow areas by diking may result in greater evaporation savings than that indicated by a comparison of the ratio of the water surface due to temperature reduction of the water.

To the above list by Veihmeyer should be added a fourth category of energy-reducing treatments such as coloring the water, shading by suspended materials and floating reflective barriers such as perlite, that may or may not be a vapor barrier. Cooley (1970, 1973) did considerable research in this area. In a joint research program Cooley and Cluff (1972) determined that while lighter than water initially, floating perlite does become saturated over a period of time and loses its buoyancy, rendering the method impractical.

Surface films formed by long-chain alcohols received considerable attention during the late 1950s and early 1960s. The research was sponsored and coordinated by the U.S. Bureau of Reclamation (Garstka, 1962). Several Land Grant Universities were involved: Colorado State (Hayes, 1959), Arizona (Cluff, 1966), Utah State (Israelson and Hansen, 1963), Oklahoma State (Crow, 1961) and Texas Tech (Meinke and Waldrip, 1958-63). The U.S. Geological Survey also conducted experiments (Cruse and Harbeck, 1960). During these studies, the use of alcohol to prevent evaporation was perfected to the point where it could be used in several physical formulations in conjunction with various methods of application including use of airplanes. However, due to wind problems, the unit cost of achieving evaporation control greatly increases as the residual

time of the film on the reservoir decreases. The residual time is dependent on the length of the reservoir in the direction of the prevailing winds.

In summary, the system is more economical on large reservoirs than on small ones but to date the cost exceeds the value of the water saved. No commercial applications of alcohol are being made at the present time. For smaller reservoirs, floating covers appear to have more potential (Cluff, 1966).

Many floating-cover methods such as polyethylene sheets (Drew, 1972), concrete slabs made with lightweight aggregate (Eng. News Record, 1966) and floating edged-sheets of expanded polystyrene (Cluff, 1967) have been tried and abandoned. A previously unreported test by the author consists of placing crushed expanded polystyrene as a reflective barrier. Evaporation savings were about 50 percent for one month, but a heavy wind completely overturned the film and caused it to become wetted. This caused evaporation savings to drop to 10 percent, making the approach impractical.

Among the leading floating-cover methods are use of wax blocks (Cooley, 1975), foamed butyl rubber (Dedrick et al., 1973) and weatherized sheets of expanded polystyrene coupled together to form a continuous raft (Cluff, 1972). A more expensive method is a polyfoam-supported rubber cover described by Dallaire (1975). The latter method recently has been used by some U.S. municipalities instead of the more conventional roofed reservoir.

These leading methods are all too expensive for conventional irrigated agriculture (Cooley, 1974). However, the overall cost is significantly reduced if the cover is used on only a portion of the reservoir

in conjunction with the compartmented system. The cover is first placed on the "last" compartment, the one containing water most of the time. Other compartments are covered if higher water storage efficiency is needed.

Seepage and Its Control

Seepage constitutes an inevitable loss to a water-storage system in shallow reservoirs overlying alluvial soil unless an effective method of control is used. Bouwer (1969) states that seepage is dependent on many factors affecting the hydraulic properties of the soil, including water chemistry, which cause change in the hydraulic conductivity with time. He further indicates that the hydraulic conductivity also is affected by the air content of the soil as well as the soil temperature, the depth of water in the reservoir and the barometric pressure.

Seepage from an earth-lined reservoir over an alluvial soil in an arid environment fits Bouwer's (1969) description of a channel with a clogged soil at its perimeter. In this case the underlying soil is unsaturated and the flow according to Sposito (1975) is controlled by the negative soil-water pressure in the underlying drier material. Sposito finds that the depth of water in a shallow reservoir may not have much effect on the seepage particularly if a swelling-clay liner is used. The effect of the swelling offsets the gravity forces, leaving the soil pressure in the underlying unsaturated material as the controlling factor in seepage. This finding indicates that in applying the concept of the compartmented reservoir system to an earth-lined reservoir there should be a reduction in seepage loss due to concentrating the water and reducing the area contributing to seepage. According to

Sposito's findings in shallow reservoirs this reduction should be greater than the increase in seepage caused by increasing the depth in the compartment to which water is being pumped. This may not be the case in situations where the flow is fully saturated (Hunt, 1973).

There are several articles concerning seepage control but those identified by the author are not very explicit with regard to cost, effectiveness and serviceability. Most articles are written with a limited objective. There seems to be none available documenting the effectiveness of seepage barriers in reservoirs over a long period of time. Some of this type of documentation is available for aqueducts in the Bureau of Reclamation's lower cost canal lining program (Wilson, 1965).

An article by Boyer and Cluff (1972), updated to some extent by Dedrick (1975) and Frobel and Cluff (1977), also lists the materials available for use in seepage control. These articles summarize most of the techniques currently used in seepage control. The methods currently used include the use of sodium salts, primarily sodium chloride or sodium carbonate (Reginato et al., 1968; Boyer and Cluff, 1972). The sodium disperses the clay and thereby provides a seal. Wetting and compaction helps speed up this dispersion process. It also helps to reduce clay migration noted by Cluff et al. (1972). This migration proves to be a real problem in soils with a low clay content when sodium is used without compaction for waterproofing to form water harvesting catchments. In reservoir construction this same phenomena contributes to a sodium-caused piping that has contributed to dam failures in some areas (Sherard et al., 1974). For the non-dispersive soil there is a definite threshold velocity below which flowing water causes no erosion.

For dispersive clay, according to Sherard et al. (1974), there is no threshold velocity; the colloidal clay particles go into suspension even in quiet water.

Bentonite clay also has been used as a sealant for many years (Rollins and Dylla, 1970; Dirmeyer, 1959). The bentonite works best when there is already a substantial amount of clay in the soil. Soil cement can be used for sandier soils (Portland Cement Assoc., 1958).

In recent years there has been an accelerated use of synthetic membranes: polyethylene, vinyl and rubber. Lauritzen (1966) was one of the first researchers in the 1950s to investigate installation procedures for these materials. Polyethylene plastic is the cheapest, followed by vinyl, with rubber products being the most expensive. The most popular rubber product at present is reinforced hypylon sheeting because of its economy and ease in field seaming (Frobel and Cluff, 1977). Membranes, especially the plastics, should be covered with a soil ballast to protect them from mechanical damage in addition to reducing the seepage loss should a rupture in the film occur (Boyer and Cluff, 1972). One type of cover investigated at the University of Arizona is a thin layer of wire-reinforced mortar. This type of cover can be less than one inch in thickness. The use of the mortar makes it possible to protect plastic when it is placed against steep slopes. The mortar serves primarily to protect the plastic which provides the seepage barrier (Cluff et al., 1972). This is particularly important in constructing smaller compartmented reservoirs.

The final method reviewed is the use of reinforced asphalt linings. These can be either reinforced with fiberglass or plastic sheeting. This method is cost-competitive with polyethylene and/or vinyl liners

particularly if an asphalt dispersing truck is available (Frobel and Cluff, 1976).

Embankment Design and Construction

With respect to dam design and construction, the literature review is restricted to earth and rock-filled dams since these are the types primarily used for small reservoirs in flat terrain where the compartmented tank is most appropriate.

The use of laboratory soil tests for design and control of reservoirs was instituted by the City of Los Angeles, Bureau of Water Works and Supply as described by R. R. Proctor in the "Engineering News Record," beginning in August 1933. The Bureau of Reclamation started its soils laboratory in the fall of the same year (Ruettgers and Blanks, 1936).

Most large earth and rock-filled dams now are constructed only after extensive soil testing. However, smaller reservoirs are built with limited or no soil testing. The Bureau of Reclamation (1973) and U.S. Army Corps of Engineers (1970) have published guidelines for the construction of small dams. These publications stress the importance of soil testing and soil moisture control during compaction.

Uginchus (1966) presents a study on seepage through earth dams. He developed a method of accounting for seepage going through a dam with a tailrace. This method approximates the dividing dike between two compartments. Seepage through earth dams also is covered in a design manual of the U.S. Army Corps of Engineers (1952).

Sowers (1962) discusses the effects of sudden drawdown in which the seepage pattern in the upstream half of the embankment is reversed. The

upstream slopes become surfaces of zero pressures and water seeps in both directions from the embankment. Sowers indicates that, depending on the amount of water retained by capillarity in the voids, loss of only a small quantity of water by seepage may be necessary to substantially lower the seepage line. In clays and silts the seepage discharge is usually insignificant and so the position of the line of seepage moves more rapidly than would be supposed from their low permeability coefficient and seepage velocity. A sudden rise in water levels will cause the opposite effect. The effect of water loading on embankment deformations also was studied by Carter et al. (1974). They found that larger horizontal movements are developed when seepage occurred than when an impermeable membrane existed on the upstream face.

The sudden filling or drawdown is a routine occurrence in the compartmented system and must be considered in every design. An impermeable reservoir lining with stabilized banks may be necessary in unstable soils.

The primary considerations for embankment design as given by Sowers (1960) are:

1. Character of site.
    a. Topography.
    b. Foundation conditions.
    c. Material for embankment construction.
2. Construction program.
    a. Equipment and methods available.
    b. Weather.
    c. Inflow, seepage and consumptive demand.
    d. Finance.

3. Costs and benefits.

4. Safety against failure.

The basic structural element of the compartmented reservoir is the earthen or rock-filled embankment. The height of this embankment can be reduced in a design where the embankment materials are obtained from the reservoir site (see Appendix B).

The amount of freeboard required in all compartments except the receiving compartment is primarily a function of the wave height. The wave height as given by Parker (1971) is estimated from the following empirical relationship:

$$H = 0.313\ F^{0.423}\ U^{1.154}$$

$$T = 2.45\ F^{0.778}\ U^{0.556}$$

where H = the effective wave height in feet,

F = the fetch in miles,

U = the effective wind velocity in miles per hour,

T = the wind duration in hours.

Water Harvesting

One of the promising ways of increasing both the quantity and dependability of water in arid and semiarid lands is through water harvesting. This term has had many definitions but for the purposes of this research project it is defined as the artificial treatment of soil to increase the water yield. The water thus produced is captured as surface runoff and stored or put to beneficial use before it is evaporated. The combination of a water harvesting catchment and reservoir is called a water harvesting system (Cluff et al., 1972). A summary of the then current methods used in water harvesting is given in the Proceedings

of the Water Harvesting Symposium held in Phoenix in March of 1974. A summary prepared by some of the participants of the symposium is given in a National Academy of Sciences Report (1974). This report and an article by Cluff and Dutt (1975) gives the leading methods as being:

1. Land Alteration (clearing, shaping and compaction).
2. Chemical Treatment (sodium salts, silicones).
3. Soil Cementation (wax, reinforced asphalt, in situ membranes).
4. Soil Covers (gravel-covered plastic sheets, butyl rubber and sheet metal).

The more promising of these methods, listed in order of their cost, are: (1) Shaped compacted-earth (or roaded catchments), (2) shaped compacted-earth sodium-treated, compacted-earth wax-treated, gravel-covered plastic and reinforced asphalt (Frobel and Cluff, 1977; Frasier, 1975; National Academy of Sciences, 1974).

The development of these methods of treatment greatly reduces costs and increases the efficiency and life of the systems. The first two of the above listed methods are inexpensive enough that they are used in conjunction with growing high-value crops. This is particularly true in marginal dryland areas that need only a small amount of additional water to optimize production. An analogy might be made herein to the use of fallowing by the wheat farmer in the great plains. It is estimated by the author that the wheat farmer spends an equivalent of $50 to $60 per acre-foot of water disking his land to provide a mulch. This mulch is needed to store two to three inches of one-year's precipitation to go with the precipitation of the next year, so that a crop can be grown. This process in which a farmer plants every other year is called fallowing. It does not work south of the Texas High Plains because of

the excessive evapotranspiration potential. However, concentration of precipitation through water harvesting has the potential of accomplishing the same purpose for close to the same price with no sacrifice in the net amount of land cropped per year. Furthermore, the system will work in areas where fallowing is impractical.

Hall and Dracup (1970), in reference to Lewis et al. (1969), indicate that far more product per unit of water is possible through the use of concentrated rainwater than through the "relatively inefficient process of streamflow, reservoir, diversion, aqueduct, farm ditch, and irrigation with excess leaching followed by an additional system to dispose of the accumulated salt and drainage water."

The practice of treating watersheds to increase water yield so that crops can be raised is an old one as evidenced by ancient systems in the Negev Desert in Israel (Evenari et al., 1971; National Academy of Sciences, 1974). There is increasing interest and research in this area but the financial resources invested have been regrettably small in view of its potential. The ancient dwellers of the Negev utilized the soil profile to store the somewhat erratic runoff. Due to favorable soil conditions this system seemed to work.

In other semiarid lands with similar rainfall the system does not work as well, with crop failures occurring too frequently for effective commercial agriculture (Fangmeier, 1975; Morin and Matlock, 1975). Morin and Matlock report on the use of a model without surface storage. The use of the model indicates that the distribution of rainfall is more significant than total rainfall after a set minimum amount occurs. This finding supports the thesis that for water harvesting to be successful in most semiarid regions it must be combined with efficient surface

storage. Cluff et al. (1972) and later Dutt and McCreary (1974) report on a one-acre system installed at Page Ranch north of Tucson, Arizona, in which rain water is concentrated into planted strips by shaping, compacting and treating the contributing catchment with salt. The salt not only increases the runoff by dispersing the clay but also acts as a herbicide on the catchment to prevent weed growth. Erosion is controlled by shaping and utilizing a thin, naturally created sand mulch. The excess water is captured and stored in a covered reservoir and pumped back during dry periods to water the grapes and deciduous fruit trees planted in the drainage ways on the catchment. The system has had ample water since it was installed in 1971. The resulting runoff water from the salt-treated catchment is of high quality with the sodium being trapped by the clay in the soil on the catchment (Dutt and McCreary, 1975). This type of system which combines the concept of desert strip farming (Morin and Matlock, 1975) with surface water storage is referred to as a water harvesting agrisystem by the author. The operation of the system shows that surface storage of water is essential to uninterrupted production. The installation of a reservoir with a floating cover is the most expensive part and therefore a limiting factor to the water harvesting agrisystem (Cluff and Dutt, 1975). A compartmented reservoir was combined with a 20-hectare (50-acre) water harvesting system in Mexico in the spring of 1976 (Gavande et al., 1976). The author assisted in the design of the system and helped direct the initial construction. This system is discussed in Chapter 4.

Water Yield and Reservoir Regulation Models

An understanding of the principles of hydrology are essential before a water yield or reservoir regulation model can be developed. The physical processes through which a watershed reacts to precipitation and eventually yields runoff are understood to the extent that the principal parameters acting within the runoff phase have been identified and interactions between these parameters can be qualitatively described (Linsley et al., 1975).

However, because large numbers of processes are occurring over the watershed that change with time, quantitative analysis is very difficult. With the advent of the computer, various models have been devised to help quantify a watershed response to precipitation.

Several models are available for simulation of streamflow and/or water yield which vary in complexity of inputs, the number of parameters to be determined, the time interval used, and the output (Williams and LeSeur, 1976). Clarke (1973), an FAO consultant, prepared an extensive paper on the mathematical models in hydrology. Clarke explains that there are many different models, because hydrologists are required to solve many problems, each with certain aspects that are unique, but also with many aspects in common.

Some of the best known models include the Stanford Model (Crawford and Linsley, 1966; Ross, 1970) and the USDAHL-74 Model (Holtan et al., 1975) which have several parameters and use a short-time interval and output a hydrograph in addition to total flow. Holtan et al. (1975) report that the USDAHL-74 Model has a correlation coefficient of observed versus computed monthly runoff of 0.89, 0.95, 0.97 and 0.94 for four watersheds with areas ranging from 3.45 to 15.7 square miles. The

correlation between precipitation and observed runoff for the same four watersheds were 0.67, 0.77, 0.87, and 0.65, respectively. Such models work best under the conditions for which they were derived. This statement is verified to some extent by Lovely (1976) who found that USDAHL-74 "was unable to adequately simulate runoff in low water-yield years and during the summer-runoff season" on a 49-square mile semiarid watershed in Arizona.

Simons et al. (1975) simulated the land surface hydrologic cycle, sediment production, and water and sediment movement on small watersheds. In the Simons model emphasis is on the mechanisms of the water and sediment routing.

The National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) developed a model that requires the rational estimation of 16 model parameters (Peck, 1976).

Haan (1972) developed what he called a self-calibrating four parameter model. These parameters are: (1) an evapotranspiration factor, (2) a maximum-infiltration factor, (3) a maximum deep seepage rate, and (4) a seepage-return factor. In addition, daily rainfall and estimated average potential evapotranspiration are needed for the model. The model assumes distributions of daily rainfall on an hourly basis within a day and within an hour. It computed and compared monthly runoff values for eight watersheds. Haan reports that both the slope of the regression line and the correlation coefficient are needed to determine a good fit. His correlation coefficients ranged from 0.94 to 0.97 and slopes from 0.89 to 1.05 for the eight watersheds located in Kentucky and South Carolina. Ideally, both values should be 1

The final water-yield model discussed is that developed by Williams and LeSeur (1976). These researchers developed a rather simple water-yield model with four input requirements. These are: (1) an estimate of the II-condition Soil Conservation Service (SCS) runoff curve number for the watershed, (2) measured monthly runoff, (3) daily rainfall, and (4) average monthly lake evaporation. Tests on about 50 watersheds in Texas with areas from 0.5 km^2 to 2,227 km^2 are reported. Correlation values ranging from 0.35 to 0.98 were determined when comparing computed annual runoff against observed runoff. The comparison on a monthly basis was not made for all the watersheds but where it was the "r" values were, in general, lower than those based on annual flow on the watershed.

Various models have been written to provide bases for reservoir regulation. One of the principal ones is described by Brooks et al. (1972). This model, Streamflow Synthesis and Reservoir Regulation, SSARR, was developed by the U.S. Army Corps of Engineers initially for application in the northwestern United States. It was expanded and has been used on many river systems in the United States and abroad by several different agencies. The model is comprised of a water-yield model, a streamflow routing model and a reservoir-regulation model. The water-yield model is rather simplified but still requires eight types of input. Precipitation is inputted in any selected period but it then must be distributed to come up with a shorter time base.

The reservoir-regulation portion of the program operates the reservoir in response to inflow losses and beneficial consumptive uses. It routes a flood through one or several reservoirs and prints out the incoming and outgoing hydrographs. It automatically causes the

reservoir to spill if the capacity is exceeded. This system is used to operate the Columbia River system with its 28 reservoirs.

The simulation model above becomes a type of system engineering or operations research when it is used in making decisions about how to optimize the operation of the reservoir system (Wagner, 1969). Systems engineering, according to Hall and Dracup (1970), is concerned with only one phase of the total task of the water resources engineer -- that of decision making. Various mathematical tools such as linear or dynamic programming are available (Wagner, 1969; Jelene, 1970; Hall and Dracup, 1970). These methods are not utilized in the model developed herein and therefore an extensive literature review in this area is not included. An accounting or mathematical-model approach is used in the optimization procedure. They are described in Chapter 3.

CHAPTER 3

DESCRIPTION OF THE COMPARTMENTED RESERVOIR OPTIMIZATION PROGRAM (CROP-76)

The computer model was originally conceived to convert daily historical rainfall data into runoff data from either a natural and/or a treated watershed. Runoff data input was to be expressed as a weekly array and to be stored in a compartmented reservoir data bank. The compartmented reservoir was to be subjected to domestic and/or agricultural demand as well as evaporation losses. The design parameters of the compartmented reservoir were to be adjusted so that the "optimum" reservoir system would be selected. The definition of an optimum reservoir is "the system that would have the highest storage efficiency under the constraints imposed." The definition of the storage efficiency is the percent of water that passes into the storage system that is available for a desired beneficial use on a constant demand basis. Unless otherwise noted the losses which are subtracted from the water going into storage include evaporation and overflow from the receiving compartment in addition to excess water which occurs when the entire reservoir system is filled. Overflow occurs if runoff from a single storm exceeds the unfilled capacity of compartment 1. It is assumed that seepage is controlled and therefore these losses are not included.

In the operation of the model the design parameters are usually adjusted so that the amount of overflow plus excess water is kept below a specified amount, usually 4 or 5 percent. An additional constraint is

the requirement that the reservoir system is required to provide water for the desired beneficial use for a specified minimum, usually 95 or 96 percent of the time. The consumptive demand was reduced if necessary in order to fit the above constraints.

This concept of optimization is limited since it does not take economics into consideration.

From the beginning of the project it was decided to couple a water harvesting agrisystem subroutine to the compartmented reservoir portion of the program. Under this option a soil moisture-accounting routine was to be used to account for storing water in the soil in addition to storing excess water in the compartmented reservoir system.

Most of the above objectives were achieved with CROP-76. It was soon found, however, that there were too many design parameters to find a satisfactory design in a single run of the computer, within a reasonable processing time. The design, however, can be obtained by repeated computer runs by a skilled operator who helps the computer in its selection of the parameters that will meet the constraints.

The model was set up to provide an understanding of the effect of the various parameters on a compartmented reservoir system and thereby to help furnish training for an operator who would in turn reduce the amount of time needed to optimize a particular design.

It may be possible in the future to use CROP-76 in conjunction with a linear programming routine in which the objective function would be to optimize profit by allocating land as either a cropped area or a catchment area. The objective function might also include the number of compartments. The use of linear programming would help decide which

crops to plant that would provide the greatest profit under a water and land constraint.

The 76 was added to the CROP acronym of the model since it was developed in 1976. It also serves as a reminder that there is still more development needed.

Appendix C contains a listing of CROP-76 in Extended Fortran IV. The listing includes a description of the Fortran coded variables used in the program. It also includes a data card summary and comment cards which are useful in understanding the actual operation of the program. Figure 3-1 gives a flow chart of the program. A more detailed discussion follows.

Water-Yield Routine

This routine is within Program CROP-76 and the two subroutines, CONVRT and WINTER. It uses the daily rainfall input and converts it to a continuous daily array. Using the area of the natural watershed and/or the area of a treated watershed and appropriate built-in factors, it then uses the daily rainfall to determine daily runoff in accordance with the following relationships:

$$Q = AxS_M xM(P_d - (\Delta txDxS_D))$$

where $P_d > (\Delta txDxS_D) < LxS_L$.

Q = daily runoff.

A = the area of the watershed.

S_M = a seasonal modifier of M.

M = the runoff multiplier that is a function of P_d.

P_d = the daily precipitation.

Δt = time in days between rainfall events.

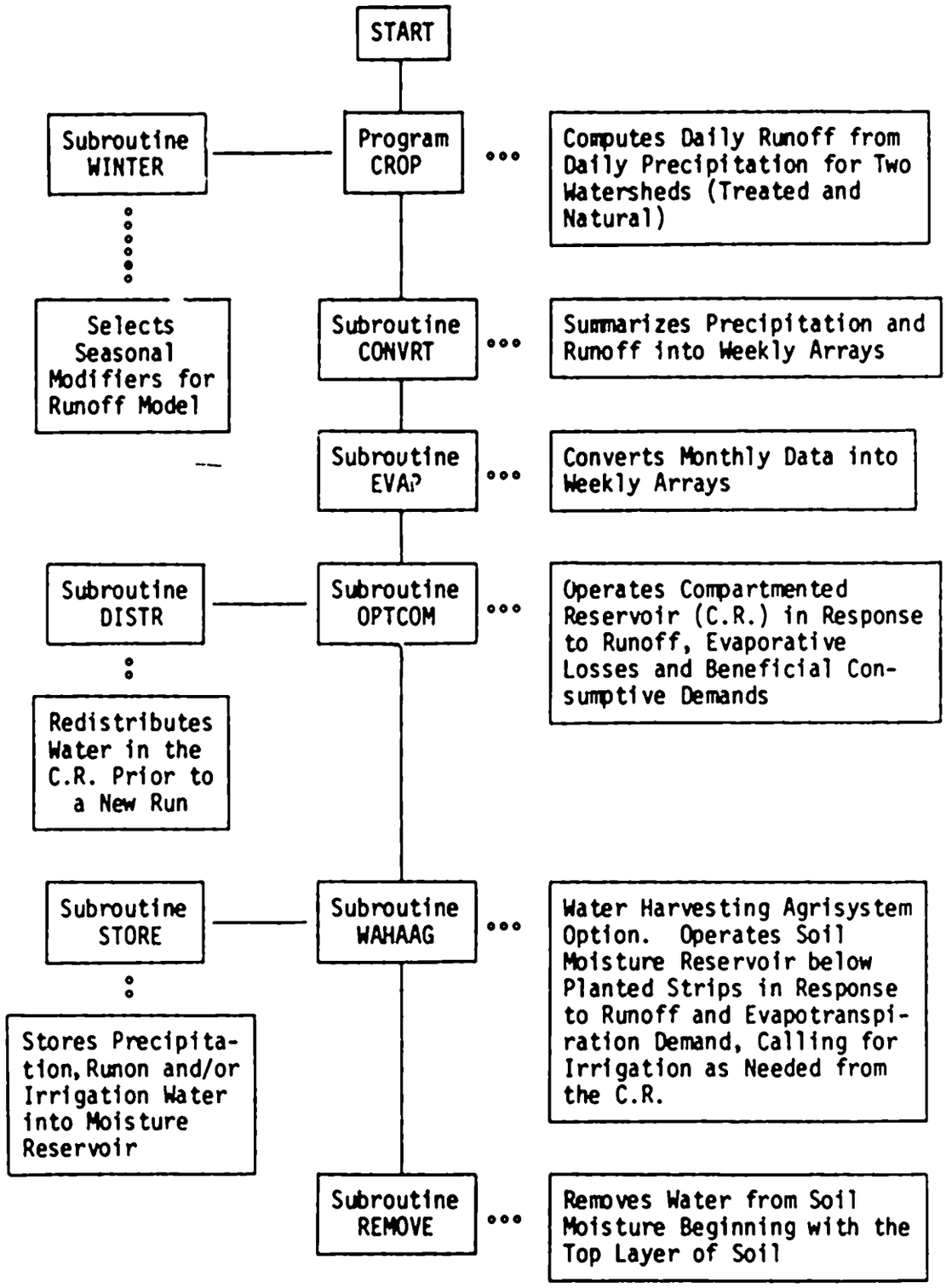

Figure 3-1. Subroutine Flow Chart for Compartmented Reservoir Optimization Program (CROP-76).

D = a selected watershed daily depletion.

S_D = a seasonal modifier of D.

L = a maximum limit on the total depletion.

S_L = a seasonal modifier of L.

After a brief study of the above variables one might recommend that the first step to take is to reduce the total number by combining M and S_M, D and S_D, and L and S_L, reducing the total number of variables needed to determine runoff from nine to six. However, it was found that it is easier to calibrate the model using average values for M, D and L which are adjusted using the seasonal modifiers. The model was calibrated using data from HL-1, a 16-acre subwatershed in the 18-square mile Atterbury Experimental Watershed. The seasonal modifiers, S_M, S_L and S_D were adjusted. The relation between M and P_d was left as originally set for both natural and treated watersheds. These functions are illustrated in Figure 3-2. The selection of these functions is based on several years of experience by the author in observing runoff events on natural and treated watersheds in southern Arizona. The relation for the treated watershed is based on experience with compacted sodium-treated watersheds. Other relations would be used with other types of treatments. By selecting appropriate coefficients the correlation coefficient between computed and measured annual runoff on the 16-acre watershed is 0.82. These values show a respectable correlation on a daily basis in 10 of the 11 years. The poor correlation in 1976 is due to a low runoff year combined with one storm in April with a below-average intensity and another on September 1 with an unusually high intensity. Table 3-1 contains the comparison of annual runoff for 11

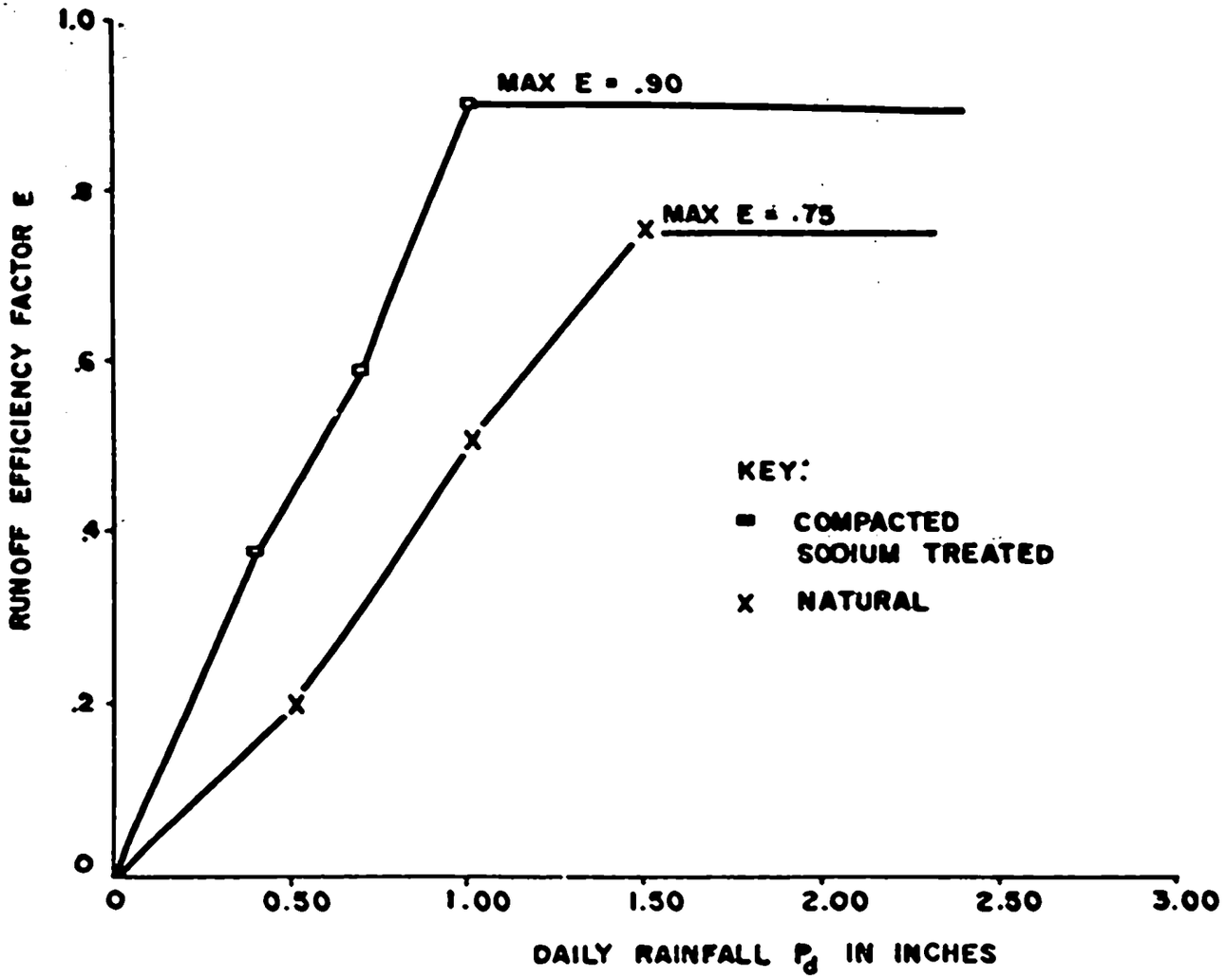

Figure 3-2. Relation between Daily Rainfall and Runoff Efficiency Factor Used in Water Yield Model of CROP-76.

Table 3-1. Measured and Computed Annual Runoff for a 16-Acre Natural Watershed (HL-1) on Atterbury Experimental Watershed near Tucson, Arizona.

Year	Rainfall (mm)	Runoff (mm)		Daily Correlation Coefficient[1]
		Measured	Model	
1966	167	15.9	16.5	0.92
1967	330	59.4	54.8	0.93
1968	266	11.2	18.9	0.56
1969	196	4.8	5.0	0.95
1970	209	20.3	20.9	0.95
1971	355	61.4	49.0	0.86
1972	309	31.8	51.6	0.89
1973	226	6.8	10.4	0.80
1974	235	22.1	23.3	0.68
1975	211	19.2	9.5	0.82
1976	217	4.6	7.6	0.15
Mean	233	257.5	267.5	0.82[2]

[1]The daily correlation was determined using daily measured and model computed values of runoff.
[2]This value was determined by correlating the annual measured and model computed values of runoff listed in the table.

years of record. The correlation coefficient based on individual runoff events for each year also is given in the table. The selection of which seasonal modifier to use is done in Subroutine WINTER. In the calibration, September is a month that fit neither the low-intensity convective frontal storm that occurs in the winter nor the high-intensity convective storms prevalent in the summer. A significant improvement in correlation is obtained when an average of winter and summer modifiers is used for September. This reflects the physical reality that both types of storms occur in September which is somewhat of a transitional month for Arizona.

The model prints out, upon demand, the daily precipitation including the date of occurrence and the runoff from the natural and/or treated watersheds with the corresponding efficiencies. The weekly array of precipitation, runoff and efficiencies is also printed out if WRITET is set to 1 (see Appendix C). Otherwise, only the annual totals and efficiencies are printed out.

CROP-76 does not include a sediment production function. A determination of sediment would be very helpful but would probably require a more sophisticated model in which both rainfall and runoff intensities were simulated.

Although the water-yield portion of the model (see Appendix C) is relatively simple, it is believed that its accuracy is sufficient for the purposes of this study. Its simplicity allows it to be used in most of the world where only limited data are available.

Evaporation Routine

The evaporation routine is listed as Subroutine EVAP. It converts monthly evaporation data into a daily array by dividing the monthly total by the number of days in the respective months and then sums the daily array into a weekly array. The weekly array and/or the annual and period summaries of evaporation are printed on demand by setting WRITET to 1 on the evaporation subroutine control card (see Appendix C).

Compartmented-Reservoir Routine

The compartmented reservoir routine includes Subroutine OPTCOM and the smaller Subroutine DISTR. The routines use the weekly-runoff array determined in the water-yield routine and stores it in a system of up to ten compartments. When the water harvesting agrisystem option is used only data from eight compartments are printed out due to space restrictions on the printout. This is found to be more than adequate.

The compartments are designated by the slope, the maximum depth, and maximum volume. In addition, the initial volume of each compartment is required as input. All compartments are assumed to be of the shape of an inverted truncated prism with four equal sides and a constant slope. A cross-sectional area taken perpendicular to any pair of opposite sides has the shape of a trapezoid. The relationships of the truncated prism are used in obtaining a unique solution for the surface area "AS" when given the volume "V", side slope "S" and bottom cross-section "AB". This relationship is given as:

$$AS = [(6VxS + (AB)^{1.5}]^{2/3}$$

Knowing the surface area, the depth "d" is computed from the relationship:

$$d = 2V/(AB + AS)$$

Given the reservoir volume this method of computating the surface area can be replaced by an appropriate function or table look-up routine if the compartment shape is different from that described above.

The model keeps track of the amount of water in each compartment, entering runoff first in the first compartment "1" and then moving it to the last compartment "K". Evaporation occurs from all compartments containing water. Withdrawals for consumptive use are made beginning with the first compartment to have water. This compartment will be designated as "n". The water is concentrated by pumping first from compartment "n" and continues to the last compartment "K-1" if needed. Pumping is done only if there is enough unused capacity in the "upper" remaining tanks "n+1", "n+2", ..., "K", to completely empty the water from compartment "n". It is done at discrete times in keeping with the operating constraint of concentrating the water by pumping with a portable pump. The model keeps track of and prints out the values of two types of pumping: (1) the amount of water it concentrates by pumping from compartments "1" to "K-1" into compartments "2" through "K", and (2) the amount of runoff transferred from the receiving compartment "1" into the remaining compartments. The only compartment requiring gravity flow from the stream channel is compartment "1". The model shows a proportionate reduction of evaporation due to a reduction in surface area only. It does not take into account the reduction of evaporation rate because of the increased depth of water as compared to a single compartment. It also does not account for the runoff from empty compartments and/or the side slopes, or the precipitation that falls directly on to the water surface in the filled compartments.

Output from the model includes a weekly summary of runoff from natural and/or treated catchments, domestic and/or agricultural consumptive uses, evaporation losses from the reservoir, the amount of pumping from compartment "1", the amount of water concentrated by pumping as well as the available storage in each compartment. Both annual and period summaries of each of the above categories are given, including an efficiency-of-use for each year and for the total period.

Water Harvesting Agrisystem Option

When MTEST is set to 1 (see Appendix C) the water harvesting agrisystem option is activated. Using this option requires reading in soil-moisture parameters for a designated number of layers of soil. The parameters are the field capacity, the wilting point, the initial soil-moisture level in each layer in addition to the remaining unfilled capacity of the soil. These data include the effect of soil moisture spreading laterally underneath the catchment area. The option is based on the premise that the cropped area of the water harvesting agrisystem is within the catchment as outlined in Cluff et al. (1972) and Dutt and McCreary (1975). This method consists of a shaped-treated catchment sloping toward a drainage area in which the crop is to be planted. The planted area could be of varying widths controlled primarily by the equipment to be used in tilling the cropped area. Thus, if tractors were used, the minimum width of the planted strips in the catchment would be in the order of two meters allowing for two rows. The maximum width probably would be four meters unless the slope of the drainage area is such as to assure adequate water distribution over a wider area. Special tillage procedures producing rows perpendicular to the direction

of a tractor's travel would greatly facilitate water distribution in the planted area of the strip farm method.

In the model, rainfall and a portion of the runoff are stored in the soil. This is called "runon". It is defined in this study as the amount of runoff going into the soil beneath the planted area. It is determined by the relation:

$$\text{Runon} = K_1 \; [\text{QTWW} - K_2(\text{AWHP})]$$

where K_1 and K_2 are constants set according to soil and slope conditions, QTWW is the weekly runoff total from the water harvesting catchment and AWHP is the area of the planted portion of the water harvesting agrisystem.

Storage and retrieval of soil moisture in the soil profile is based on a method used in a model developed by Morin and Matlock (1975). The Morin and Matlock model has no provisions for surface storage with subsequent irrigation use.

Precipitation and runon is added to the soil profile, beginning at the upper layer and extending downward. If the soil moisture profile is filled, deep percolation occurs and the water is lost to the system. Evapotranspiration demand is taken from consumptive use data available in the area. If necessary, these data are obtained by talking with farmers in the area. Evapotranspiration removes water first from the top layer of soil. When the water content of this layer is used down to the wilting point, additional water is removed if needed from the lower layers to root depth.

The program compares the available soil moisture down to root depth with the weekly evapotranspiration demand. When the soil moisture drops to 50 percent of the total water available the program calls for an

irrigation. The water supplied by the irrigation is deducted from the compartmented storage system along with losses set at a ten percent level internally within the program. This irrigation stores water first in the upper layer until field capacity is reached and then, in subsequent layers, down to plant-root depth.

The number of layers of soil moisture available is controlled by a specified plant-root function. A linear root function of depth versus time is used in the model. This function can easily be changed to fit whatever crop is being planted. The function is in the form:

$$NRTM = RSLOPE \times IW - RCROSS$$

where NRTM is the number of layers, RCROSS is the y-axis intercept, RSLOPE is the rate (or slope) of root growth, and IW is a weekly counter. The above root function is only activated during the period in which there is a evapotranspiration demand.

The agrisystem option has been kept relatively simple in principle so that it can be used in areas where data are limited. The option appears to be adequate for planning purposes in showing how effectively the compartmented reservoir system can be used in conjunction with moisture storage in the soil for growing crops in areas where agriculture is unfeasible if limited to conventional irrigation methods.

When the water harvesting agrisystem option is used, the total available soil moisture and the amount of irrigation, if any, are printed out for each week in addition to all of the other data described earlier. A sample listing of the agrisystem output for San Francisco del Barreal, Coahuilla, Mexico, is in Appendix D. Also given is the input data and a listing of the recommended surface area, depth and embankment side slopes of each compartment. The volume of each

compartment is listed as well as the amount of water each compartment contains at the end of the period of record.

CHAPTER 4

DEMONSTRATION OF THE COMPARTMENTED RESERVOIR USING THE CROP-76 MODEL

To illustrate the utility of the compartmented reservoir, the CROP-76 computer model was applied to different types of storage problems including those previously investigated in Africa and Mexico. These applications are discussed in this chapter.

Storage for Ground Water Pumped with Solar Power, Arizona

Shortly after the model was functional an opportunity arose to interface with a research project studying ground-water pumping using solar energy (Larsen et al., 1976). Larsen et al. have shown that it is economically advantageous to pump into surface storage on an annual basis. The surface storage was used to match annual pumping to the more seasonal irrigation demand. The estimated pumping and irrigation demands for the 64-hectare (160-acre) project are shown in Figure 4-1 which is taken from the Larsen et al. report. Average weekly pumping and consumptive use values were input for a modified model. The water yield portion of the model was not used. Four years of monthly evaporation data were used to demonstrate the compartmented system. The initial storage and consumptive use were varied to reach an equilibrium over the four-year period. A depth of six meters is suggested by Larsen et al. as being realistic for this application. As shown later, the use of a greater depth reduces the evaporation savings obtained when

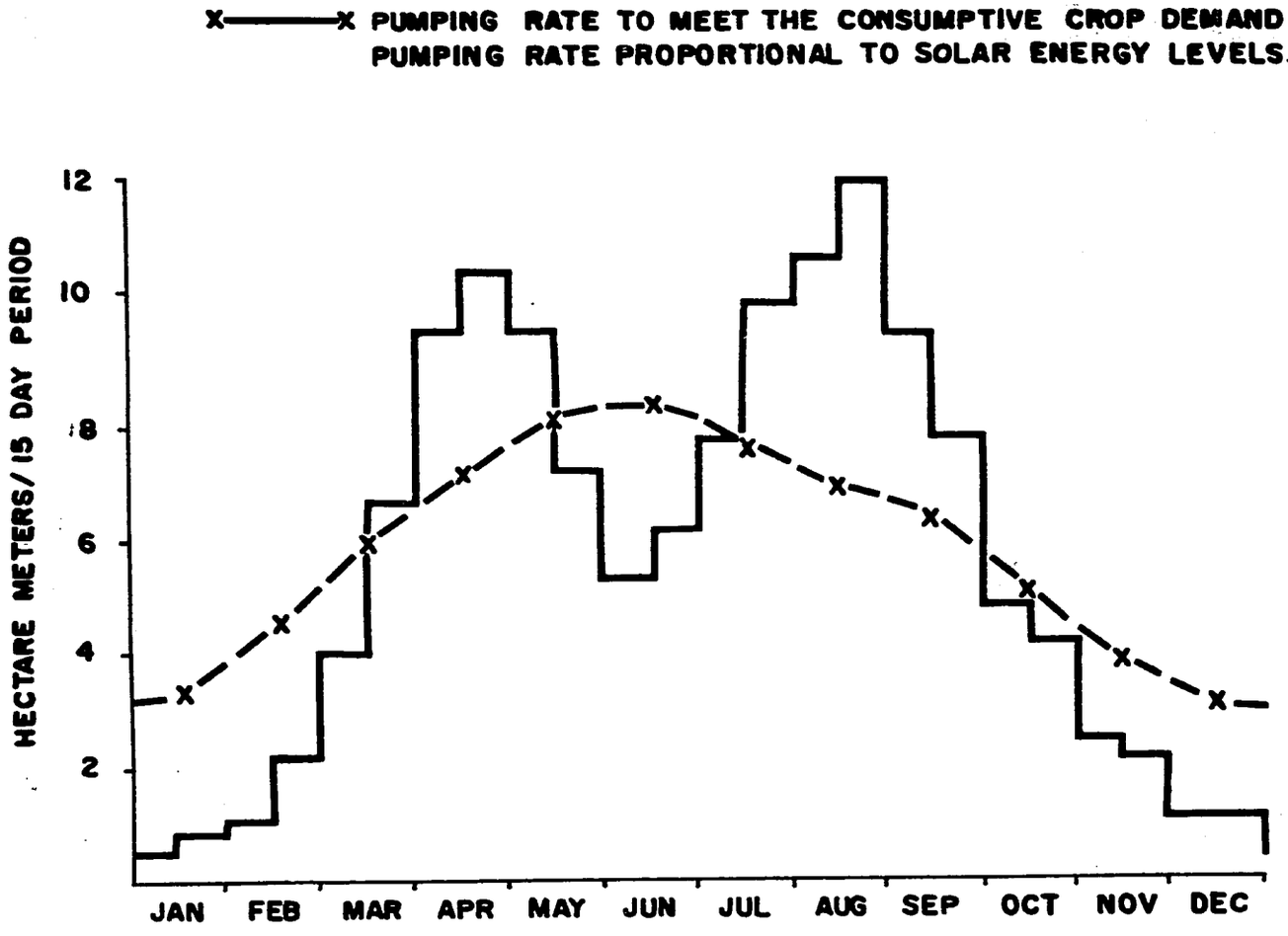

Figure 4-1. Matching Consumptive Demand from Water Storage where Pumping Is Proportional to Solar Energy Input. -- Bar graph irrigation demand for 16 hectares each of cotton, lettuce, sorghum and alfalfa and 32 hectares of wheat grown on a 64-hectare (160-acre) farm near Mesa, Arizona (Larson et al., 1976).

compartmenting the reservoir. In contrast, the use of a lesser depth would increase the importance of compartmenting.

Table 4-1 gives the result of the analysis made for four reservoir systems for storage of seasonally pumped ground water using solar energy. The table shows that there is a 30.3 percent and a 37.5 percent evaporation savings resulting from the use of two and four compartments, respectively. There is a slight decrease in evaporation savings when the number of compartments is increased from four to eight; therefore, no more than a four-compartmented system is recommended.

A single compartment should cover 227x227 m, or 5.15 hectares. A two-compartmented reservoir should cover 315x172 m, or 5.42 hectares. A four-compartmented reservoir should cover 235x246 m or 5.57 hectares. The single-compartmented reservoir requires 39,394 m^3 of embankment if the cut and fill were balanced. The four-compartmented reservoir requires 48,640 m^3, a difference of 9246 m^3. Three additional discharge pipes and valves are required in the four-compartmented system.

The amount of pumping required to keep the water concentrated also is given in Table 4-1. It is very small because solar-pumped water can be placed in any compartment to keep the water concentrated as much as possible. This reduces the need for auxiliary pumping as compared to the storage of floodwaters.

The use of a compartmented reservoir should significantly reduce evaporation loss. In addition, there are other advantages of a compartmented tank in this system. These are: (1) repair and maintenance is simplified because it is relatively easy to drain a compartment if needed; and (2) the average depth of water in the storage tank is much deeper, thus reducing the rate of bottom weed growth and the evaporation

Table 4-1. Summary of Four Designs of a Compartmented Reservoir for a Solar-Energy-Powered Pumping System.

	Number of Compartments			
	One[1] (m^3)	Two[2] (m^3)	Four[3] (m^3)	Eight[4] (m^3)
Evaporation				
1967	68,715	47,705	41,196	40,756
1968	68,726	47,741	42,572	43,310
1969	70,576	49,326	45,085	45,756
1970	72,604	50,882	46,572	46,925
Total Evaporation	280,621	195,651	175,425	176,747
Average Evaporation	70,155	48,913	43,856	44,187
Consumptive Use[5]	1,295,851	1,303,651	1,319,251	1,319,251
Water Pumped	1,364,722	1,364,722	1,364,722	1,364,722
Change in Storage[6]	+3,897	-3,256	+2,183	+628
Amount Concentrated	0	0	6,802	5,036
% Evaporation Savings	-	30.3	37.5	37.0
% Storage Efficiency	94.95	95.52	96.67	96.67

[1]The capacity of the single reservoir is 205,000 m^3.
[2]The compartments are all 96,000 m^3.
[3]The compartments are all 48,000 m^3.
[4]The compartments are all 24,000 m^3. All compartments are rectangular with six-meter depths and 1:2 side slopes. The total volume of all compartmented systems is 192,000 m^3.
[5]The consumptive use and input data are given in graphical form in Figure 4-1.
[6]Represents the change in storage from the beginning to the end of the four-year period.

rate. The latter reduction as indicated earlier was not taken into account in the model.

In both types of storage systems the period during which excess storage is available coincides with summer rains, making salvage of floodwaters a possibility. In this case an auxiliary compartment would need to be constructed to hold floodwater until it could be pumped into the main storage compartment.

Storage for Floodwaters of Ephemeral Streams, Arizona

In 1975 there was an 185.0-mcm (150,000-af) overdraft from the Tucson, Arizona, ground-water basin (Pingray, 1976). But there was then an average of 27.8 mcm (22,540 af) of surface water from a watershed of 9,073 km^2 leaving the basin as flood flow in the Santa Cruz River. The amount of surface flow is increasing each year as more desert land is paved during the urbanization process. The flood flow is not being used at present because it is highly variable. There are no sites available for a conventional reservoir deep enough to store this varying flood flow without excessive evaporation loss. Twenty-four years of daily streamflow data are available from the U.S. Geological Survey gaging station at Cortaro Road, northwest of Tucson, Arizona. These data were used to test the use of a compartmented-reservoir system for storage of floodwaters of a large ephemeral stream.

The Cortaro-Marana Irrigation District is pumping from the Tucson water basin an amount of water approximately equivalent to the annual outflow of the Santa Cruz River. It was decided to ascertain if a compartmented reservoir could efficiently store floodwater to be used for irrigation. This system would make an amount of ground water equal

to flood flow available for urban use. The same consumptive use per hectare and evaporation losses used in the solar-power pump example were used so that the results could be more directly comparable. The results of repeated analyses of different compartmented systems for the 24-year record are shown in Tables 4-2 and 4-3. There is considerable improvement in efficiency using a compartmented reservoir when the compartments are five meters deep. The efficiency increases from zero percent for a conventional reservoir to 40 percent for a three-compartmented reservoir. It is seen that a one-compartment system (the conventional reservoir five-meters deep) does not provide any water on a continuous demand basis. The reservoir was empty 96 weeks without any beneficial consumptive use. The conventional reservoir could not even maintain its own evaporation losses. However, with a three-compartmented system of equal total volume, 40 percent of the water is supplied on a schedule commensurate with the agricultural demand of 576 hectares. A six-compartmented system would be 49 percent efficient in providing water for 704 hectares.

The difference in efficiency between a one-compartmented system and three- and six-compartmented systems diminishes as the depth increases. For a 100-meter (305-ft) deep system, the difference becomes insignificant.

Again it is noted in the example that relatively small amounts of water need to be pumped in a compartmented reservoir once the compartments were initially filled. Concentration is achieved primarily by emptying and filling the appropriate compartment. Thus, if it is possible to divert and fill as well as drain the compartmented reservoir

Table 4-2. Summary of the Use of a Compartmented Reservoir for Irrigation on the Santa Cruz River below Cortaro Gaging Station near Tucson, Arizona, for the Period 1951-1974.

Depth	5 m			10 m			20 m			100 m		
Number of Compartments[1]	1	3	6	1	3	6	1	3	6	1	3	6
Hectares Irrigated	0.0	576.0	704.0	576.0	896.0	960.0	960.0	1120.0	1152.0	1280.0	1280.0	1280.0
Consumptive Use (mcm)[2]	0.0	274.7	335.7	274.7	427.3	457.8	457.8	534.1	549.4	610.4	610.4	610.4
Evaporation (mcm)	680.7	376.4	314.4	378.3	220.7	192.2	189.9	117.2	103.2	91.7	38.4	41.4
Overdraft (mcm)	-	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Number of Weeks	(96)	-	-	(1)	-	-	-	-	(1)	-	-	-
Change in Storage (mcm)	-	-17.1	-20.0	-22.8	-18.8	-19.9	-17.6	-21.1	-22.2	-22.0	-18.7	-21.4
Storage Efficiency (%)[3]	0.0	40.0	49.0	40.0	62.0	67.0	67.0	77.0	80.0	88.0	89.0	89.0
Minimum Storage (mcm)	0.0	0.5	0.4	0.0	3.1	1.5	5.6	1.2	0.0	1.1	4.2	1.4
Amount Pumped:												
Concentration (mcm)	0.0	38.1	47.0	0.0	30.5	23.3	0.0	11.6	16.1	0.0	1.9	1.9
Initial (mcm)	637.4	574.3	555.9	576.6	539.3	535.4	541.4	523.9	522.6	556.0	513.0	513.0

[1]Total capacity of the reservoir system was kept constant at 90,000,000 m^3. When three compartments were used, compartments were 30,000,000 m^3 in size, when six were used, compartments were 15,000,000 m^3 in size. Slopes were 1:2.
[2]Consumptive use was from the data in Figure 4-1 and the irrigated hectares indicated above.
[3]Efficiency = 100 (C.U. ± change in storage)/runoff. Total runoff = 668.3 mcm. Runoff greater than 25,000,000 m^3 per week was counted as overflow. This value was 38.1 mcm for the total period.

Table 4-3. Effect of Changing the Compartment Size on a Compartmented Reservoir System[1] on the Santa Cruz River below Cortaro Gaging Station near Tucson, Arizona, for the Period 1951-1974.

	Three Compartments[2]			Six Compartments[3]		
	Constant Size	Decreasing in Size	Increasing in Size	Constant Size	Decreasing in Size	Increasing in Size
Hectares Irrigated	576.0	576.0	480.0	704.0	704.0	576.0
Consumptive Use (mcm)	274.7	274.7	228.9	335.7	335.7	274.6
Evaporation (mcm)	376.4	374.1	423.7	314.4	314.6	374.0
Overdraft (mcm)	0.0	0.0	0.7	0.0	0.1	0.0
Change in Storage (mcm)	-17.1	-18.7	-21.6	-20.0	-20.1	-18.3
Storage Efficiency (%)	40.0	40.0	33.2	49.0	49.0	40.0
Minimum Storage (mcm)	0.5	1.5	0.0	0.4	0.0	2.8
Amount Pumped:						
Concentration (mcm)	38.1	63.8	47.2	47.0	46.6	55.1
Initial (mcm)	574.3	566.8	575.5	555.9	555.9	566.8

[1]A depth of 5 meters, a side slope of 1:2 and a total volume of 90,000,000 m^3 was used in the above analysis. Total runoff = 668.3 mcm; overflow (runoff greater than 25 mcm per week) = 38.1 mcm.

[2]Three compartments (mcm): Constant: $V_A = V_B = V_C = 30$.
Increasing: $V_A = 20$, $V_B = 30$, $V_C = 40$.
Decreasing: $V_A = 40$, $V_B = 30$, $V_C = 20$.

[3]Six compartments (mcm): Constant: $V_A = V_B = V_C = V_D = V_E = V_F = 15$.
Increasing: $V_A = 2.5$, $V_B = 7.5$, $V_C = 17.5$, $V_D = 17.5$, $V_E = 22.5$, $V_F = 27.5$.
Decreasing: $V_A = 27.5$, $V_B = 22.5$, $V_C = 17.5$, $V_D = 12.5$, $V_E = 7.5$, $V_F = 7.5$.

by gravity, very little pumping is required as long as the appropriate filling and diversion structures are constructed and utilized.

Table 4-3 indicates that for the five-meter depth systems there is no increase in efficiency between constant-volume compartments versus compartments that are decreasing in size. There is a reduction in efficiency (as expected) when the last compartment to be utilized (but the first to be filled) is made larger in volume. Usually it is observed from the results of the model that a compartmented system provides a significant improvement in efficiency up to a 20-meter depth. At an 100-meter depth there is little improvement in efficiency from use of the compartmented reservoir.

Figure 4-2 gives the amount of earthwork required per cubic meter of storage for a one-, three- and six-compartmented system at the various depths, if the reservoir is built on flat terrain. As is evidenced in the figure, the cost of building an 100-meter deep reservoir is excessive. It requires half as much embankment to build a three-compartmented system 10 meters deep than a one-compartment system 20 meters deep, even though both systems give close to the same storage efficiency. There are safety and seepage problems that become almost insurmountable at the 20-to-100 meter depths.

Storage for Floodwaters of a Small Watershed, Goumbau, Mali

As indicated earlier the multi-compartmented reservoir was first conceived during a consulting trip to the Sahel in Mali, West Africa (Cluff, 1975). This method was developed in order to utilize floodwaters on a fixed demand basis throughout the year.

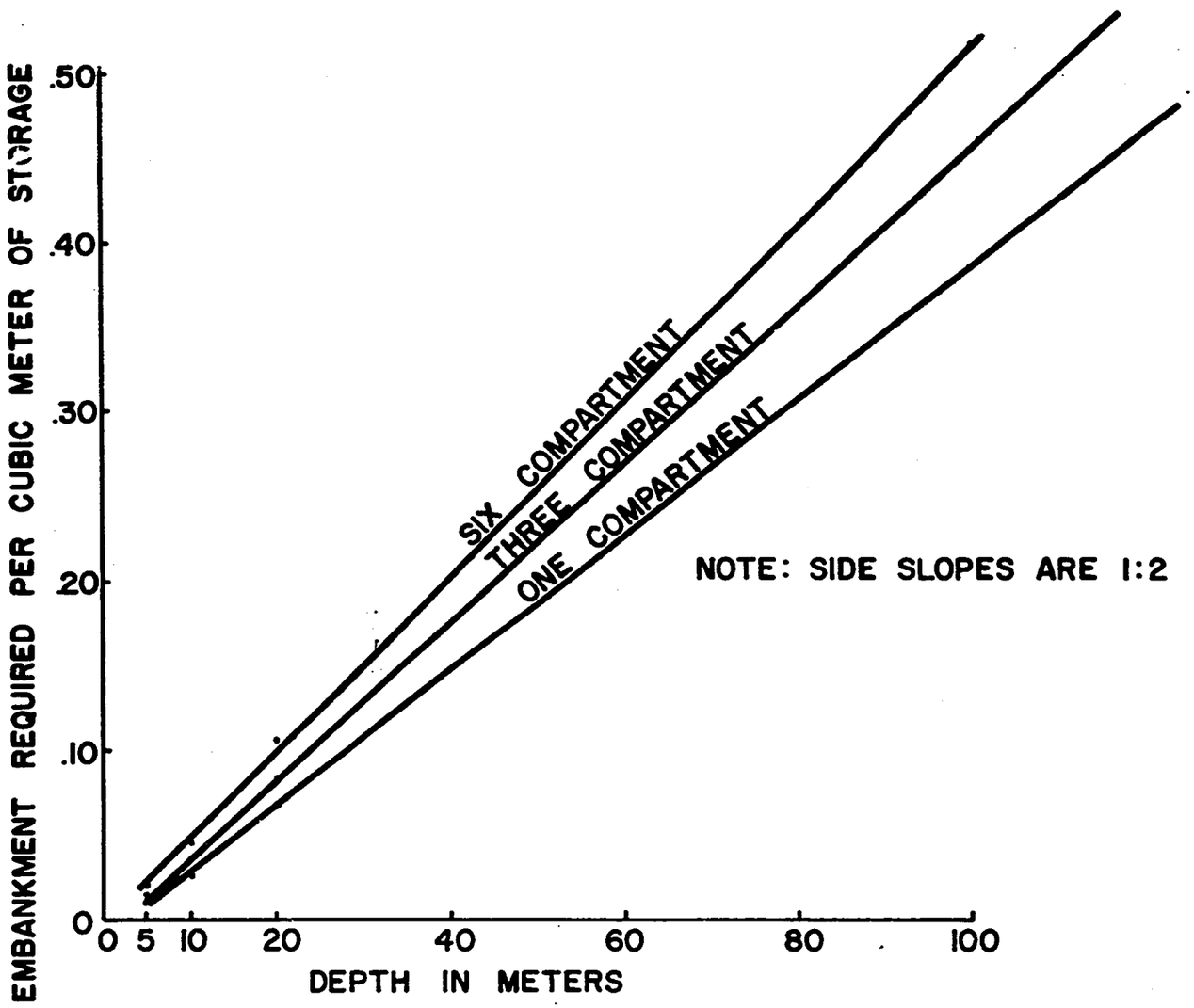

Figure 4-2. Depth Versus Embankment Required per Cubic Meter of Storage.

The rainfall in the Sahel varies from 250 to 500 mm (Wernstedt, 1972). It is received primarily during May through October with approximately 80 percent falling in the months of July and August. The rainfall is highly variable as evidenced by the recent drought in the Sahel in which many people died due to lack of food and water.

Two areas of Mali were investigated. The Nara area near Mauritania, west of Mopti, and the Dogan area near Songa, east of Mopti.

The villages in the two regions are lacking in an adequate domestic water supply. In addition, water is needed for irrigation. Although differing in hydrological characteristics both areas contain natural depressions referred to as "mares" in which water collects during the rainy seasons. The mares are rarely deeper than one meter in areas where the evaporation loss can exceed two meters per year. Therefore, most of the water is lost to evaporation and the mares always dry up completely between rainy seasons. The mares are very similar to the playas of the southwestern United States and northern Mexico. The water quality of the mare is, in general, better than that stored in the playas.

Nine sites for a compartmented reservoir were surveyed during a month's stay in Mali during the summer of 1975. A program was devised for a programmable Hewlett-Packard calculator (HP-25) to determine a design for the compartmented reservoir. This program is listed in Appendix E. It is based on using monthly values for precipitation and evaporation to determine runoff and reservoir losses. A simple runoff model was used which subtracts an assumed depletion from the monthly precipitation and then multiplies the result by an appropriate efficiency factor, and the area of the watershed.

Figure 4-3 contains the location of mare number 4 within its watershed. This watershed is located near the village of Goumbau about 30 miles south of Nara. Table 4-4 contains the results of the HP-25 analysis for a compartmented reservoir system. This table shows the recommended design which is based on leaving the existing mare as the collection compartment and building two additional compartments five meters deep, each with a volume of 12,500 m^3. With this design it is determined that during an average year the safe yield would be 2000 m^3 per month.

During a dry period between 1960 and 1964, according to the analysis, it would have been possible to maintain a consumptive use supply of 1500 m^3 per month. This amount would have furnishes about 18 percent of the domestic water for the village of Goumbau.

The above design was checked with CROP-76 using daily rainfall data and monthly evaporation data to form weekly arrays. Rainfall records are available from 1921-1965. Coefficients were selected for the water-yield model which gave an average of 38.8 percent of the precipitation appearing as runoff. The low-percentage runoff year was 1963 when only 19.9 percent of the precipitation appeared as runoff, with the high being 51.4 percent in 1934. The results of the simulation of the compartmented-reservoir system given in Table 4-5 show that over the 45-year period, the system, as designed, would have supplied 346 m^3 of water per week or 1500 m^3 per month and would have been dry only 14 weeks. The overall storage efficiency of the system is 32.4 percent. This is lower than previously determined since the earlier values were calculated only for average and lower rainfall years. The operation of the system shown in Table 4-4 also was simulated using CROP-76 but with

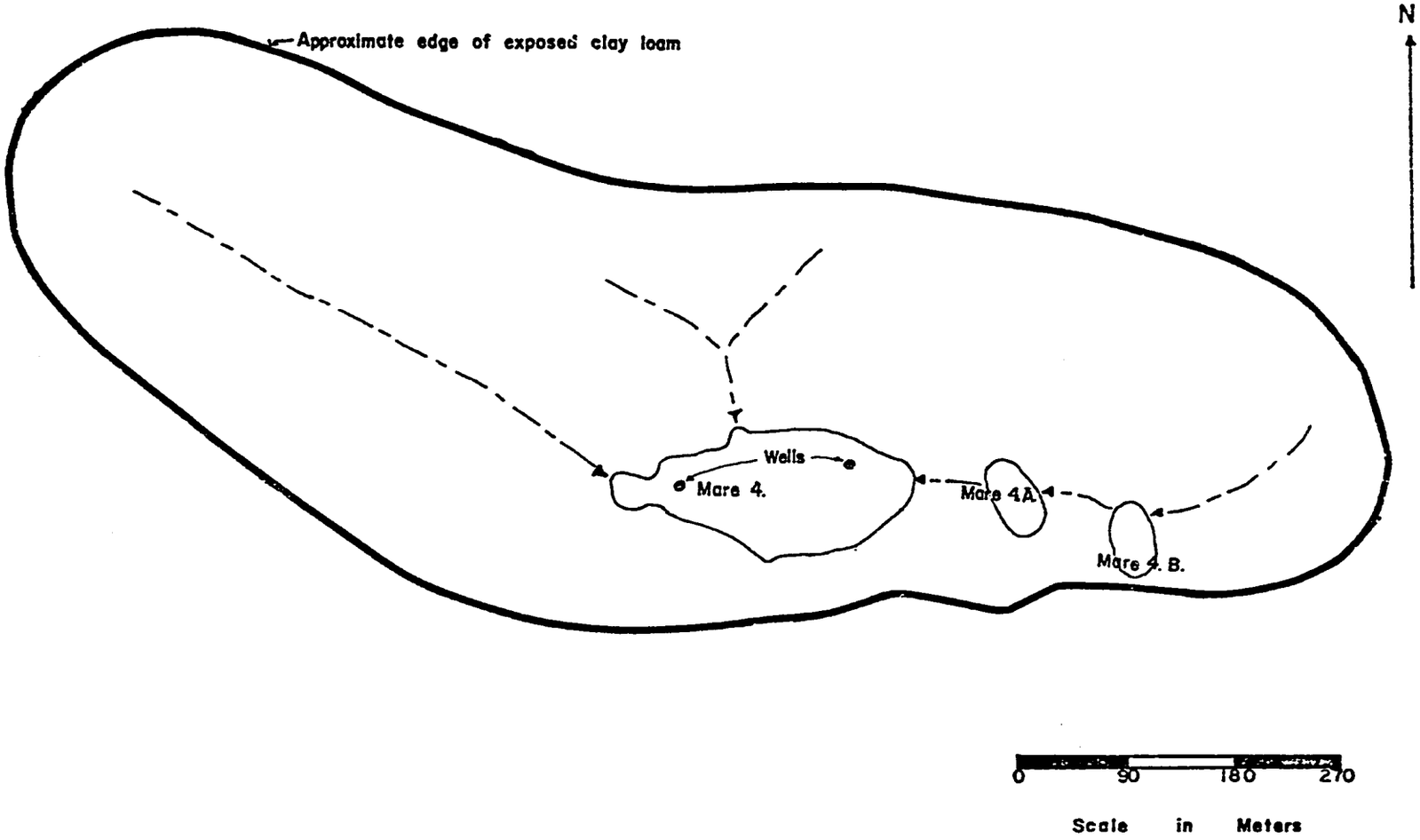

Figure 4-3. Schematic Map of Watershed of Mare 4 at Goumbau, Mali (Cluff, 1975).

Table 4-4. Goumbau, Mali -- Original Design of a Compartmented Reservoir for Mare 4. -- From Cluff (1975).

Effective Watershed Area: 240,000 m^2
Runoff Efficiency Modifier: 0.50
Average Rainfall: 494 mm
Existing Reservoir: Total Area = 15,900 m^2
Total Volume = 11,900 m^3

Depletion: .20 mm
Average Potential Runoff: 47,424 m^3

Recommended Design:

	Three Compartments			
	Compartment A	Compartment B	Compartment C	Total
Depth (m)	1	5	5	-
Area (m^2)	10,000	2,500	2,500	15,000
Volume (m^3)	10,000	12,500	12,500	35,000

	Average				1960-1961			1961-1962			1962-1963			1963-1964		
Year Month	Evap. (mm)	Rain (mm)	VT (tcm)	ET (tcm)	Rain (mm)	VT (tcm)	ET (tcm)	Rain (mm)	VT (tcm)	ET (tcm)	Rain (mm)	VT (tcm)	ET (tcm)	Rain (mm)	VT (tcm)	ET (tcm)
Initial	-	-	25.0	0.0	-	25.0	-	-	32.0	19.6	-	31.8	39.0	-	26.8	58.6
Sep.	109	80	29.6	1.6	80	30.3	1.6	47	31.9	21.2	34	31.5	40.6	53	28.8	60.0
Oct.	183	16	25.7	4.4	16	26.7	4.4	0	27.6	23.9	15	27.9	43.4	23	26.1	62.9
Nov.	253	0	19.9	8.2	0	21.4	8.2	0	23.8	27.7	0	22.6	47.1	0	20.8	66.7
Dec.	256	0	16.7	9.5	0	18.7	9.4	0	21.0	29.0	0	19.8	48.4	0	18.0	68.0
Jan.	281	0	13.2	10.9	0	15.8	10.9	0	18.1	30.4	0	16.9	49.9	0	15.1	69.4
Feb.	317	0	9.7	12.4	0	12.7	12.5	0	15.0	32.0	0	13.8	51.4	0	12.0	71.0
Mar.	402	2	6.7	13.4	0	9.2	14.5	0	11.5	34.0	0	10.3	53.4	0	9.5	72.0
Apr.	405	4	3.6	14.5	35	9.7	15.5	2	9.0	35.0	5	7.8	54.5	0	7.0	73.0
May	423	14	0.6	15.5	15	7.7	16.5	12	6.7	36.1	38	8.6	55.5	4	4.5	74.1
June	317	59	3.7	16.3	35	8.4	17.3	38	7.8	36.9	40	9.9	56.3	107	13.0	75.7
July	163	133	15.6	17.1	140	21.7	18.2	81	14.0	37.7	128	21.8	57.1	128	23.2	78.1
Aug.	95	182	31.6	18.6	120	32.0	19.6	183	31.8	39.0	76	26.8	58.6	211	32.1	79.5
Total	3,204	494			441			363			336			526		
C.U. (m^3/mo)		2,000				1,500			1,500			1,500			1,500	
Storage Efficiency (%)		56				48			48			48			46	

an evaporation cover on compartment C. The constant consumptive use or safe yield could be increased to 425 m^3 per week for an efficiency of 39.9 percent when a floating cover the size of the bottom area of compartment C is used.

In general the use of CROP-76 confirmed the reliability of the earlier simplified design technique. Repeated runs of CROP-76 were made in order to get a better understanding of the relationships between parameters.

Table 4-5 gives information for three depths (2.5, 5.0 and 7.5 meters) and three sets of compartments (1, 3 and 6). The compartments in each set are of equal volume with the total volume of each set equal to 75,000 m^3. The range in depth is selected to be within the constraints of physical reality. Due to the relatively small volume, depths much deeper than 7.5 meters are not justified. For the single-reservoir system it is difficult to excavate even 2.5 meters below stream gradient since hard schist exists at two meters depth. However, compartments with deeper depths were analyzed for comparative purposes.

The analysis shows that the evaporation loss is so large that the 2.5-meter deep single-compartmented reservoir is empty 509 weeks, or 21.7 percent of the time, with no beneficial consumptive use. The six-compartmented system supplies up to 100 m^3 per week for the entire period except for five weeks; i.e., water would be available 99.8 percent of the time. At a 100-m^3 per week use rate, the storage efficiency of use for a one-compartmented system is still zero whereas for a three-compartmented reservoir the efficiency is 25.9 percent and for a six-compartmented system the efficiency is 33.0 percent. With a 7.5-meter depth, a 21.2-percent utilization can be obtained with a

Table 4-5. Summary of the Use of Compartmented Reservoir Systems for Mare 4, Goumbau, Mali. -- Depth versus number of compartments with constant volume[1].

Depth	2.5 Meter			5.0 Meter			7.5 Meter		
Number of Compartments	1	3	6	1	3	6	1	3	6
Consumptive Use:									
Total (tcm)	0.0	0.0	234.0	0.0	643.5	819.0	526.5	936.0	936.0
Weekly (m^3)	-	-	100.0	-	275.0	350.0	225.0	400.0	400.0
Evaporation (tcm)	2638.8	2479.7	2239.4	2409.3	1793.1	1633.0	1868.4	1497.0	1071.0
Overdraft (tcm)	-	-	0.5	-	0.8	2.2	0.2	0.4	0.2
Number of Weeks	(509)	(16)	(5)	-	(3)	(7)	(1)	(1)	(1)
Change in Storage (tcm)	+1.2	+12.5	+10.9	+15.9	+13.1	+11.1	+14.3	+12.0	+11.7
Storage Efficiency (%)[2]	0.0	0.0	9.4	0.0	25.9	33.0	21.2	37.7	38.1
Minimum Storage (tcm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amount Pumped:									
Concentration (tcm)	0.0	464.1	347.2	0.0	340.0	198.9	169.7	254.6	148.0
Initial (tcm)	-	2506.0	2077.6	0.0	2309.8	2288.6	2293.4	2251.1	2256.5
Excess (tcm)[3]	14.2	21.4	0.0	88.2	45.5	33.3	85.0	49.7	43.4

[1]Total capacity of the reservoir system was kept constant at 75,000 m^3. When three compartments were used, compartments were 25,000 m^3 in size; when six were used, compartments were 12,500 m^3 in size.
[2]Efficiency = 100 (C.U. ± change in storage)/runoff. Total runoff = 2493.9 mcm.
[3]Excess = runoff more than the total available storage of 75,000 m^3.

one-compartmented system versus 37.7 and 38.1 percent for three- and six-compartmented systems, respectively. There is not much difference between a three- and six-compartmented reservoir system at this depth. An interesting observation is that there is less pumping required to keep the water concentrated in the six-compartmented system than in the three-compartmented system. The amount of pumping and number of times the pump is required also decreases with increasing depth.

The information in Table 4-5 was obtained from CROP-76 by assuming a 50,000 m^3-collection reservoir from which the water is pumped into the other compartments. Since this collector compartment was used only as a temporary retainer, for purposes of the analysis, it is not included in the summaries.

Tables 4-6 and 4-7 contain the results of modifying the volume and order of compartments for both the three- and six-compartmented system for depths of 5.0 and 7.5 meters. This analysis indicates there was little or no significant difference between increasing the volume of the compartments from A to D or decreasing the volume, with respect to the order in which the compartments are drained. For the three-compartmented system there was only a slight improvement in efficiency by decreasing the volume of the compartments with respect to the order in which they are drained. This is probably not enough improvement to justify the added construction and layout costs that different sized compartments would require. There was no decrease in efficiency caused by increasing the volume from compartments A to D. This result came as a surprise since intuitively one might suppose that the system with its increasing compartment size would have more losses when the water becomes concentrated into the larger compartments and therefore should be less

Table 4-6. Summary of Use of a Three-Compartmented Reservoir System for Mare 4, Goumbau, Mali. -- Depth versus compartments with different volumes.

Depth	5.0 Meter			7.5 Meter		
Volume of Compartments[1]	Constant Size	Increasing in Size	Decreasing in Size	Constant Size	Increasing in Size	Decreasing in Size
Consumptive Use:						
Total (tcm)	643.5	643.5	702.0	936.0	936.0	994.0
Weekly (m^3)	275.0	275.0	300.0	400.0	400.0	425.0
Evaporation (tcm)	1793.1	1793.0	1742.4	1496.9	1496.9	1445.7
Overdraft (tcm)	0.8	2.2	1.1	0.4	1.6	2.6
Number of Weeks	(3)	(6)	(4)	(1)	(4)	(6)
Change in Storage (tcm)	+13.1	+11.8	+10.9	+12.1	+10.4	+10.9
Storage Efficiency (%)[2]	25.9	25.9	28.3	37.7	37.7	40.0
Minimum Storage (tcm)	0.0	0.0	0.0	0.0	0.0	0.0
Amount Pumped:						
Concentration (tcm)	340.0	333.4	302.3	254.6	275.5	230.2
Initial (tcm)	2309.8	2306.6	2306.6	2251.1	2248.3	2243.5
Excess (tcm)	45.5	0.0	40.5	44.7	57.1	45.6

[1]Total capacity of the reservoir system was kept constant at 75,000 m^3:
Constant (tcm): $V_A = V_B = V_C = 25$.
Increasing (tcm): $V_A = 15$, $V_B = 25$, $V_C = 35$.
Decreasing (tcm): $V_A = 35$, $V_B = 25$, $V_C = 15$.
[2]Efficiency = 100 (C.U. ± change in storage)/runoff.

Table 4-7. Summary of the Use of a Six-Compartmented Reservoir System for Mare 4, Goumbau, Mali. -- Depth versus number of compartments with different volumes.

Depth	5.0 Meter			7.5 Meter		
Volume of Compartments[1]	Constant Size	Increasing in Size	Decreasing in Size	Constant Size	Increasing in Size	Decreasing in Size
Consumptive Use:						
Total (tcm)	819.0	819.0	819.0	936.0	936.0	936.0
Weekly (m^3)	350.0	350.0	350.0	400.0	400.0	400.0
Evaporation (tcm)	1633.0	1631.4	1636.7	1488.1	1501.0	1506.0
Overdraft (tcm)	2.2	0.3	0.2	0.2	0.0	1.2
Number of weeks	(7)	(8)	(7)	(1)	-	(4)
Change in Storage (tcm)	+11.1	+11.1	+10.5	+11.2	+11.8	+11.2
Storage Efficiency (%)[2]	33.0	33.0	33.0	38.1	37.7	37.7
Minimum Storage (tcm)	0.0	0.0	0.0	0.0	0.0	0.0
Amount Pumped:						
Concentration (tcm)	198.9	238.3	223.0	148.0	196.3	176.2
Initial (tcm)	2288.6	2286.0	2290.3	2256.0	2254.0	2257.6
Excess (tcm)	33.3	35.6	31.4	43.4	0.0	0.0

[1]Total capacity of the reservoir system was kept constant at 75,000 m^3:
Constant (tcm): $V_A = V_B = V_C = V_D = V_E = V_F = 12.5$.
Increasing (tcm): $V_A = 5$, $V_B = 8$, $V_C = 11$, $V_D = 14$, $V_E = 17$, $V_F = 20$.
Decreasing (tcm): $V_A = 20$, $V_B = 17$, $V_C = 14$, $V_D = 11$, $V_E = 8$, $V_F = 5$.
[2]Efficiency = 100 (C.U. ± change in storage)/runoff.

efficient. There was a significant difference in the distribution of remaining water in storage between the various systems throughout the 45-year period but overall not much difference in efficiency for the total period.

Table 4-8 shows the relatively large reduction in consumptive use required to reduce the period 45 weeks to seven weeks during which the system was dry. The last column shows the benefit of placing an evaporation cover on the last compartment for increasing the dependable supply of water. Covering 16.6 percent of the total area resulted in an efficiency of 49.4 percent for an increase of approximately 50 percent over the 33.0-percent efficiency for the uncovered system.

Storage for Floodwaters of Median-Sized Watersheds in Mali

Reservoir System in Nara, Mali

The concept of the compartmented system was applied also to the Nara, Mali, area. Nara, a village of 5,000 persons, is a regional center of local government in northeast Mali near Mauritania. The source of water during the dry season is from limited shallow wells dug in and around a large mare near the village. Two wells have been dug several kilometers away and a six-inch connecting pipeline was under construction when the author visited there in July of 1975. This pipeline should take care of present domestic needs but it will not provide much water for agriculture and/or for the expected growth of the village.

The watershed feeding the mare at Nara was roughly surveyed and is shown in Figure 4-4. The proposed location of a three-compartment system also is shown in the figure. The watershed consists primarily of exposed clay loam having a relatively low infiltration rate. It is

Table 4-8. Summary of Use of a Six-Compartmented Reservoir System at Different Rates of Consumptive Use for Mare 4, Goumbau, Mali[1].

Consumptive Use:						
Total (tcm)	1170.0	1105.3	936.0	877.5	819.0	1122.8
Per Week (m^3)	500.0	450.0	400.0	375.0	350.0	525.0[3]
Evaporation (tcm)	1318.6	1422.6	1526.7	1580.1	1633.0	1165.1
Overdraft (tcm)	15.9	9.1	5.2	3.7	2.4	3.2
Number of Weeks	(32)	(19)	(11)	(8)	(5)	(7)
Change in Storage (tcm)	+7.2	+8.6	+9.8	+10.5	+11.1	+14.5
Storage Efficiency (%)[2]	47.1	42.4	37.7	35.3	33.0	49.4
Minimum Storage (tcm)	0.0	0.0	0.0	0.0	0.0	0.0
Amount Pumped:						
Concentration (tcm)	180.6	181.6	197.1	192.0	198.9	171.9
Initial (tcm)	2242.8	2258.5	2273.1	2280.1	2288.6	2152.6
Excess (tcm)	14.6	20.0	26.7	30.5	33.3	94.3

[1]Total capacity of the system was kept constant at 75,000 m^3. Compartments were 12,500 m^3 in size. Depth of compartments was five meters.
[2]Efficiency = 100 (C.U. ± change in storage)/runoff. Total runoff = 2493.9 mcm. Water in excess of 35,000 m^3 per week or in excess of total available storage of 75,000 m^3 plus the 35,000 m^3 collection compartment was counted as overflow.
[3]An evaporation cover was placed on the sixth compartment in this example.

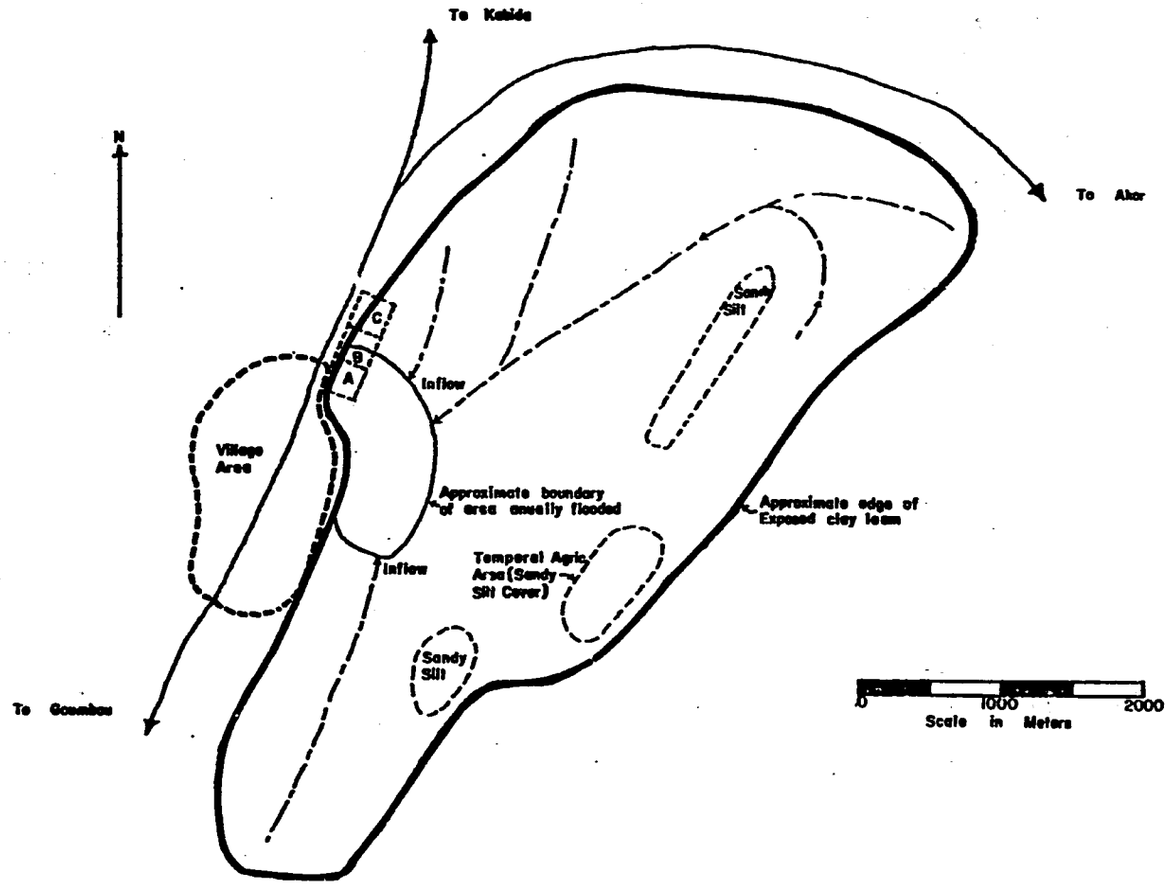

Figure 4-4. Outline of Nara Watershed Showing Location of Compartmented Reservoirs (Cluff, 1975).

believed that the 40-percent efficiency with a 10 mm depletion used in the original design could be easily attained on this watershed by constructing two or three drainage channels.

A summary of the original design computed using the HP-25 is shown in Table 4-9. The table shows both a 50,000 m^3 per month and a 100,000 m^3 per month consumptive use during an average year and 80,000 m^3 per month during 1962-1963. This same design was analyzed on the CDC 6400 using CROP-76 in conjunction with the water-yield model which projected a 38.6 percent overall runoff over the 45-year period. The results using both a 50,000 m^3 per month and 100,000 m^3 per month consumptive use are summarized in Table 4-10.

It is interesting to note that CROP-76 gave results similar to the abbreviated version as shown in Table 4-9. The use of the previously recommended design would provide 100,000 m^3 per month (23,077 cubic meters per week) for all except two weeks during the 45-year period.

Tables 4-11 and 4-12 contain information for Nara for reservoir systems of various sizes and a consumptive use of 150,000 m^3 and 200,000 m^3 per month, respectively. A 16-year period covering the critical drought years during the 45-year record was used in this comparison. The comparison was made to show how the size of the compartments affect efficiency of a storage system. In the previous examples the consumptive use and depth of the reservoir were varied while the compartment volume remained fixed. In these comparisons consumptive use and depth were fixed and the volume of reservoir was varied. It was interesting to note that the amount of overdraft from the compartmented tanks was somewhat insensitive to change in compartment size whereas the overdraft from the single-compartmented reservoir was much more sensitive to

Table 4-9. Nara, Mali -- Original Design for a Compartmented Reservoir. -- From Cluff (1975).

Effective Watershed Area:	Estimated at 14,550,000 m^2
Runoff Efficiency Modifier:	Estimated at 0.40 with channelization
Depletion:	10 mm
Average Rainfall:	494 mm
Average Potential Runoff:	Without channelization = 1,427,000 m^3 With channelization = 2,853,000 m^3

Recommended Design:

	Three Compartments			
	Compartment A	Compartment B	Compartment C	Total
Depth (m)	10	10	10	-
Area (m^2)	50,000	50,000	50,000	150,000
Volume (m^3)	500,000	500,000	500,000	1,500,000

Required Earthwork: 338,900 m^3

Year		Average Year					1962-1963		
Month	Evap. (mm)	Rain (mm)	VT[1]	ET[1]	VT[1]	ET[1]	Rain (mm)	VT[1]	ET[1]
Initial	-	-	750.0	0.0	750.0	0.0	-	750.0	0.0
Sep.	109	80	1088.0	16.4	1038.0	16.4	34	797.7	10.9
Oct.	183	16	1045.2	43.8	945.2	43.8	15	728.3	29.2
Nov.	253	0	957.2	81.8	819.9	69.1	0	623.0	54.5
Dec.	256	0	881.6	107.4	694.3	94.7	0	517.4	80.1
Jan.	281	0	803.5	135.5	566.2	122.8	0	409.3	108.2
Feb.	317	0	721.8	167.2	434.5	154.5	0	313.4	124.0
Mar.	402	2	631.6	207.4	314.4	174.6	0	213.4	144.2
Apr.	405	4	541.1	247.9	194.1	194.9	5	113.1	164.4
May	423	14	471.9	290.2	96.1	216.0	38	173.7	185.6
June	317	59	673.3	321.9	263.3	231.8	40	251.1	201.4
July	163	133	1309.3	346.3	857.4	248.1	128	836.4	217.7
Aug.	95	182	1435.8[2]	360.6	1385.7	262.4	76	1123.3	231.9
Totals	3204	444					336		
C.U. (m^3 per month)			50,000		100,000			80,000	
E (m^3)			360,000		262,400			231,900	
Storage Efficiency (%)			62.5		82.0			80.5	

[1]Units are in thousands of cubic meters.
[2]Runoff exceeded storage capacity.

Table 4-10. Summary of Use of Compartmented Reservoir for Nara, Mali. -- Using 45 years of records, 1921-1965).

Depth (m)	10	10
Number of Compartments[1]	3	3
Consumptive Use:		
Monthly (m^3)	50,000	100,000
Weekly (m^3)	11,500	22,500
Evaporation (tcm)	21,912.5	20,505.7
Overdraft (tcm)	0	39.4
Number of Weeks	-	(2)
Change in Storage (tcm)	+650.4	+ 648.2
Storage Efficiency (%)[2]	55.8	72.3
Minimum Storage (tcm)	648.5	0
Amount Concentrated by Pumping (tcm)	2339	2811.3

[1]Total capacity of the reservoir system was kept constant at 1500 tcm. Three compartments were used; compartments were 500 tcm.

[2]Efficiency = 100 (C.U. ± change in storage)/water stored. Total runoff = 151.2 mcm. Runoff in excess of the capacity of the above reservoir system was kept in an existing "mare" which was approximated by a 4,000,000 m^3 reservoir four meters deep. The loss in water from the mare was not included in the determination of the above efficiencies.

Table 4-11. Summary of Use of 10-Meter Deep Compartmented Reservoir for Nara, Mali, Using 150,000 m^3 per Month Consumptive Use[1]. -- Using 16 years of records, 1950-1965.

	One Compartment				Three Compartment				Six Compartment			
Consumptive Use[2]:												
Monthly (tcm)	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Weekly (tcm)	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6
Overdraft:												
Number of Weeks	16	6	4	7	38	39	53	72	15	3	0	0
Percent of Total Time	1.92	0.72	0.48	0.84	4.57	4.69	6.37	8.65	1.80	0.36	0	0
Efficiency (%)[2]	54.6	55.2	55.0	55.1	52.9	52.6	51.6	50.1	54.6	55.3	55.3	55.7
Efficiency Factor (%)[3]	53.5	54.8	54.7	54.6	50.5	50.1	48.3	45.8	53.6	55.1	55.3	55.7
Minimum Storage (tcm)	0	0	0	0	0	0	0	0	0	0	92.5	162.5
Compartment Size (mcm)	1.0	1.5	2.0	2.5	3.0	4.5	6.0	7.5	0.5	.75	1.0	1.25

[1]Total capacity of the reservoir system was varied according to the given compartment size.
[2]Storage efficiency = 100 (C.U. ± change in storage - overflow)/runoff. Total runoff = 51,955,320 m^3.
[3]Efficiency factor - efficiency x fraction of time the system meets the C.U. demand.

Table 4-12. Summary of the Use of a 10-Meter Deep Compartmented Reservoir for Nara, Mali, Using a 200,000 m^3 per Month Consumptive Use[1]. -- Using 16 years of records, 1950-1965.

	One Compartment				Three Compartments				Six Compartments			
Consumptive Use[2]:												
Monthly (tcm)	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
Weekly (tcm)	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5
Overdraft:												
Number of Weeks	79	85	108	149	50	43	42	47	47	38	35	38
Percent of Total Time	9.5	10.2	13.0	17.9	6.0	5.2	5.0	5.6	5.6	4.6	4.2	4.6
Efficiency (%)[2]	66.4	65.8	63.6	59.7	69.2	69.8	69.8	69.3	69.5	70.3	70.4	70.1
Efficiency Factor (%)[3]	60.1	59.1	55.3	49.1	65.0	66.9	66.3	65.4	65.6	67.1	68.1	66.9
Minimum Storage (tcm)	0	0	0	0	0	0	0	0	0	0	0	0
Compartment Size (mcm)	3.0	4.5	6.0	7.5	1.0	1.5	2.0	2.5	0.5	.75	1.0	1.25

[1]Total capacity of the reservoir system was varied according to the above given compartment size.
[2]Efficiency = 100 (C.U. ± change in storage)/runoff. Total runoff = 51,955,000 m^3.
[3]Efficiency factor = efficiency x fraction of time the system meets the C.U. demand.

changes in compartment size. Figure 4-5 is an illustration of this property. An "efficiency factor" was plotted against the compartment size for each of the three systems tested at the two consumptive-use levels. The efficiency factor was calculated as the product of the efficiency and the percent of time that water was supplied by the system. This figure shows a near vertical relationship in the multi-compartmented systems with much more curvature in the one-compartmented system.

It should be noted that the differences between a one-compartmented and multi-compartmented system would be even more dramatic with lower reservoir depths. This already has been illustrated and therefore was not repeated in this example.

Table 4-13 shows the effect of a changing consumptive use on a three-compartmented system of constant volume and depth. The size of compartment was selected based on information contained in Tables 4-11 and 4-12. Table 4-13 shows that the efficiency factor begins to decrease after 250,000 m^3 per month. At a 300,000 m^3 per month consumptive use the system can supply water for only 78.4 percent of the time.

Reservoir System near Youga-Na, Mali

Youga-Na, Mali, is located about 16 kilometers northwest of Songa in eastern Mali. It is located in the Dogan area of Mali where geology is dominated by a sandstone outcrop of considerable areal extent rising up to 300 meters above the surrounding plain. Youga-Na is located on the side of a small sandstone escarpment near the base of vertical cliffs. The "island" escarpment is surrounded by a plain. It is separated from the main escarpment by about two kilometers.

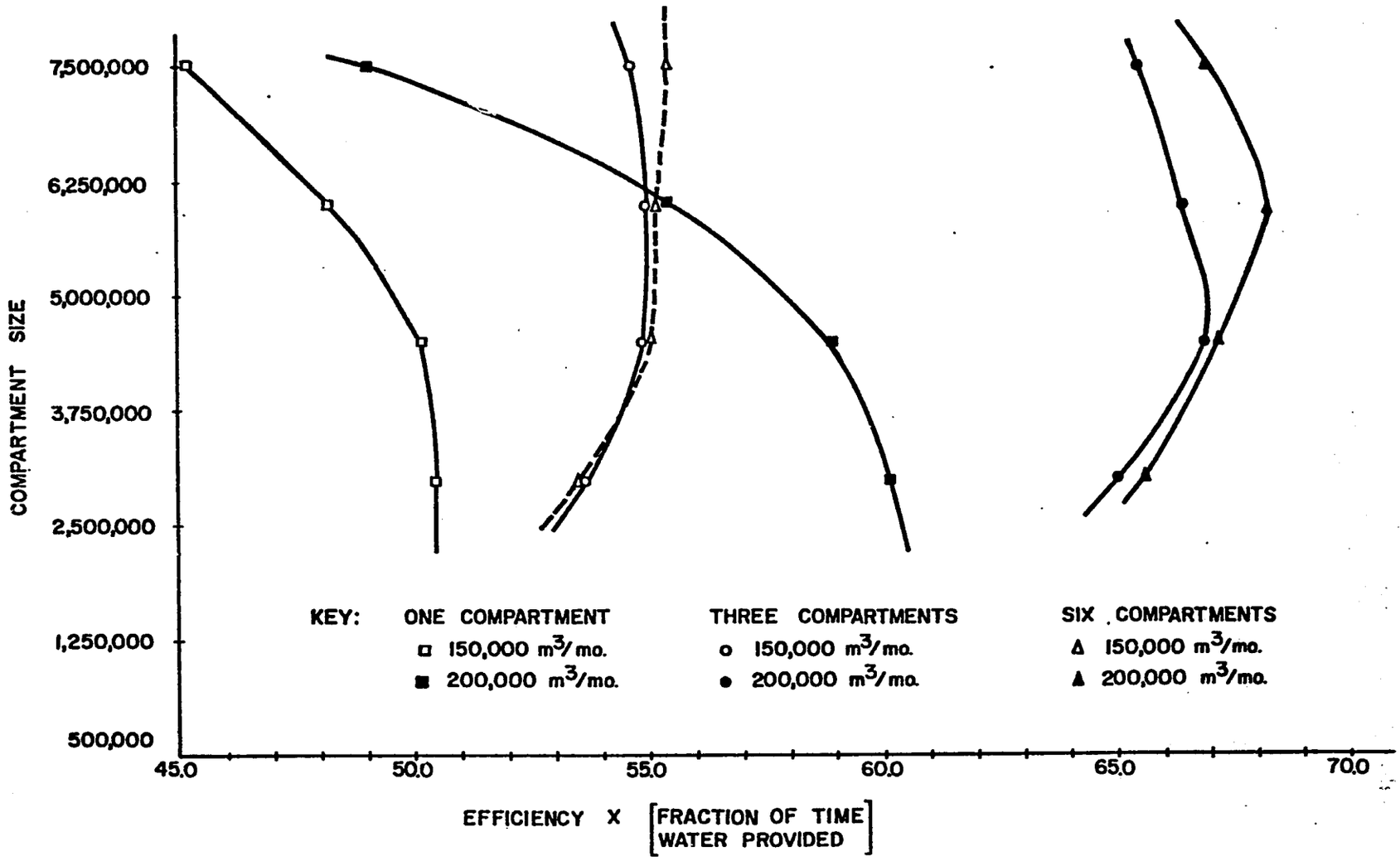

Figure 4-5. Compartment Size Versus an Efficiency Factor for Compartmented Reservoir Systems, Nara, Mali.

Table 4-13. Summary of Use of a 10-Meter Deep Three-Compartmented Reservoir for Nara, Mali, with Varying Consumptive Use[1]. -- Using 16 years of records, 1950-1965.

Consumptive Use (tcm)[2]	100.0	150.0	200.0	250.0	300.0
Overdraft:					
Number of Weeks	0	4	42	93	179
Percent of Total Time	0	0.5	5.1	11.2	21.6
Change in Storage (tcm)	-	-	-	-	-
Efficiency (%)[3]	38.0	55.0	69.8	81.0	86.1
Efficiency Factor (%)[4]	-	54.7	66.3	71.9	67.5
Minimum Storage (tcm)	1321	0	0	0	0
Compartment Size (tcm)	2000	2000	2000	2000	2000

[1]Total capacity of the reservoir system was kept constant at 6,000,000 m^3.
[2]Consumptive use was varied as indicated above.
[3]Efficiency = 100 (C.U. ± change in storage)/runoff. Total runoff = 51,955,320 m^3.
[4]Storage efficiency factor is the product of the efficiency and the fraction of time the system meets the C.U. demand.

The population of Youga-Na is about 500 persons. Many persons have moved out because of the problem of an inadequate water supply. The village was about one-third to one-half inhabited at the time of the author's visit in 1975.

Approximately two kilometers west of Youga-Na is a large mare located on the plains. At the time of our visit the water in the mare covered approximately 12 hectares with an average depth of one meter. The gradient in all directions from the mare was less than one percent. The mare has a large and effective watershed estimated to be 400 hectares. This watershed includes a large area of impervious sandstone. The runoff efficiency of the watershed was estimated at 60 percent with a 15-mm depletion. Because the mare was very shallow relative to the evaporation rate its efficiency was close to zero.

Table 4-14 contains information compiled using average monthly rainfall and evaporation data and the HP-25 program in Appendix E. This table indicates that consumptive use of 80,000 m^3 per month could be maintained with a 10-meter deep, three-compartmented system with each compartment having a 200,000 m^3 capacity in an average year. Using this system, 87 percent of the incoming water could be utilized during an average year.

CROP-76 is used in conjunction with the above design using 45 years of daily precipitation from Bandiagara which is located about 45 km to the southwest. The average rainfall was 506 mm as compared to 592-mm average in Table 4-14.

The water-yield model routed 49.9 percent of this precipitation as runoff through the storage system. This compares with 49.3 percent given in Table 4-14. This analysis showed that 91 percent of the water

Table 4-14. Youga-Na, Mali -- Original Design for a Compartmented Reservoir for the Mare on the Plain. -- From Cluff (1975).

Effective Combined Watersheds:	4,000,000 m^2
Runoff Efficiency Modifier:	0.60
Depletions:	15 mm
Average Rainfall:	592 mm
Average Potential Runoff:	1,170,000 m^3
Recommended Ultimate Design:	Construct three high rise compartments each with 200,000 m^3 capacity. Use a depth of 10 meters. Use the existing mare for collection only.

	Compartment A	Compartment B	Compartment C	Total
Depth (m)	10	10	10	-
Area (m^2)	20,000	20,000	20,000	60,000
Volume (m^3)	200,000	200,000	200,000	600,000
Bank Slope	1:2	1:2	1:2	-
Ave. Depth of Cut (m)	3	3	3	-

Required Earthwork: 178,000 m^3

Year Month	Average Evap. (mm)	Average Rain (mm)	Runoff (m^3/1000)	V (m^3/1000)	E (m^3/1000)	Excess Water (m^3/1000)
Initial	-	-	-	600.0	0.0	-
Nov.	252	3		505.0	15.1	
Dec.	267			408.9	31.1	
Jan.	304			310.6	49.4	
Feb.	352			216.5	63.5	
Mar.	448	2		118.6	81.4	
Apr.	428	10		30.1	89.9	
May	391	22	16.8	0.0[1]	97.8	
June	291	68	127.2	41.4	103.6	
July	181	148	319.2	273.3	110.8	
Aug.	101	200	444.0	600.0	116.9	31.3
Sep.	97	111	230.4	600.0	122.7	144.6
Oct.	161	28	31.2	541.5	132.4	

[1]Only 40,000 available this month.

Note: C.U. = 80,000/month; Storage Efficiency = 87%; and runoff efficiency = 49.3%.

stored in the system could be used. However, 28 percent of the runoff overflowed from compartment 1 and is not included in the amount going into the reservoir system. In addition there is an overdraft 45 percent of the time. Obviously more storage is needed.

This illustrates that reservoir designs cannot be based on the use of average hydrologic data.

An additional three runs of CROP-76 were required before a match was found between maximum constant consumptive use and compartmented-reservoir system. Using the 45 years of daily data, 1921-1965, each run required 8.4 seconds of compilation time and a core capacity of 115,000. A four-compartmented system was used with a five-meter deep collection compartment having a capacity of 1,000,000 m^3 and three ten-meter deep compartments each with a capacity of 400,000 m^3. This system would support a continuous consumptive use of 40,000 m^3 per month without any deficiency. The minimum storage of 18,200 m^3 occurred in 1952. There was a 4.8 percent overflow from compartment "1" using this sytem. Some overflow is acceptable since it would usually be uneconomical to try to utilize all of the runoff. The overall storage efficiency excluding the overflow was 51.3 percent. The increase in dependability was achieved at cost of a reduction in efficiency.

Storage for Water Harvesting Agrisystem at San Francisco del Barreal, Coahuilla, Mexico

The San Francisco Ejido is approximately 30 kilometers south of Parras near the southern border of Coahuilla in northeastern Mexico. The Ejido covers an area of 24,000 hectares that supports a population of 350 inhabitants. The people have few resources primarily due to the arid nature of their environment. Although precipitation data are

lacking, there are records nearby at Parras, Coahuilla, and Viesca, Coahuilla. Of the two stations the one at Viesca comes closer to representing the climatic conditions at San Francisco Ejido although it is a little lower in elevation. Ten years of daily records, 1966-1975, from Viesca are available. These data include daily precipitation and daily pan evaporation.

The annual precipitation ranged from a high of 342 mm in 1968 to a low of 97 mm in 1920. The average is 181 mm. The long-term average at Parras is higher at 347 mm.

The water resources are very meagre throughout the broad alluvial valley in which San Francisco is located. There is a shallow groundwater source (water depth = 30 m) in the alluvial fill beneath the Ejido but it is saline. A domestic well at the Ejido was drilled into a hard rock aquifer below the alluvium. The quality is a little better but it is still relatively saline. Tests have shown that the water is unsuitable for agriculture unless it is blended with high quality runoff water. Further supply is limited and can be used only for agriculture during periods of drought.

Soil analyses indicate that the soils are saline-sodic containing about 10 percent clay. The soil contains enough sodium to yield a high percentage of runoff when compacted. The soil under the planted area can be reclaimed if high-quality surface water is used.

The conditions for a water harvesting system seem ideal except for the relatively low precipitation. The relatively low annual precipitation makes the use of a compartmented reservoir essential for optimum water production. A small number of mature peach and fig trees in temporal areas provide encouraging evidence that fruit trees do survive.

However, the production from the trees is limited to the years when high precipitation is obtained.

A 20-hectare water harvesting system with a three-compartmented reservoir was laid out in the form shown in Figure 4-6. Photographs of the system are shown in Figure 4-7. The 20-hectares were cleared first. Then a D-8 dozer was used to pull a root plow to loosen the soil under the area which was to be planted. A nine-meter spacing was used. A road grader then shaped the catchment. The catchment was to be compacted sometime in the future after a rain.

The compartmented reservoir system was matched to the 20-hectare system using a modified version of the HP-25 program detailed in Appendix E.

The HP-25 analysis for an average rainfall year is shown in Table 4-15. Monthly precipitation data from Parras were used after being reduced to accommodate elevation differences. A series of three years (1956, 1957 and 1958) was also used in the HP-25 program in a similar manner as Table 4-15. These years had the lowest cumulative rainfall of any three-year sequence on record. They were used to establish the design used in Table 4-15. The design was checked using CROP-76 and the ten years of records available from Viesca. The analysis shows that the design is adequate except that the receiving compartment needs to be twice as large in capacity to avoid excessive overflow before the water can be pumped into the deeper compartments. Interestingly, the Fundo Candelillero had already discovered the deficiency (without the use of CROP-76) and had built a second receiving compartment before the author's recent visit.

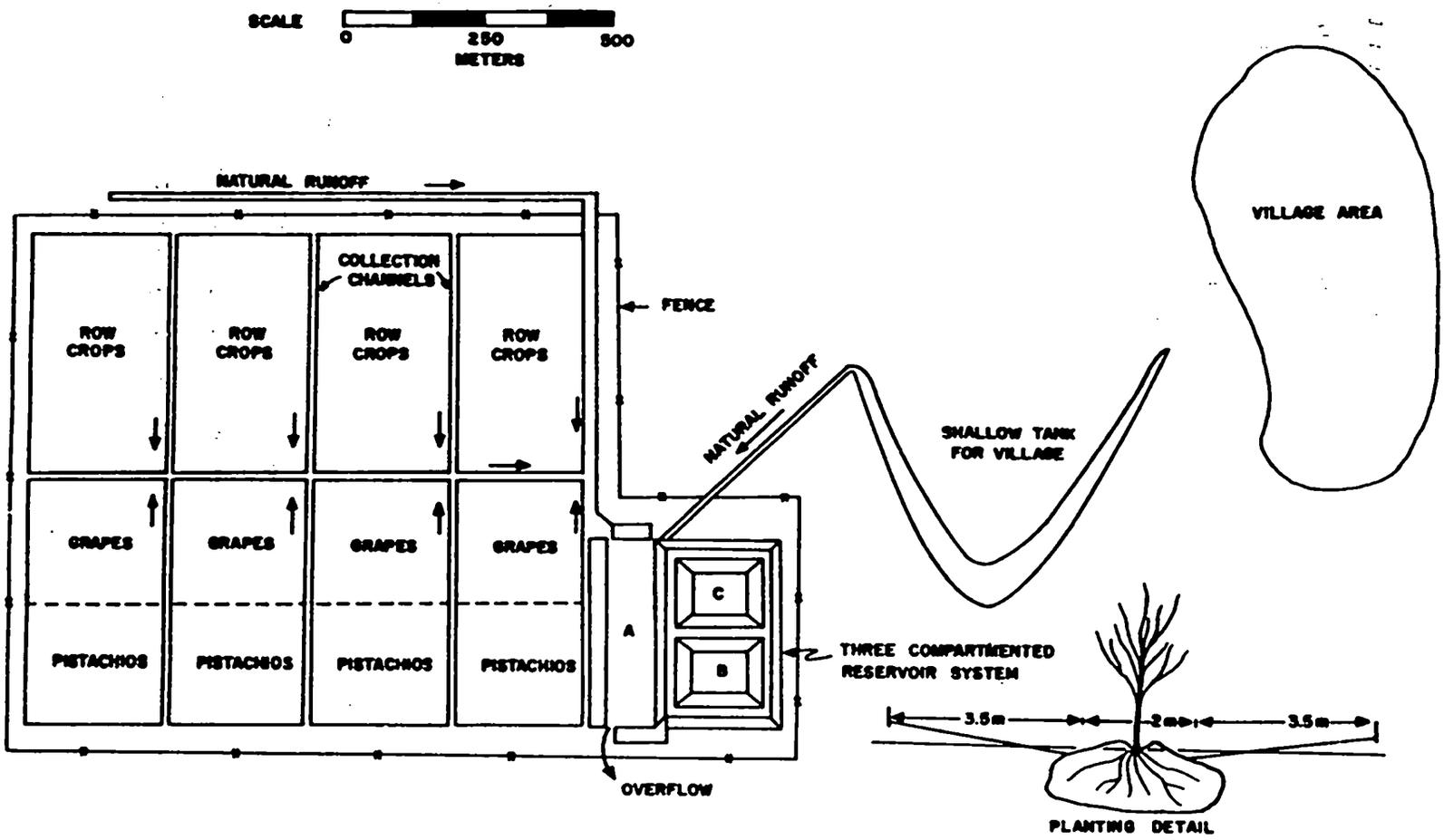

Figure 4-6. Twenty-Hectare Water-Harvesting Agrisystem and Compartmented Reservoir.

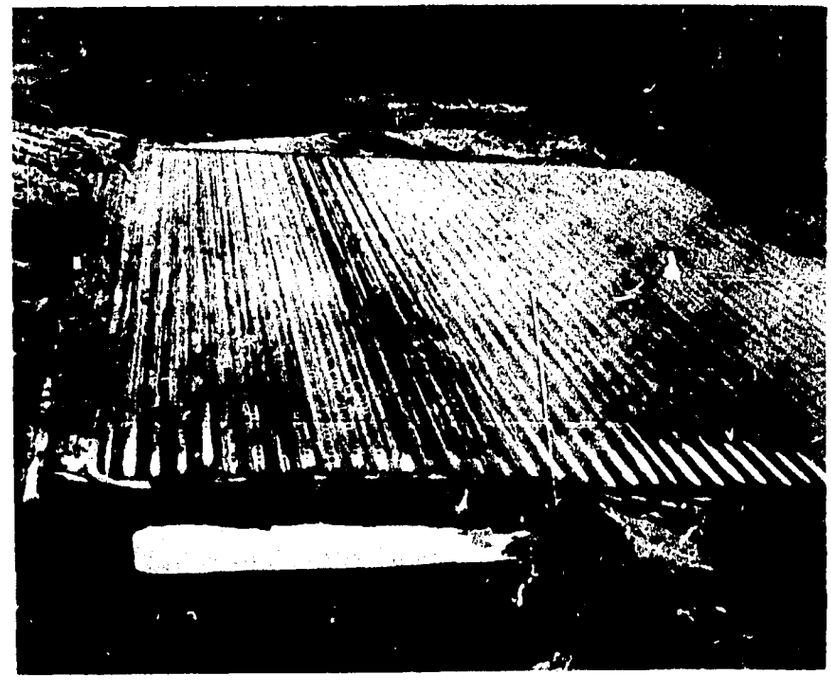

Figure 4-7. Twenty-Hectare Water Harvesting Agrisystem near San Francisco, Coahuilla, Mexico. -- Above: Aerial View of the Catchment during Construction. Below: The Compartmented Reservoir.

Table 4-15. Water Budget for San Francisco del Barreal Water Harvesting Agrisystem. -- From Cluff (1976). For explanation of footnotes see the next page.

Months	Evap. (mm)[1]	Rain (mm)[2]	Runoff (m^3)			Consumptive Use (m^3)		Available Soil Moisture[7] m^3	Surface Storage (m^3)		
			Treated[3]	Natural[4]	Total	Orchard[5]	Row Crops[6]		Inflow and Discharge[8]	Evap. Loss[9]	Net Volume[10]
Jan.	111	8						11,250		480	28,220
Feb.	127	8				465		10,785		549	27,670
Mar.	196	5				1395		9,390		847	26,825
Apr.	226	6				1800		7,590		976	25,840
May	229	16	720		720	2325		11,250	-5791	989	10,060
June	203	37	3,240	2,400	5,640	2325		14,565			19,060
July	194	48	4,560	4,600	9,160	2325	2700+	15,000	+6400		22,760
Aug.	170	41	3,720	3,200	6,920	1860	2200	15,000	+5060		25,620
Sep.	135	38	3,360	2,600	5,960	1350	1500	15,000	+4610	583	28,150
Oct.	113	20	1,200		1,200	930	1000	15,000	+270	488	26,935
Nov.	94	8				225		14,775		496	26,530
Dec.	105	10						14,775		454	26,070
Totals	1910+	250	16,800	12,800	29,600	15,000	(7400)			5772	
% Runoff			34	5.1							

Table 4-15. Continued. Footnotes (see preceding page).

[1]Pan evaporation at Parras was used after multiplying by a 0.85 pan coefficient insteady of the usual 0.70 to reflect the higher evaporation loss at San Francisco del Barreal.

[2]Average rainfall for Parras, Coahuilla, was reduced by (250/247) to reflect the difference in climatic regimes.

[3]Runoff from treated area = 0.0006 A (R-10) where A = 200,000 m^2 (20 hectares) and R = the monthly rainfall in mm.

[4]Runoff from natural area - 0.002 A (R-25) where A = 1,000,000 m^2 (100 hectares) and R = monthly rainfall in mm.

[5]Consumptive use is based on 6800 liters per tree with 220 trees per Ha. Total annual consumptive use was 15,000 m^3.

[6]Consumptive use is based on 500 mm of supplemental water for the area planted. This planted zone represents 22 percent of the temporal or row crop area.

[7]The available soil moisture is the difference between the field capacity and the permanent wilting point in the soil area within reach of the roots of the trees. The total amount of available soil moisture was 15,000 m^3. The soil moisture was allowed to go down to only 50 percent of capacity of 7500 m^3. At this time the orchard was irrigated to bring the soil moisture back to 75 percent of capacity.

[8]When the soil moisture is at field capacity, excess water goes into the tank. Withdrawals for irrigation is indicated by the negative sign.

[9]Evaporation loss is a function of storage. An evaporation cover is proposed for compartment C. When the volume in storage drops below the volume stored in compartment C, there are no losses. Initial storage assumed was 1/2 of the total capacity of 57,400 m^3. The compartmented tank used in obtaining the data in this table had the following sizes:

$A_A = 4320\ m^2$	$A_B = A_C = 4320\ m^2$
$d_A = 1.9\ m$	$d_B = d_C = 5.7\ m$
$V_A = 8200\ m^3$	$V_B = V_C = 24{,}600\ m^2$

[10]Net storage remaining in the compartmented tank.

The analysis by CROP-76 indicated that an evaporation cover on compartment C is essential to assure maximum production from the 2.25 hectares of mature trees and/or grapes.

The Viesca precipitation data were multiplied by a ratio of 250/180 and a row crop evapotranspiration demand was added to the demand for mature trees. CROP-76 was run again to ascertain if, under these conditions, both the orchard and the temporal could be planted. The complete printout of this run is shown in Appendix D. It shows that the reservoir went dry for three weeks in July of 1971 but that there was adequate soil moisture to assure full production of both the orchard and the row-cropped area.

The operational procedure is to delay planting the row crops until adequate water is stored in the compartmented reservoir. Under this procedure planting would have been delayed until the 31st week in 1971.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

The objectives of the dissertation project were satisfied by the development and use of CROP-76. This mathematical model proved to be effective in clarifying the functions of various parameters involved in the operation of the compartmented reservoir. The effect of varying the parameters within constraints of the physical system is determined by making repeated runs with the computer. The parameters of the water-yield routine were first calibrated to give an appropriate amount of runoff. The main criterion used in the calibration was the runoff efficiency for the entire period. Runoff efficiency is defined as the percent of total precipitation that appeared as runoff into the reservoir. If the runoff efficiency was satisfactory it was usually found that the distribution of the runoff with time was also acceptable. This procedure was verified to some extent in the calibration process of watershed HL-1 on the Atterbury Experimental Watershed. Measured runoff data for a ten-year period was compared to that computed by the model on a daily and annual basis. This calibration indicated that the water-yield routine was satisfactory for the purposes of this study. Other suitable water-yield models can be interfaced with CROP-76 if desired.

The concept of the compartmented reservoir lends itself to staged construction. The first compartment could be excavated and used for collecting runoff for a period of time. Measurements of rainfall and runoff could then be made to aid in the calibration of the model before

a final sizing of additional compartments was made. This would also provide a source of construction water, a vital ingredient of a successful embankment construction.

The model is successful in simulating activities related to pumping, or moving water from one compartment to the others, when there is sufficient unused capacity. The pumping was to be done at discreet times in order to allow for the use of portable high-capacity pumps. These pumps were described in Appendix A and are vital to the operation of a compartmented system in flat terrain where it is expensive to develop head through excavation. Where there is sufficient topographic relief a gravity-fed compartmented reservoir can be installed. Under this system compartments, connected by pipes or elevated canals, are spaced down a slope so that the upper compartments can be completely drained into lower compartments. Spacing is dependent on the degree of slope, depth of the tank and size of the pipe.

The model showed that the amount of water pumped for "concentration" in the operation of a compartmented system is usually less than the amount of water available for consumptive use if the water is removed at a constant rate. However, if a compartmented reservoir is used only to supply water during the dry part of the year or during drought years, the amount of "concentration" pumping would probably exceed the amount of water available for consumptive use. Based on the evidence given in Appendices A and B if efficient high-capacity portable pumps are used the cost of pumping would be small in comparison to the amortization costs of the installation of the compartmented reservoir.

Seven examples of the application of a compartmented reservoir were presented including the 6,000 m^3 system at the HL-1 subwatershed of

Atterbury Experimental Watershed near Tucson, Arizona. This watershed was used for calibration of the model. This model calibration is described in Chapter 3. The other systems are given in Chapter 4. The sizes of the combined compartments ranged from the 6,000 m^3 reservoir at Atterbury HL-1 to the 90,000,000 m^3 reservoir which is proposed to store floodwaters from the Santa Cruz River near Tucson, Arizona. The use of the model with systems that would store solar pumped water as well as for water harvesting agrisystems indicates the wide application of the concept in areas of high evaporation loss.

Most of the understanding of the relation between compartmented reservoir parameters comes from the repeated use of CROP-76 for the Santa Cruz River reservoir in Arizona and the Goumbau and Nara reservoirs in Mali. The Youga-Na, Mali, example was included because of the interest of the sponsoring agency (AID) and the comparison it afforded with a previous design made using the simplified HP-25 program and monthly data. The results obtained using the HP-25 calculator were similar to those obtained using CROP-76. The notable exception was the compartmented reservoir design at Youga-Na. In this example the HP-25 design was based on data from an average year.

The interrelationship of the parameters of volume, area, depth and slope of the embankment for each compartment was studied using the above examples.

The following conclusions are made:

1. The rate of increase in storage efficiency is greatest when a one-compartmented system is converted to a two-compartmented system. There is an additional significant improvement when going from two to three compartments. However, the rate of

increase in storage efficiency diminishes as the number of compartments increases.

2. The model did not indicate a significant difference in overall storage efficiency resulting from varying the relative size of the several compartments provided the total size as well as other factors remain constant. As observed in Chapter 4 this came as a surprise since one might suppose that higher efficiency would result if the "last" water was stored in the smallest compartment. The slight improvement obtained by sizing compartments differently does not appear to be worth the additional cost involved. However, this idea was not studied in conjunction with the evaporation cover. In that case it might be more expedient if the last compartment to have water in it was made smaller in order to reduce the cost of the evaporation cover.
3. The increase in efficiency due to the use of the compartmented system decreases as the depth of the reservoir increases, becoming insignificant at a depth or 20 or more meters.

The model has shown the advantages of adding an evaporation cover to the last compartments if more water is needed. This is much more cost effective than trying to cover the entire reservoir in a conventional one-compartment system. Covering only the last compartment has the advantage of covering all remaining water when it is most needed during dry periods.

The evaporation savings as determined by CROP-76 are based on a reduction of surface area only. There should also be a significant reduction in the rate of evaporation in decreasing the temperature by

increasing the average depth. In smaller systems there might also be a reduction in evaporation caused by the embankments shielding the water surface from wind.

The use of CROP-76 has increased the general understanding of the compartmented reservoir. The extent of the compartmented reservoir applicability has been elucidated. The use of the model has shown that the compartmented reservoir system can provide a dependable method of storage in the drier areas of the world. Hall and Dracup (1970) made the statement that water harvesting systems "are tantalizingly near to economic feasibility." The compartmented reservoir may be the missing link that will make water harvesting practical. It then can be used to stabilize agriculture in marginal dry land areas and open up additional land for production of food and fiber in semiarid areas.

Finally, the use of CROP-76 has demonstrated that evaporation losses can be significantly reduced by compartmentalizing shallow impervious reservoirs and concentrating water by pumping it from one compartment to another.

CHAPTER 6

RECOMMENDATIONS FOR FUTURE STUDY

Additional research is needed to determine the effect of the compartmented reservoir on reducing water temperature and rate of evaporation loss.

More work is needed to develop design and construction procedures of gravity-fed separated compartmented reservoirs.

A suitable sediment transfer routine needs to be incorporated into CROP-76 in order to estimate the cleaning interval of the receiving compartment.

Additional data are needed to determine the relationships involved between compartmented reservoirs and seepage. This effect, when documented, can be included in CROP-76.

A detailed economical study of the compartmented reservoir system in various applications in different parts of the world needs to be made.

New construction methods may be needed to minimize the cost of constructing earthen embankments between compartments.

A four-wheel drive pickup or similar vehicle needs to be equipped with a power-take-off and used in conjunction with the pumps given in Appendix A. This combination needs to be used for compartmented reservoirs in one area over a period of time to further prove this method of pumping in the compartmented system.

Additional work is justified in improving the soil moisture accounting method in the agrisystem option of CROP-76. A possible direction to take would be to utilize an overland flow and infiltration routine as was done by Hanson et al. (1975).

The coupling of CROP-76 with a linear programming routine evaluating economic factors should be investigated, particularly with regard to the optimization of cropping schedules and land use optimization in the water harvesting agrisystem option.

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APPENDIX A

PUMPING METHODS FOR COMPARTMENTED RESERVOIRS

Any conventional pumping system suitable for low head pumping would work with a compartmented reservoir. Small centrifugal pumps would work in low-volume, isolated areas where only one or two reservoir systems are installed. Hand, animal, solar or wind powered pumps can be used. A summary of the available pumps for the developing world has been made by Wood (1976).

Analyses indicate that when the capacity of the reservoir system or systems is high enough, the best economy can be obtained by using a portable high-capacity pump that is operated using a power-take-off (PTO) from either a tractor or a truck. For the smaller and intermediate size reservoirs the use of a portable high-capacity pump is important in reducing pumping costs.

The author knows of three companies in the United States that manufacture portable pumps ideally suited for the compartmented reservoir. These are the Crisafulli Pump Company in Glendine, Montana, the SSR Pump Company in Michigan, North Dakota, and the M & W Pump Works, Inc., Deerfield Beach, Florida. There may be other companies around the world that manufacture similar pumps.

The Crisafulli Company manufactures tractor PTO-operated pumps that range in size from 4" to 24" with capacities from 112 m^3/hr to 5450 m^3/hr. The price varies from approximately $1900 to $2800 for the 4" to 16" sizes. The cost of the 24-inch 5450 m^3/hr pump is approximately $6500. The pumps are capable of working without screens in silt laden water. This sediment laden water would cause damage to a centrifugal-type pump.

The capacity versus total dynamic head curves for these pumps are very flat. Their efficiency drops off dramatically with an increase in

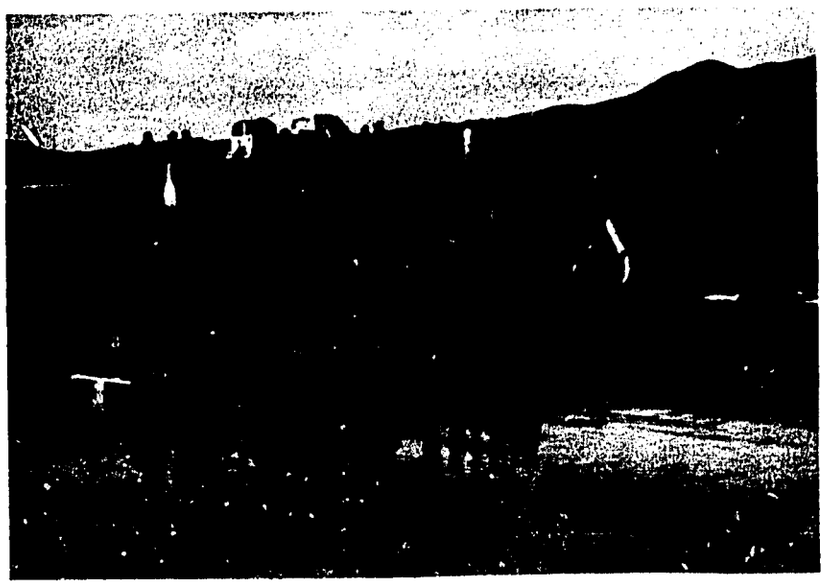
head. They are built to operate under 30 to 40 (9.1 to 12.1 meters). The brake horse power requirements for up to the 16-inch pump (2270 m^3/hr) are less than 30.

The 12-inch pump (1360 m^3/hr) from the SSR Company is being used in Mexico. This particular model has a ratchet arrangement whereby it can be lowered to pump in as little as 10 cm of water. This size was selected for ease in portability. It is used primarily in the Parras, Coahuilla, area where 11 compartmented reservoirs have been constructed, with more scheduled for construction. A photograph of this pump is shown in Figure A-1.

The operating cost of the low-head pumps is close to the operation cost of a farm tractor. In Mexico these costs were determined to be $4.00 per hour for a diesel 75 H.P. farm tractor. (A gasoline-powered tractor would be much higher.)

The amortization costs for the pump are not known since the life of the pump is not known. For the purposes of this report it will be assumed that the pump will last for 10 years when used 20 percent of the time. The total useful life would be 17,520 hours. The amortization cost at a 12 percent interest rate on a $3000 pump (including butyl rubber tubing) would be $401 per year or $0.23 per hour of use. The total cost would be $4.23 per hour or $3.11 per 1000 m^3 for the 1360 m^3 per hour pump.

One pump takes care of several small compartmented reservoirs which greatly reduces the capital expenditure per tank. This aspect reduces maintenance costs as compared with maintaining a small pump for each tank.



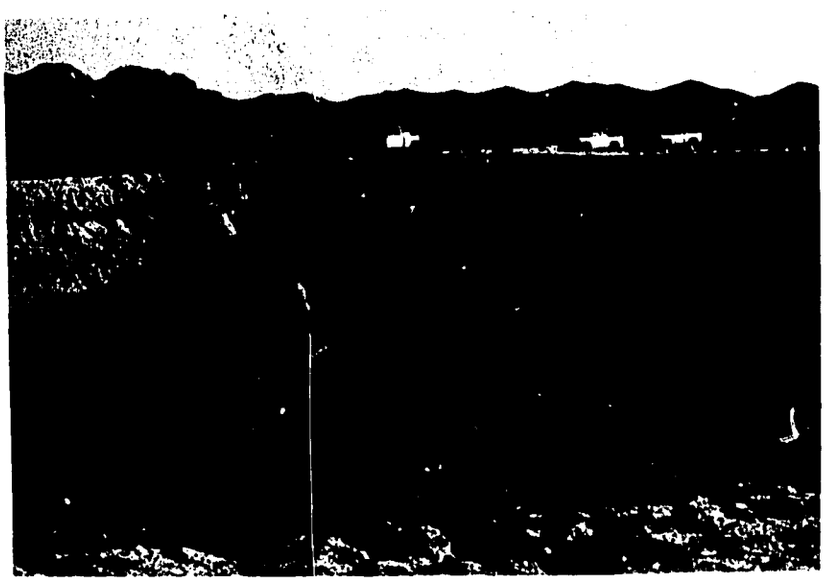


Figure A-1. Twelve Inch SSR Portable Pump Operating at the Ejido Menchaca, Coahuilla, Mexico.

The M & W Pump Works, Inc., manufactures a Mobile Hydroflow pump that is completely portable including the engine. It is different from the above models in that the entire trailer does not back into the water. Rather it has a pipe with a submersible pump on the end that can be extended from a two-axle trailer. These models are available from 8 inches up to 24 inches with flows of 500 to 3900 cubic meters per hour, respectively.

A screw-type pump has the advantages of the above illustrated pumps in that it is possible to pump solid particles. It has the additional advantage that there is very little delivery loss making it very efficient. A new type of screw pump manufactured by the CPC Engineering Corporation of Sturbridge, Massachusetts, rotates the entire cylinder instead of a screw rotary within a stationary pipe. The chief disadvantage is that it requires a 54-inch pump to give the same production as the 12-inch pump offered by SSR and as presently constructed the pumps are not portable.

APPENDIX B

REQUIRED EMBANKMENT MATERIALS FOR COMPARTMENTED RESERVOIRS

Table B-1 gives the volume of embankment material and costs of a six-meter deep reservoir of various sizes and bank slopes. The table shows how the quantity of embankment material drops as the size of the reservoir increases. The table also gives the required cut over the reservoir area needed to provide sufficient material for the embankment. Figure B-1 gives the volume of embankment versus depth for various side slopes. This figure shows graphically how the use of flatter slopes dramatically increases the volume of embankment particularly in the deeper reservoir.

Table B-2 gives an estimated cost per cubic meter of constructing a compartmented system where the compartments would be built against an existing dam or built separately. When built against an existing structure the first compartment would require three sides and the succeeding compartments would require only two. When built by itself or in the middle of an existing reservoir the first compartment would require four sides and succeeding compartments would require three.

These costs do not include seepage control or interconnecting pipeline.

TABLE B-1. EMBANKMENT QUANTITIES AND COSTS OF SIX METER DEEP RESERVOIRS OF THE INDICATED SIZE AND BANK SLOPES FOR A TOP WIDTH OF ONE METER.

SIZE HECTARES	RESERVOIR VOLUME (tcm)	REQ. BANK MATERIAL (tcm)				BANK MATERIAL/m^3 STOR.			
		1:1	1:1.5	1:2	1:2.5	1:1	1:1.5	1:2	1:2.5
1/2	30	7.0	8.7	9.7	10.7	0.23	0.281	0.324	0.358
1	60	11.1	13.9	16.5	18.5	0.19	0.233	0.275	0.308
2	120	17.6	22.3	26.5	29.9	0.15	0.186	0.221	0.249
4	240	26.7	35.3	42.3	47.9	0.11	0.147	0.176	0.200
8	480	39.1	53.7	73.5	76.4	0.081	0.112	0.153	0.159
16	960	59.1	78.6	98.4	116.5	0.062	0.082	0.102	0.121
32	1,920	86.4	11.9	149.3	177.2	0.045	0.062	0.078	0.092
64	3,840	126.2	171.2	218.6	281.6	0.033	0.045	0.057	0.073

SIZE HECTARES	COST[1]/m^3 STOR.				REQUIRED CUT[2] (m)			
	1:1	1:1.5	1:2	1:2.5	1:1	1:1.5	1:2	1:2.5
1/2	0.093	0.116	0.130	0.143	1.5	1.8	2.1	2.3
1	0.074	0.093	0.110	0.123	1.2	1.5	1.7	1.9
2	0.059	0.074	0.088	0.100	0.9	1.2	1.4	1.6
4	0.045	0.059	0.071	0.080	0.7	.9	1.1	1.3
8	0.033	0.045	0.061	0.069	0.6	.7	1.0	1.0
16	0.025	0.033	0.041	0.049	0.4	.6	.7	.8
32	0.018	0.025	0.031	0.037	0.3	.4	.5	.6
64	0.013	0.018	0.023	0.029	0.2	.3	.4	.5

[1]The costs are based on $0.40 per cubic meter.

[2]This is the depth of material over the given area of the reservoir that is needed to construct the banks at the indicated slope.

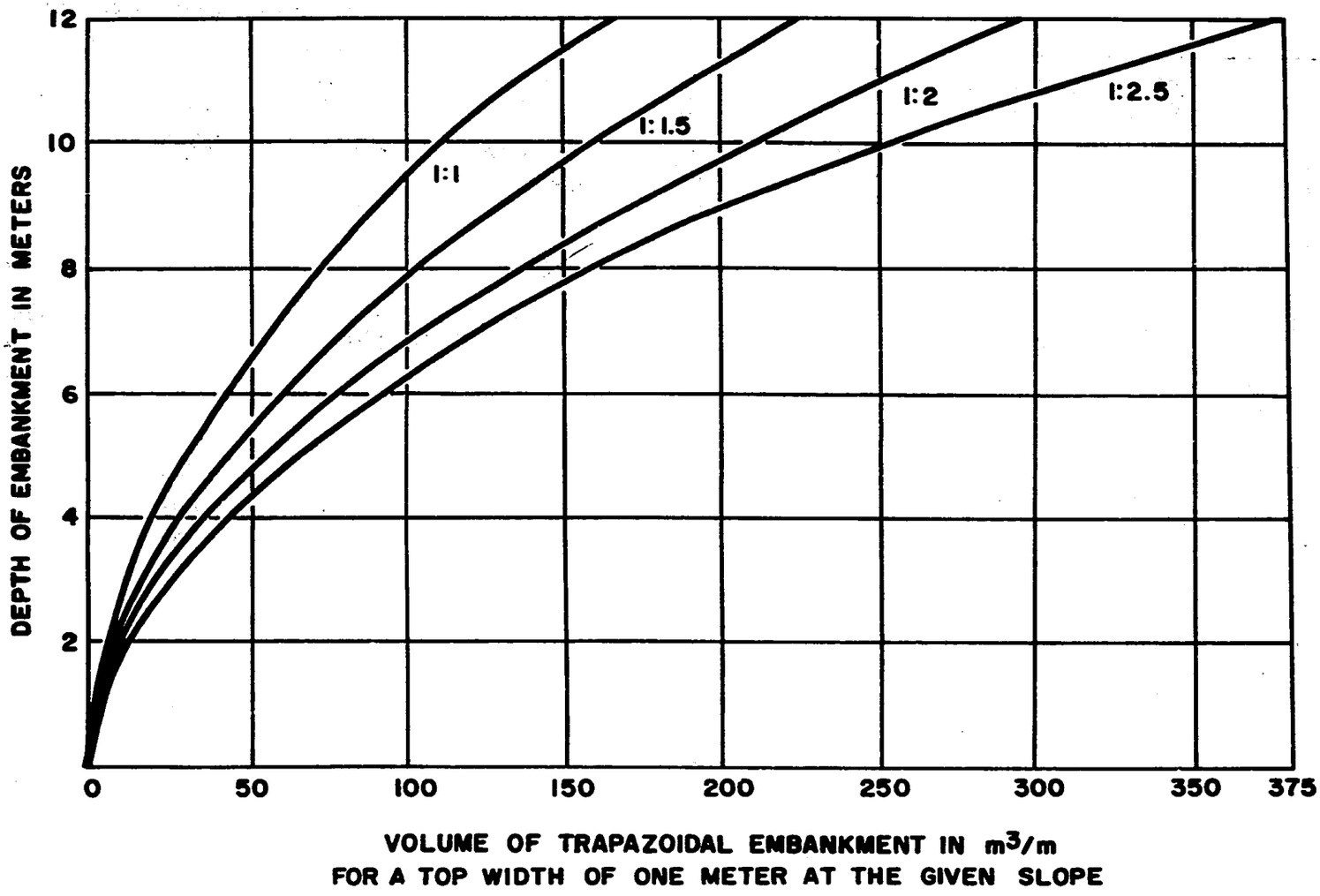


Figure B-1. Volume of Embankment Versus Depth for Various Side Slopes.

TABLE B-2

COST ESTIMATING INFORMATION FOR THE COMPARTMENTED RESERVOIR WHERE CUT EQUALS THE VOLUME OF EMBANKMENT

Where d = 6.0m with a 0.5m freeboard

Bank slopes = 1:2.5

Top width = 1m

Construction cost = $0.40 (U.S.) per m^3 plus 25% for engineering and miscellaneous.

Av. Size Ha.	Volume (m^3)	Capital Cost/m^3 of Storage (U.S.) Four Banks	Three Banks	Two Banks
1/2	30,000	$ 0.197	$ 0.171	$ 0.137
1	60,000	0.169	0.145	0.110
2	120,000	0.138	0.117	0.084
4	240,000	0.110	0.089	0.073
8	480,000	0.095	0.071	0.051
16	960,000	0.067	0.054	0.037
32	1,920,000	0.051	0.039	0.027

Av. Size Ha.	Volume in 1000 m^3			Av. Cost/1000 m^3 Storage (U.S.) Against an existing dam			Middle of existing reservoir		
	No. of Compartments			No. of Compartments			No. of Compartments		
	two	three	four	two	three	four	two	three	four
1/2	60	90	120	154	148	146	184	180	178
1	120	180	240	128	122	119	157	153	151
2	240	360	480	101	95	92	128	124	122
4	480	720	960	81	78	77	100	96	94
8	960	1,440	3,840	61	58	56	88	79	77
16	1,920	2,880	7,680	46	43	41	61	58	57
32	3,840	5,760	15,360	33	31	30	45	43	49

APPENDIX C

FORTRAN IV LISTING OF CROP-76

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      PROGRAM CROP76 (INPUT, OUTPUT, TAPE 5 = INPUT, TAPE 6 = OUTPUT)
C  ******************************************************************
C                    VARIABLES USED IN PROGRAM CROP-76
C A          MODIFIER TO ADJUST THE DOMESTIC USE IF CALLED FOR.
C A(J)       CURRENT AREA OF COMP. J.
C AB         BOTTOM AREA OF RESERVOIR.
C ABSTN      DAILY DEPLETION FOR NATURAL WS.
C ABSTW      DAILY DEPLETION FOR TREATED WS.
C AF         MODIFIER TO ADJUST ET USE IF CALLED FOR.
C AM(J)      MAXIMUM SURFACE AREA OF COMP. J.
C AMAXN      MAXIMUM DEPLETION VALUE FOR NATURAL WS.
C AMAXW      MAXIMUM DEPLETION VALUE FOR TREATED WS.
C AMAXN1     TEMPORARY STORAGE FOR AMAXN.
C AMAXW1     TEMPORARY STORAGE FOR AMAXW.
C AN         AREA OF THE NATURAL (N) WATERSHED (WS).
C ASM        AN ARRAY OF AVAILABLE SOIL MOISTURE FOR EACH LAYER.
C ATEST      COUNTER FOR AREA REDUCTION, DEPTH INCREASING SECTION OF PROG.
C AW         AREA OF WATER HARVESTING CATCHMENT OR TREATED WATERSHED (WS).
C AWHP       THE PLANTED AREA, IF THE W.H. AGRISYSTEM IS USED THE AREA IS
C            WITHIN THE CATCHMENT OTHERWISE IT IS OUTSIDE THE WATERSHEDS.
C CUSET      A FLAG SET TO 1 IF ONE CARD IS USED FOR DOMESTIC AND ET USE.
C CUTEST     MODIFIER FOR THE DOMESTIC CONSUMPTIVE USE.
C D(J)       CURRENT DEPTH OF COMPARTMENT J.
C DABN       SEASONAL MODIFIER FOR ABSTN.
C DABW       SEASONAL MODIFIER FOR ABSTW.
C DCUSE      WEEKLY ARRAY FOR DOMESTIC USE.
C DCUSEA     ANNUAL DOMESTIC USE.
C DCUSET     TOTAL DOMESTIC USE FOR THE PERIOD.
C DELETE     A FACTOR USED TO DETERMINE RUNON.
C DELTAS     WEEKLY CHANGE IN STORAGE.
C DETEST     A FLAG SET TO ONE IF DEPTH IS INCREASED TO IMPROVE EFFIC.
C DIM        A DIVISOR THAT DETERMINES THE NO. OF DIGITS IN RES. OUTPUT.
C DM(J)      MAXIMUM DEPTH OF COMPARTMENT J.
C DSR        ABSOLUTE VALUE OF DELTAS.
C DWEEK      WEEKLY DOMESTIC USE TOTAL.
C E          A TEMPORARY MONTHLY ARRAY FOR ONE YEARS EVAPORATION.
C EAT        ANNUAL EVAPORATION RATE.
C ED         A TEMPORARY ARRAY FOR ONE YEARS DAILY EVAPORATION WHICH, IS
C            COMPUTED FROM THE MONTHLY EVAPORATION.
C EN         RUNOFF EFFICIENCY FOR NATURAL WS.
C ESA        ANNUAL RESERVOIR EVAPORATION LOSS.
C EST        TOTAL RESERVOIR EVAPORATION LOSS FOR PERIOD.
C ETANK      TEMP. STORAGE FOR EVAPORATION FOR A GIVEN COMPARTMENT.
C ETSA       ANNUAL EVAPOTRANSPIRATION USE.
C ETST       TOTAL EVAPOTRANSPIRATION FOR PERIOD.
C ETT        PERIOD TOTAL EVAPORATION RATE.
C ETW        WEEKLY ARRAY FOR EVAPOTRANSPIRATION.
C ETWEEK     WEEKLY EVAPOTRANSPIRATION TOTAL.
C EW         ARRAY OF TOTAL EVAP LOSS FROM THE RESERVOIR.
C EWEEK      WEEKLY RESERVOIR EVAPORATION TOTAL.
C EWH        RUNOFF EFFICIENCY FOR TREATED WS.
C EXCES      WEEKLY EXCESS RUNOFF NOT STORED IN SYSTEM.
C EXCESA     ANNUAL EXCESS RUNOFF NOT STORED IN SYSTEM.
C EXCEST     TOTAL EXCESS RUNOFF NOT STORED IN SYSTEM.
C F          MODIFIER TO ADJUST DOMESTIC USE IF CALLED FOR.
C FACTN      SEASONAL MODIFIER OF EN.
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C FACTW     SEASONAL MODIFIER OF EWH.
C FCAP      AN ARRAY GIVING THE FIELD CAPACITY OF EACH SOIL LAYER.
C ID        COUNTER FOR THE DAY WITHIN A YEAR 1....365.
C ID1       NUMBER OF DAY WITHIN A YEAR OF FIRST STORM.
C IDTE      TEMPORARY STORAGE OF ID.
C IF4       TEMPORARY STORAGE LOCATION FOR IW1.
C ILW       TEMPORARY STORAGE LOCATION FOR IWL.
C IM1       FIRST MONTH.
C IML       LAST MONTH.
C IN1       FIRST YEAR.
C IW        COUNTER FOR THE WEEK 1....52.
C IW1       NUMBER OF WEEK WITHIN A YEAR OF FIRST STORM.
C IWE       INTERMEDIATE COUNTER.
C IWL       NUMBER OF WEEK WITHIN THE YEAR OF THE LAST STORM.
C IY1       NUMBER OF YEAR OF FIRST STORM IT IS SET TO 1.
C J         TEMPORARY STORAGE LOCATION FOR K.
C JSAVE     TEMPORARY STORAGE FOR COUNTER J.
C K         THE NUMBER OF COMPARTMENTS.
C KTEST     A FLAG THAT WILL ACTIVATE THE AUTOMATIC SELECTION AND
C           INCREMENTING OF K.
C M2        INTERMEDIATE COUNTER.
C MTEST     A FLAG SET TO ONE IF AGRISYSTEM OPTION IS ACTIVATED.
C N1        COUNTER FOR A YEAR IY1....NYT.
C N11       TEMPORARY STORAGE FOR NY.
C ND        COUNTER FOR DAILY EVAPORATION.
C NDAY      DAY OF MONTH THAT RAINFALL OCCURRED.
C NDAY1     TEMPORARY STORAGE FOR NDAY.
C NDT       NUMBER OF DAY WITHIN THE YEAR OF THE LAST STORM.
C NL        COUNTER USED FOR SOIL LAYER.
C NM        MAXIMUM NUMBER OF LAYERS USED IN PROGRAM.
C NMO       MONTH THAT RAINFALL OCCURRED.
C NMO1      TEMPORARY STORAGE FOR NMO.
C NRTM      THE NUMBER OF LAYERS CORRESPONDING TO THE DEPTH OF THE ROOTS.
C NY        YEAR THAT RAINFALL OCCURRED.
C NYT       NUMBER OF YEAR OF LAST STORM.
C NYEAR     THE LAST TWO DIGITS OF THE FIRST YEAR OF RECORD.
C NYTE      TEMPORARY STORAGE FOR N1.
C OVRDA     ANNUAL OVERDRAFT NEEDED FOR C.U.
C OVRDT     TOTAL OVERDRAFT FOR PERIOD NEEDED FOR C.U.
C OVRDW     WEEKLY OVERDRAFT NEEDED FOR C.U.
C OVRFA     ANNUAL OVERFLOW FROM COMP. 1.
C OVRFT     TOTAL OVERFLOW FOR PERIOD FROM COMP. 1.
C OVRFW     WEEKLY OVERFLOW FROM COMP. 1.
C OVTEST    FLAG SET TO ONE TO INCREASE RES. VOL. DUE TO EXCESS OVERFLOW.
C P         DAILY PRECIPITATION ARRAY.
C PA        ANNUAL PRECIP.
C PERCA     ANNUAL DEEP INFILTRATION LOST TO SYSTEM.
C PERCT     PERIOD TOTAL DEEP INFILTRATION LOST TO SYSTEM.
C PERCW     WEEKLY DEEP INFILTRATION LOST TO SYSTEM.
C PQWM      A REDUCED QWM THAT IS USED TO SIZE COMPARTMENT 1.
C PREC1     TEMPORARY ARRAY FOR PRECIP USED IN INPUT.
C PRECIP    DAILY PRECIPITATION VALUE.
C PS        THE RAINFALL TOTAL OF THE FIRST OF TWO STORMS IN SAME DAY.
C PST       TEMPORARY STORAGE FOR PS.
C PT        TOTAL PRECIP FOR THE PERIOD.
C PUMPR     WEEKLY TOTAL OF RUNOFF PUMPED FROM COMP. 1.
C PUMPRA    ANNUAL TOTAL OF RUNOFF PUMPED FROM COMP. 1.
C PUMPRT    TOTAL RUNOFF PUMPED FROM COMP. 1.
C PUMPW     WEEKLY TOTAL OF PUMPING FOR CONCENTRATION.
C PUMPWA    ANNUAL TOTAL OF PUMPING FOR CONCENTRATION.
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C PUMPWT    PERIOD TOTAL OF PUMPING FOR CONCENTRATION.
C PW        WEEKLY PRECIP ARRAY.
C QA        SUM OF AVERAGE RUNOFF FROM NATURAL AND TREATED WATERSHEDS.
C QTAST     TEMPORARY STORAGE FOR QTN.
C QTN       DAILY RUNOFF ARRAY, NATURAL WS.
C QTNA      ANNUAL RUNOFF FOR NATURAL WS.
C QTNT      TOTAL RUNOFF FOR PERIOD FOR NATURAL WS.
C QTNTAU    AVERAGE RUNOFF FOR PERIOD FOR NATURAL WS.
C QTNW      WEEKLY RUNOFF ARRAY FOR NATURAL WS.
C QTW       DAILY RUNOFF ARRAY, TREATED WS.
C QTWA      ANNUAL RUNOFF FOR TREATED WS.
C QTWAV     AVERAGE RUNOFF FOR PERIOD FOR TREATED WS.
C QTWST     TEMPORARY STORAGE FOR QTW.
C QTWT      TOTAL RUNOFF FOR PERIOD FOR TREATED WS.
C QTWW      WEEKLY RUNOFF ARRAY FOR TREATED WS.
C QWM       MAXIMUM WEEKLY RUNOFF DURING THIS PERIOD.
C R         COMBINED RUNOFF FROM NATURAL AND TREATED WATERSHEDS.
C RCAP      THE MAX. AMOUNT OF RUNOFF ABSORBED BY THE PLANTED AREA.
C RCROSS    THE Y INTERCEPT OF THE ROOT FUNCTION.
C REMOVE    TEMPORARY STORAGE FOR ET LOSSES FROM SOIL UNDER PLANTED AREA.
C RMCAP     AN ARRAY GIVING THE REMAINING SOIL MOISTURE IN EACH LAYER.
C RSLOPE    THE SLOPE OF THE ROOT FUNCTION.
C RUNON     THE AMOUNT OF RUNOFF INFILTRATING INTO THE PLANTED AREA.
C SDABN     SUMMER VALUE OF DABN.
C SDABW     SUMMER VALUE OF DABW.
C SFACTN    SUMMER VALUE FOR FACTN.
C SFACTW    SUMMER VALUE FOR FACTW.
C SMLEV     AN ARRAY GIVING THE SOIL MOISTURE LEVEL IN EACH LAYER.
C STOR1     INNITIAL TOTAL VOLUME OF STORAGE.
C STOR2     TEMPORARY STORAGE FOR STOR1.
C SWFN      SUMMER VALUE OF WFN.
C SWFW      SUMMER VALUE OF WFW.
C TASM      TOTAL AVAILABLE SOIL MOISTURE.
C TCAP      TOTAL SOIL MOISTURE CAPACITY.
C TLR       THE TIME IN DAYS TO THE LAST PREVIOUS RAIN.
C TRCAP     TOTAL REMAINING SOIL MOISTURE CAPACITY.
C TW        TOTAL DEPTH OF SOIL MOISTURE AVAIL. TO THE PLANT IN METERS.
C UNIT      DIMENSION FACTOR.  SET TO 1 IF THE INPUT AND OUTPUT OF RAIN
C           OR EVAPORATION IS IN INCHES.  IF IT IS IN MILLIMETERS SET
C           TO 25.4.  AREAS ARE IN SQ. METERS AND RUNOFF IS IN CU. METERS.
C V(J)      CURRENT VOLUME OF COMPARTMENT J.
C VM(J)     MAXIMUM VOLUME OF COMPARTMENT J.
C VOLSAV    TEMPORARY STORAGE FOR STOR1.
C VOLSAV    TEMPORARY STORAGE FOR VOLSAV.
C VTM       MAXIMUM VOLUME OF K COMPARTMENTS.
C WATER     THE AMOUNT OF PRECIP. AND/OR RUNOFF GOING IN THE ROOT ZONE.
C WDABN     WINTER VALUE OF DABN.
C WDABW     WINTER VALUE OF DABW.
C WFACTN    WINTER VALUE FOR FACTN.
C WFACTW    WINTER VALUE FOR FACTW.
C WFN       SEASONAL MODIFIER OF AMAXN.
C WFW       SEASONAL MODIFIER OF AMAXW.
C WIRR      WEEKLY IRRIGATION USING WAHAAG.
C WIRRA     ANNUAL IRRIGATION USING WAHAAG.
C WIRRT     PERIOD TOTAL IRRIGATION USING WAHAAG.
C WPOINT    AN ARRAY GIVING THE WILTING POINTS IN EACH LAYER.
C WRITET    A FLAG SET TO 1 IF DAILY AND/OR WEEKLY PRINTOUT IS WANTED FOR
            PRECIP, RUNOFF, AND EVAPORATION.
C WWFN      WINTER VALUE OF WFN.
C WWFW      WINTER VALUE OF WFW.
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C  ******************************************************************
C                          DATA CARD SUMMARY

C CARD NO.                    DESCRIPTION

C  1          UP TO 80 COLUMNS CAN BE USED FOR ALPHA-NUMERIC DESIGNATION
C             OF LOCATION OF SYSTEM

C  2          CROP CONTROL CARD. NYEAR1, ID1, IW1, IY1, NDT, IWL, NYT,
C             AMAXN, AMAXW, AN, AW, WRITET, UNIT, AND DIM IN FORMAT(7I4,
C             2F5.3, 2F10.1, I4, F5.1, F6.0).

C  3          CROP CONTROL CARD. WDABN,WDABW,WFACTN,WFACTW,WWFN,
C             WWFW, SDABN, SDABW, SFACTN, SFACTW, SWFN, SWFW ARE IN
C             FORMAT (12F6.3).

C  4 TO N     CROP CONTROL CARD. PRECIPITATION DATA CONTAINING 5 EVENTS
C             PER CARD IN SEQUENTIAL ORDER. NDAY1, NMO1, N11, PREC1 IN
C             FORMAT (5(2I3, I4, F6.2)).

C  N+1        EVAPORATION CONTROL CARD. IM1, IML, IW1, IWL, IY1, NYT,
C             WRITET IN FORMAT (7I4).

C  (N+2)      MONTHLY EVAPORATION DATA CONTAINING ONE YEARS DATA PER
C  TO M       CARD. N1, (E(I), I=1, 12) IN FORMAT ( I4, 12F6.3).

C  M+1        OPTCOM CONTROL CARD. AWHD,KTEST,OVTEST,DETEST,MTEST AND
C             CUSET IN FORMAT (F10.0,5I4).

C  (M+2) TO     OPTCOM CONTROL CARDS FOR WAHAAG.  REMOVE IF MTEST IS NOT
C  (M+2)+NM   EQUAL TO 1.  THERE WILL BE ONE CARD CORRESPONDING TO EACH
C             LAYER OF SOIL UP TO A TOTAL OF NM.  FCAP,WPOINT, SMLEV,
C             ASM,AND RMCAP ARE IN FORMAT(4X,5F6.3).

C  (M+2) +    ETW AND OCUSE IN FORMAT(4X,2F10.4).  IF CUSET = 1 ONLY ONE
C  NM TO L    DATA CARD IS NEEDED OTHERWISE 52 CARDS ARE CALLED FOR.

C  L+1        OPTCOM CONTROL CARD.  CUTEST AND K IN FORMAT(F10.3,I4).

C  L+1 TO     SPECIFICATIONS FOR TEN STORAGE COMPARTMENTS.  DUMMY VALUES
C  L+11       SHOULD BE USED TO FILL OUT THE ARRAY WHEN K IS LESS THAN 10
C             V,VM,DM,AND S ARE IN FORMAT(2F10.0,2F5.1).

C  ******************************************************************
C  ******************************************************************

C  THIS PART OF THE COMPARTMENTED RESERVOIR OPTIMIZATION PROGRAM (CROP)
C  DETERMINES RUNOFF FROM NATURAL AND/OR TREATED WATERSHEDS FROM DAILY
C  DATA AND SUMMARIZES THE PRECIP AND THE RUNOFF IN WEEKLY ARRAYS.

      DIMENSION QTNW(52,45),QTWW(52,45),EW(52,45),ETW(52,45)
     1,OCUSE(52,45),VM(10),AM(10),DM(10),V(10),D(10),S(10),A(10),
     1QTN(370,2),QTW(370,2),NDAY1(5),NMO1(5),N11(5),PREC1(5)
     1, P(370,2), PW(52,45)
      INTEGER WRITET

C     READ AND WRITE ALPHA-NUMERIC DESIGNATION OF THE LOCATION OF THE
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C  COMPARTMENTED SYSTEM.  SPACE LIMIT = 80 CHARACTERS

      READ (5,21) A1,A2,A3,A4,A5,A6,A7,A8
   21 FORMAT(8A10)
      WRITE (6,31) A1,A2,A3,A4,A5,A6,A7,A8
   31 FORMAT(1H1,8A10)

C  READ AND WRITE A CARD STATING INITIAL CONDITIONS

      READ (5,20) NYEAR1,ID1,IW1,IY1,NDT,IWL,NYT,AMAXN,AMAXW,AN,AW
     1,WRITET,UNIT,DIM
   20 FORMAT(7I4,2F5.3,2F10.1,I4,F5.1,F6.0)
      WRITE (6,22)
   22 FORMAT(1H0," THIS DATA REPRESENTS INITIAL CONDITIONS")
      WRITE(6,29) NYEAR1,ID1,IW1,IY1,NDT,IWL,NYT,AMAXN,AMAXW,AN,AW
     1,WRITET
   29 FORMAT("NYEAR1=",I3,", ID1=",I4,", IW1=",I3,", IY1=",I3,", NDT=",
     1I4,", IWL=",I3,", NYT=",I3,", AMAXN=",F5.3,", AMAXW=",F5.3,", AN="
     1,F10.1,", AW=",F10.1,", WRITET=",I4)
      WRITE ( 6,19) UNIT, DIM
   19 FORMAT ("UNIT =", F5.1,",  DIM =",F6.0)

C  READ AND WRITE WATERSHED FACTORS FOR THE RAINFALL-RUNOFF MODEL

      READ(5,32) WDABN,WDABW,WFACTN,WFACTW,WWFN,WWFW,SDABN,SDABW,SFACTN,
     1SFACTW,SWFN,SWFW
   32 FORMAT(12F6.3)
      WRITE(6,33) WDABN,WDABW,WFACTN,WFACTW,WWFN,WWFW
   33 FORMAT(1H0,"WINTER VALUES FOR DABN,DABW,FACTN,FACTW,WFN AND WFW
     1ARE,",6F6.3)
      WRITE(6,34) SDABN,SDABW,SFACTN,SFACTW,SWFN,SWFW
   34 FORMAT(1X,"SUMMER VALUES ARE,",6F6.3)

      AMAXW1=AMAXW
      AMAXN1=AMAXN
      IDP=ID1
      IYP=IY1
      IWP=IW1
      PT =0.00000001
      QTNT=0
      QTWT=0
      NY=1
      N1=1
      IF (WRITET.NE. 1) GO TO 28
      WRITE (6,23)
   23 FORMAT (1H0,"MONTH  DAY   DAY OF   YEAR   PRECIP   RUNOFF   EFFICN
     1   RUNOFF   EFFICW    TLR")
      WRITE (6,24)
   24 FORMAT (1X,"                YEAR                    NATURAL
     1  HARVEST")
   28 I=5
   25 IF(I .EQ. 5) GO TO 26
      I=I+1
      GO TO 27

C  READ STORM DATE AND PRECIP
   26 READ(5,30) (NMO1(I),NDAY1(I),N11(I),PREC1(I),I=1,5)
   30 FORMAT(5(2I3,I4,F6.2))
      IF(EOF(5))999,9999
 9999 I=1
```

```
   27 PRECIP=(PREC1(I)*25.4)/UNIT
      NDAY=NDAY1(I)
      N1=N11(I)
      NMO=NMO1(I)
      N1=N1-NYEAR1+1
      NYTE = N1

C  CONVERT DATE TO NUMBER OF DAYS (IDTE) IN YEAR (NYTE)

      GO TO (1,2,3,4,5,6,7,8,9,10,11,12),NMO
    1 IDTE =NDAY
      GO TO 13
    2 IDTE = 31+NDAY
      GO TO 13
    3 IDTE = 59+NDAY
      GO TO 13
    4 IDTE =90+NDAY
      GO TO 13
    5 IDTE = 120+NDAY
      GO TO 13
    6 IDTE = 151+NDAY
      GO TO 13
    7 IDTE = 181+NDAY
      GO TO 13
    8 IDTE = 212 + NDAY
      GO TO 13
    9 IDTE = 243+NDAY
      GO TO 13
   10 IDTE = 273 + NDAY
      GO TO 13
   11 IDTE = 304 + NDAY
      GO TO 13
   12 IDTE = 334+NDAY

C  TEST TO SEE IF THE YEAR IS THE SAME AS PRECEEDING YEAR IYP

   13 IF(NYTE.EQ.IYP) GO TO 55
      IF(NYTE .NE.(IYP+1)) GO TO 601
      IYP=NYTE

C  IF THE YEAR IS DIFFERENT THEN THE REMAINDER OF THE PRECEEDING YEAR
C  MUST BE SET TO 0
      DO 40 ID=IDP,365
      P(ID,NY) = 0
      QTN(ID,NY) = 0
   40 QTW(ID,NY) = 0
      TLR = (365-IDP) + (IDTE-1)+1
      CALL CONVRT (P,PW,QTNW,QTWW,NY,IDP,IWP,AN,AW,QTN,QTW,N1,ID1,IWE,
     1NYEAR1,QTNT,QTWT,PT,WRITET,UNIT)

C  AFTER SETTING ALL INTERVENING PRECIP TO ZERO THE STORM PRECIP IS
C  ADDED TO THE ARRAY
   45 M2 = IDTE-1
      DO 50 ID=1,M2
      P(ID,NY) = 0
      QTN(ID,NY) = 0
      QTW(ID,NY) = 0
   50 CONTINUE
      GO TO 60
   55 M2 = IDTE-1
```

```
      DO 56 ID=IDP,M2
      P(ID,NY) =0
      QTN(ID,NY)=0
      QTW(ID,NY)=0
   56 CONTINUE
      TLR = IDTE-IDP+1.0

C   INSERT PRECIP INTO ITS ARRAY AND THEN GO TO NATURAL RUNOFF ROUTINE
   60 ID=IDTE
      IF (TLR.EQ.0.) GO TO 61
   62 P(ID,NY) = PRECIP/25.4
      IDP=IDTE+1

C  SELECT USING SUBROUTINE WINTER, APPROPRIATE MODIFIERS ACCORDING TO
C  THE MONTH THAT RAINFALL OCCURS.
      CALL WINTER (NMO,DABN,DABW,FACTN,FACTW,WFN,WFW,SWFW,SWFN,
     1WDABN,WDABW,WFACTN,WFACTW,WWFN,WWFW,SDABN,SDABW,SFACTN,SFACTW)

      AMAXN=AMAXN1
      AMAXW=AMAXW1
      IF (AN.EQ.0) GO TO 86
      AMAXN=AMAXN*WFN
      ABSTN = DABN* TLR
      IF(ABSTN.GT.AMAXN) GO TO 70
      GO TO 69
   61 QTNS = QTNST
      QTWS = QTWST
      PS = PST
      TLR = 0.5
      GO TO 62
   70 ABSTN = AMAXN

   69 IF (P(ID,NY) .GT.ABSTN) GO TO 71
      GO TO 82
   71 IF (P(ID,NY).GT.0.50) GO TO 75
      EN = (0.40)*P(ID,NY)
      GO TO 80
   75 IF (P(ID,NY) .GT.1.00) GO TO 76
      EN = (0.20 + (0.60*(P(ID,NY)-0.50)))
      GO TO 80
   76 IF (P(ID,NY) .GT. 1.50) GO TO 77
      EN = (0.50 + (0.50*(P(ID,NY)-1.00)))
      GO TO 80
   77 EN=0.75
   80 QTN(ID,NY)=EN*AN*(P(ID,NY)-ABSTN) *.0254 *FACTN
   81 EFFICN=1000*(100*QTN(ID,NY)/(AN*.00001)/(P(ID,NY)*25.4))
      IF (AW.EQ.0) GO TO 90
      GO TO 100
   82 QTN(ID,NY) = 0
      GO TO 81
   90 IF (WRITET.NE. 1) GO TO 901
      WRITE (6,603) NMO,NDAY,ID,N1,P(ID,NY),QTN(ID,NY),EFFICN,QTW(ID,NY)
     1,EFFICW,TLR
  603 FORMAT (1X,I2,5X,I2,6X,I3,3X,I2,6X,F4.2,2X,F10.1,1X,F4.1,2X,F10.1,
     12X,F4.1,4X,F5.1)
  901 PST = P(ID,NY)
      QTNST = QTN(ID,NY)
      QTWST = QTW(ID,NY)
      IF (TLR.EQ.0.50) GO TO 88
   89 IF (N1 .EQ.NYT) GO TO 92
```

```
      IWE=52
      IF (365.GT.IDTE) GO TO 25
      P(ID,NY) = P(ID,NY)*UNIT

   91 CALL CONVRT (P,PW,QTNW,QTWW,NY,IDP,IWP,AN,AW,QTN,QTW,N1,ID1,IWE,
     1NYEAR1,QTNT,QTWT,PT,WRITET,UNIT)
      IYP=N1
      GO TO 600
   88 P(ID,NY) = P(ID,NY) + PS
      QTN(ID,NY) = QTN(ID,NY) + QTNS
      QTW(ID,NY) = QTW(ID,NY) + QTWS
      GO TO 89
   92 IWE=IWL
      IF (ID .EQ.NDT) GO TO 1110
      GO TO 25
  602 PRINT (6,200)
  200 FORMAT (1H1,2X,28H ERROR NO AREA IN WATERSHEDS)
      STOP

C  THIS PART OF THE PROGRAM COMPUTES RUNOFF FROM WATER HARVESTING AREA
  103 ABSTW = DABW* TLR
      AMAXW = AMAXW*WFW
      IF (ABSTW .GT.AMAXW) GO TO 105
      GO TO 104
  105 ABSTW = AMAXW
  104 IF (P(ID,NY) .GT. ABSTW) GO TO 106
      GO TO 111
  106 IF (P(ID,NY) .GT. 0.40)  GO TO 107
      EWH= (0.80)*P(ID,NY)
      GO TO 110
  107 IF (P(ID,NY) .GT. 0.70) GO TO 108
      EWH= (0.32 + 0.90*(P(ID,NY)-0.40))
      GO TO 110
  108 IF (P(ID,NY) .GT. 1.00) GO TO 109
      EWH= (0.59 + (1.00*P(ID,NY)-0.70))
  109 EWH= 0.90
  110 QTW(ID,NY)=(EWH*AW*(P(ID,NY)-ABSTW)) * .0254*FACTW
  112 EFFICW=1000*(100*QTW(ID,NY)/(AW+.00001)/(P(ID,NY)*25.4))
      GO TO 90
  111 QTW(ID,NY) = 0
      GO TO 112
 1110 N1=N1+1
      GO TO 91

  601 PRINT (6,199)
  199 FORMAT (1H1,2X,24H ERROR DATA OUT OF ORDER)
      STOP

C  WRITE TOTALS FOR PERIOD OF PRECIP, RUNOFF AND EFFICIENCIES.
  600 EFFNT=100*((QTNT/(AN+0.00001))/(PT*.0254))
      EFFWT=100*((QTWT/(AW+0.00001))/(PT*.0254))
      WRITE (6,501) PT,QTNT,EFFNT,QTWT,EFFWT
  501 FORMAT(1H-,"TOTALS FOR THE PERIOD   PRECIP",F7.2," RUNOFFN  ",
     1F10.0,"  EFFICN  ",F4.1,"  RUNOFFW  ",F10.0,"  EFFICW  ",F4.1)

      NTOTAL=NYT-IY1+1
      QTWTAV = QTWT/NTOTAL
      QTNTAV = QTNT/NTOTAL
      CALL EVAP(EW,UNIT)
      CALL OPTCOM(QTNW,QTWW,EW,IY1,IW1,STOR1,IWE,NYT,QTNTAV,QTWTAV,QWM,
```

```
     1NYEAR1,DIM,PW)
      STOP
C  IF BOTH AREAS ARE 0.0 AN ERR2 MESSAGE IS PRINTED.
   86 IF (AW .EQ. 0) GO TO 602
      GO TO 100
999   END
C  THIS SUBROUTINE ADJUSTS COEFFICIENTS BASED ON WHETHER THE RAIN
C  OCURRED IN THE WINTER OR SUMMER SEASON

      SUBROUTINE WINTER (NMO,DABN,DABW,FACTN,FACTW,WFN,WFW,SWFW,SWFN,
     1WDABN,WDABW,WFACTN,WFACTW,WWFN,WWFW,SDABN,SDABW,SFACTN,SFACTW)
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12),NMO
    6 GO TO 105
    7 GO TO 105
    8 GO TO 105
    9 GO TO 95
   10 GO TO 100
   11 GO TO 100
   12 GO TO 100
    1 GO TO 100
    2 GO TO 100
    3 GO TO 100
    4 GO TO 100
    5 GO TO 100
   95 DABN=(WDABN+SDABN)/2.
      DABW=(WDABW+SDABW)/2.
      FACTN=(WFACTN+SFACTN)/2.
      FACTW=(WFACTW+SFACTW)/2.
      WFW=(WWFW+SWFW)/2.
      GO TO 110
  100 DABN=WDABN
      DABW=WDABW
      FACTN=WFACTN
      FACTW=WFACTW
      WFN=WWFN
      WFW=WWFW
      GO TO 110
  105 DABN=SDABN
      DABW=SDABW
      FACTN=SFACTN
      FACTW=SFACTW
      WFN=SWFN
      WFW=SWFW
  110 RETURN
      END

C  THIS SUBROUTINE CONVERTS THE ANNUAL PRECIP AND RUNOFF ARRAYS INTO
C  WEEKLY ARRAYS FOR A GIVEN YEAR NY.  IT ALSO COMPUTES ANNUAL TOTALS
C  AND RUNOFF EFFICIENCIES.

      SUBROUTINE CONVRT(P,PW,QTNW,QTWW,NY,IDP,IWP,AN,AW,QTN,QTW,N1,ID1,
     1IWE,NYEAR1,QTNT,QTWT,PT,WRITET,UNIT)
      DIMENSION P(370, 2), QTN(370, 2), QTW(370, 2), QTNW(52, 45),
     1QTWW(52, 45),PW(52,45)
      INTEGER WRITET

C  WRITE THE HEADING FOR THE WEEKLY ARRAY
      IF (WRITET.NE. 1) GO TO 652
      WRITE (6,650)
```

```
  650 FORMAT (1H-,2X,"THIS DATA IS THE WEEKLY RUNOFF ARRAY")
      WRITE (6,651)
  651 FORMAT (1H0,1X,"DAY WEEK  YEAR  PRECIP  RUNOFF N  RUNOFF W")

  652 PA = 0.0000001
      QTNA = 0
      QTWA = 0
      NY=1
      N1=N1-1
      DO 2 IW=IWP,IWE
      PWT=0
      QTNWT=0
      QTWWT=0

C  CONVERT DAILY PRECIP AND RUNOFF INTO WEEKLY TOTALS
      M2=ID1+6
      DO 1 ID=ID1,M2
      QTWWT=QTWWT+QTW(ID,NY)
      QTNWT=QTNWT+QTN(ID,NY)
      PWT=PWT + P(ID,NY)
    1 CONTINUE

C  ADD WEEKLY TOTALS TO WEEKLY ARRAYS AND TO ANNUAL SUMMARIES AND INCRMT
      QTWW(IW,N1)=QTWWT
      QTNW(IW,N1)=QTNWT
      PW(IW,N1) = PWT
      NC=N1+NYEAR1-1
      IF (WRITET .NE. 1) GO TO 653
      WRITE (6,502) ID,IW,NC,PWT,QTNW(IW,N1),QTWW(IW,N1)
  502 FORMAT (3I4,3F10.2)
  653 QWT=QTNWT+QTWWT
      IF(QWM.LT.QWT) GO TO 503
      GO TO 504
  503 QWM=QWT
  504 QTNA=QTNA + QTNWT
      QTWA = QTWA+QTWWT
      PA = PA + PWT
      EFFN=(100*(QTNA/(AN+0.0001)/PA))*1000/25.4
      EFFW=(100*(QTWA/(AW+0.0001)/PA))*1000/25.4
      ID1=ID1+7
    2 CONTINUE
      N1=N1+1

C  WRITE ANNUAL TOTALS OF PRECIP, RUNOFF AND EFFICIENCIES
      WRITE (6,500) NC,PA,QTNA,EFFN,QTWA,EFFW
  500 FORMAT(1H-,"TOTALS FOR THE YEAR ",I4,"PRECIP ",F5.2 ," RUNOFFN  ",
     1F10.0,"EFFICN  ",F4.1," RUNOFFW  ",F10.0," EFFICW ",F4.1)

C  SET IDP AND IW TO ONE AND ADD ANNUAL TOTALS TO TOTAL SUMMARY
      ID1=1
      IDP = 1
      IWP = 1
      PT = PT + PA
      QTNT = QTNT + QTNA
      QTWT = QTWT + QTWA
      IF(NC.EQ.(NYT+NYEAR1-1)) GO TO 25

C WRITE NEW HEADINGS FOR NEW YEAR
      IF (WRITET .NE.  1) GO TO 25
      WRITE (6,23)
```

```
   23 FORMAT (1H1,"MONTH   DAY   DAY OF   YEAR   PRECIP   RUNOFF   EFFICN
     1   RUNOFF   EFFICN    TLR")
      WRITE (6,24)
   24 FORMAT (1X,"                YEAR                    NATURAL
     1  HARVEST")
   25 RETURN
      END

C  THIS SUBROUTINE ROUTES AN ARRAY OF WEEKLY RUNOFF FROM A NATURAL
C  AND/OR TREATED WATERSHED THROUGH A COMPARTMENTED RESERVOIR SYSTEM
C  SUBJECT TO WEEKLY DOMESTIC AND/OR AGRICULTURE CONSUMPTIVE USE.

      SUBROUTINE OPTCOM (QTNW,QTWW,EW,IY1,IW1,STOR1,IWE,NYT,QTNTAV,
     1QTWTAV,QWM,NYEAR1,DIM,PW)
      DIMENSION QTNW(52,45),QTWW(52,45),EW(52,45),ETW(52,45)
     1,DCUSE(52,45),VM(10),AM(10),DM(10),V(10),D(10),S(10),A(10)
      DIMENSION ASM(10),SMLEV(10),WPOINT(10),RMCAP(10),FCAP(10)
     1, PW(52,45)

      INTEGER OVTEST,DETEST,CUSET

C  THIS SUBSECTION READS DATA FOR OPTCOM
      READ(5,1020) AWHP,KTEST,OVTEST,DETEST,MTEST,CUSET
 1020 FORMAT(F10.0,5I4)
      WRITE(6,1018) AWHP,KTEST,OVTEST,DETEST,MTEST,CUSET
 1018 FORMAT(1H0,4X,"AWHP =",F10.0,"SQUARE METERS ",4X,"KTEST=",I4,
     +"OVTEST=",I4," DETEST=",I4,"MTEST=",I4," CUSET=",I4)
      IF( MTEST .NE. 1) GO TO 990
      READ(5,1024) TW,RSLOPE,RCROSS,NM
 1024 FORMAT(3F7.4,I4)
      WRITE(6,1019) TW,RSLOPE,RCROSS,NM
 1019 FORMAT(1H0,4X,"TW=",F7.4,"  RSLOPE=",F7.4,"  RCROSS=",F7.4,
     1"  NM=",I4)
      WRITE(6,1026)
 1026 FORMAT(1H0,10X,"SPECIFICATIONS FOR SOIL LAYERS",)
      WRITE(6,1027)
 1027 FORMAT(5X,"N",2X,"FCAP",3X,"WPOINT",3X,"SMLEV",3X,"ASM",4X,
     1"RMCAP")
      DO 1023 NL=1,NM
      READ(5,1022) FCAP(NL),WPOINT(NL),SMLEV(NL),ASM(NL),RMCAP(NL)
 1022 FORMAT(4X,5F6.3)
      WRITE(6,1025) NL,FCAP(NL),WPOINT(NL),SMLEV(NL),ASM(NL),RMCAP(NL)
 1025 FORMAT(4X,I3,F6.3,2X,F6.3,2X,F6.3,2X,F6.3,2X,F6.3)
      FCAP(NL)=FCAP(NL)*AWHP*TW/NM
      WPOINT(NL)=WPOINT(NL)*AWHP*TW/NM
      SMLEV(NL)=SMLEV(NL)*AWHP*TW/NM
      ASM(NL)=ASM(NL)*AWHP*TW/NM
      RMCAP(NL)=RMCAP(NL)*AWHP*TW/NM
 1023 CONTINUE
  990 IF (CUSET .NE. 1) GO TO 1021

C  THIS SECTION FILLS OUT THE CU ARRAY FOR THE FIRST YEAR USING ONE
C  VALUE IF CUSET = 1 OTHERWISE 52 VALUES ARE NEEDED.
      READ(5,1010) DCUSE(IW,N1),ETW(IW,N1)
      DO  991 IW=1,51
      ETW(IW+1,N1)=ETW(IW,N1)
      DCUSE(IW+1,N1)=DCUSE(IW,N1)
  991 CONTINUE
      GO TO 998
```

```
 1021 N1=1
      IW=1

      DO 1001 IW=1,52
      READ(5,1010) ETW(IW,N1),DCUSE(IW,N1)
 1010 FORMAT(4X,2F10.4)
 1001 CONTINUE

C  THIS SECTION FILLS OUT THE CONSUMPTIVE USE ARRAYS FOR THE FULL PERIOD
C  USING WEEKLY ARRAYS FOR ONE YEAR.
  998 M2=NYT-1
      DO 1003 N1=IY1,M2
      DO 1002 IW=1,52
      ETW(IW,N1+1)=ETW(IW,N1)
 1002 DCUSE(IW,N1+1)=DCUSE(IW,N1)
 1003 CONTINUE

C  READ AND WRITE INITIAL AND MAXIMUM CONDITIONS OF TEN COMPARTMENTS.
      READ (5,9001) CUTEST,K
 9001 FORMAT (F10.3,I4)
   90 STOR1=0
      N1=IY1
      F=1
      AF=1
      WRITE(6,99)
   99 FORMAT(1H0,"     SPECIFICATIONS FOR RESERVOIR COMPARTMENTS")
      WRITE (6,100)
  100 FORMAT(1H0,"A(J)       AM(J)     D(J)    DM(J)      V(J) VM(J)    S(J)")
      DO 1  J=1,10
      READ (5,104) V(J),VM(J),DM(J),S(J)
  104 FORMAT (2F10.0,2F5.1)
      IF(EOF(5)) 405,10
   10 CONTINUE
      AM(J)=(((VM(J)/DM(J))**0.5)+S(J)*DM(J))**2
      AB=(AM(J)**0.5-2*DM(J)*S(J))**2
      IF(V(J).GT.0) GO TO 11
      A(J)=0
      D(J)=0
      GO TO 12
   11 A(J)=(6*V(J)*S(J)+AB**1.5)**0.6666666666
      D(J)=2*V(J)/(AB+A(J))
   12 WRITE (6,101) A(J),AM(J),D(J),DM(J),V(J),VM(J),S(J)
  101 FORMAT (1H0,2F10.0,2F6.1,2F10.0,F4.1)
      STOR1=STOR1+V(J)
    1 CONTINUE

C  TOTAL AVERAGE RUNOFF IS COMPUTED AND INITIAL VALUES ASSIGNED.
      VOLSAV=STOR1
      QA = QTNTAV + QTWTAV

C  IF KTEST NE TO 1 THIS SECTION SETS AN INITIAL VALUE ON THE SIZE OF
C  COMPARTMENT 1 AND THE TOTAL NUMBER OF COMPARTMENTS K.
  198 IF (KTEST.EQ.1) GO TO 3061
      K=1
      J=1
      VTM1=VM(1)
      ATM1=AM(1)
  201 PQWM=0.9*QWM
      IF (VM(1) .GT.PQWM) GO TO 1981
```

```
      VM(1)=0.9*QWM
      AM(1)=ATM1*VM(1)/VTM1
 1981 VTM=VM(1)
      ATM=AM(1)
  199 IF (VTM .GT. (2*QA)) GO TO 200

      J=J+1
      K= K+1
      IF (K .EQ. 11) GO TO 202
      VTM=VTM+VM(J)
      ATM = ATM+AM(J)
      GO TO 199
  200 IF (VTM .GT. (4*QA)) GO TO 204
      GO TO 306

  202 WRITE (6,102)
  102 FORMAT (1H0,"COMPARTMENTS ARE TOO SMALL, WILL INCREASE SIZE")
      WRITE (6,1100) K,VTM
 1100 FORMAT (I4,F10.1)
      DO 205 J=2,10
      AM(J) = 1.1*AM(J)
      VM(J)=1.1*VM(J)
  205 CONTINUE
      GO TO 198
  204 IF (K.LT.2) GO TO 206
      K=K-1
      GO TO 306
  206 WRITE (6,103) QA,K,VTM
  103 FORMAT (1H0,"COMPARTMENTS ARE TOO LARGE, SUBMIT NEW ARRAY, QA="
     1,F10.1,"K= ",I4," VTM= ",F10.1)
      STOP
 2061 WRITE(6,2062)
 2062 FORMAT(1H0,"THE LAST GIVEN DESIGN WILL SATISFY THE GIVEN CONSUMPTI
     1VE USE FOR THE ENTIRE PERIOD")
      READ (5,9001) CUTEST,K
      IF(EOF(5)) 405,2063
 2063 J=K
      CALL DISTR(VM,V,VT,STOR1,VOLSAV,J)
      GO TO 90

  207 K=K+1
      GO TO 3061

  306 IF (KTEST .EQ. 1) GO TO 207
 3061 IF (K .EQ. 11) GO TO 405


C  THIS SECTION COMPUTES THE DELTA STORAGE FROM ADDITIONS AND DEPLETIONS
C  INTO THE COMPARTMENTED SYSTEM.  WATER IS REMOVED BEGINNING WITH
C  COMPARTMENT 1.  RUNOFF IS STORED FIRST IN COMPARTMENT 1 AND THEN MOVED
C  TO COMPARTMENTS K,K-1 AND ECT.  OVERFLOW CAN OCCUR WHEN EITHER THE
C  CAPACITY OF 1 IS EXCEEDED IN ANY GIVEN WEEKS RUNOFF OR THE TOTAL
C  CAPACITY OF ALL THE COMPARTMENTS IS EXCEEDED.

      N1 = IY1
      ETST=0
      EST=0
      DCUSET=0
      IPW = IW1
      ILW = 52
```

```
      EXCEST = 0
      OVRFT = 0
      PUMPWT=0
      PUMPRT=0
      OVRDT=0
      QTNT=0
      QTWT=0
      WIRRT = 0
      PERCT = 0
C ***********************************************************************
      DO 400 N1 = IY1,NYT
      QTWA=0
      QTNA=0
      OVRFA = 0
      EXCESA = 0
      OVRDA=0
      PUMPRA=0
      PUMPWA=0
      DCUSEA=0
      ESA=0
      ETSA = 0
      WIRRA = 0
      PERCA = 0
      IF (N1 .EQ. NYT) GO TO 600
      GO TO 601
  600 ILW=IWE
C  TEST TO SEE IF WH AGRISYSTEM ROUTINE IS WANTED
  601 IF(MTEST.EQ.1) GO TO 6010
      WRITE (6,6001)
 6001 FORMAT(1H1,"WK YR  K  RUNOFF RUNOFF EVAPT EVAP DMSTIC WATER PUMPED
     1  TOTAL")
      WRITE (6,6002)
 6002 FORMAT (1H ,"          NATRL HARVST AGRIC WATER WATERC V(1)   CONC
     1 .  VOLUME   1      2      3      4      5      6      7      8
     1   9      10")
      GO TO 6015
 6010 WRITE (6,6011)
 6011 FORMAT(1H1,"WK YR  K  RUNOFF RUNOFF EVAPT EVAP DMSTIC WATER PUMPED
     1  SOIL          TOTAL")
      WRITE (6,6012)
 6012 FORMAT (1H ,"          NATRL HARVST AGRIC WATER WATERC V(1)   CONC
     1  MOISTURE IRRIG VOLUME    1      2      3      4      5      6
     1   7      8 ")
C ***********************************************************************
 6015 DO 390 IW=IFW,ILW
      PUMPW=0
      PUMPR=0
      OVRFW = 0
      OVRDW = 0
      EXCESW = 0
      WIRR = 0
      QTNA=QTNA+QTNW(IW,N1)
      QTWA=QTWA+QTWW(IW,N1)
      QTWT=QTWT+QTWW(IW,N1)
      QTNT=QTNT+QTNW(IW,N1)
      ETWEEK=ETW(IW,N1)*AWHP
      DWEEK=DCUSE(IW,N1)*F*CUTEST
```

```
C  TEST TO SEE IF WH AGRISYSTEM ROUTINE IS WANTED.
      IF( MTEST.EQ.1) GO TO 3071
 6003 DELTAS = QTNW(IW,N1) + QTWW(IW,N1) - ETWEEK-DWEEK
      R = QTNW(IW,N1) + QTWW(IW,N1)
      IF (R .GT. (VM(1)-V(1)))  GO TO 308
  307 GO TO 320
 3071 CALL WAHAAG (FCAP,WPOINT, SMLEV, ASM, RMCAP, WIRR, WIRRA, WIRRT,
     1PW,AWHP,QTWW,ETWEEK,VT,V,TASM,PERCA,PERCT,RSLOPE,RCROSS,
     1 K,VM,STOR1,VOLSAV,NM,IW,N1)
      GO TO 6003
  308 EXCESW = R-(VM(1)-V(1))
      DELTAS=DELTAS-EXCESW
      EXCESA=EXCESA+EXCESW
      EXCEST=EXCEST+EXCESW
      GO TO 307

C  THIS SUBSECTION COMPUTES THE AREA OF WATER SURFACE OF EACH COMPARTMENT
C  USING THE VOLUME, THE BOTTOM AREA AND THE SLOPE OF THE BANKS.  IT
C  COMPUTES THE EVAP LOSS FROM EACH COMPARTMENT AND SUBTRACTS IT FROM
C  THE VOLUME OF EACH.  IT SUMS UP THE WEEKLY AND ANNUAL EVAP LOSS.
  320 VT = 0
      AT = 0
      VTM=0
      EWEEK=0
      DO 333 J=1,K
      VTM=VTM+VM(J)
      IF (V(J) .EQ. 0.)  GO TO 328
      AB=(AM(J)**0.5-2*DM(J)*S(J))**2
      A(J)=(6*V(J)*S(J)+AB**1.5)**0.6666666666
 3201 ETANK=(EW(IW,N1)*A(J)*25.4)/1000
      V(J)=V(J)-ETANK
      EWEEK=EWEEK+ETANK
  321 IF (V(J).LE.0.)  GO TO 328
      VT = V(J) + VT
      AT = A(J) + AT
      IF (J.NE.K) GO TO 333
      EWEEK=EWEEK-ETANK
      GO TO 333

  328 V(J) = 0
      A(J)=0
      D(J)=0
  333 CONTINUE
      ESA=ESA+EWEEK
      EST=EST+EWEEK


C  THIS SECTION COMPUTES THE AMOUNT OF WATER OVERDRAWN AND REDUCES CON-
C  SUMPTIVE USE AND/OR INCREASES THE NUMBER OF COMPARTMENTS AND/OR IN-
C  CREASES THE SIZE OF THE COMPARTMENTS AND THEN STARTS ALL OVER.
  340 IF (DELTAS .LT. (VTM-VT)) GO TO 350
      OVRFW = DELTAS-(VTM-VT)
      OVRFA = OVRFA+OVRFW
      OVRFT = OVRFT+ OVRFW
      DELTAS = VTM-VT
      GO TO 350
  350 IF (DELTAS .LT.0.0) GO TO 352
      GO TO 370
```

```
  352 IF(VT.LT.DWEEK) GO TO 366
  353 DSR = ABS(DELTAS)
      DO 356 J= 1,K
      IF (DSR .GT. V(J)) GO TO 354
      V(J) = V(J)-DSR
      DSR=0
      GO TO 376
  354 DSR=DSR-V(J)
      V(J)=0
  356 CONTINUE
      OVRDA = DSR + OVRDA
      OVRDT = DSR + OVRDT
      OVRDW= DSR

C  IF THE OVERFLOW FOR THE YEAR IS GREATER THAN 10 PERCENT OF THE TOTAL
C  VOLUME INCREASE K OTHERWISE DISTRIBUTE THE OVERDRAFT DEFICIENCY
C  FIRST TO AGRIC. SECOND TO DOMESTIC USERS.

      IF(OVTEST .NE. 1) GO TO 3560
      IF ((OVRFA-OVRDA) .GT. 0.10*VTM)GO TO 358
 3560 IF (DSR.LE.ETWEEK) GO TO 3561
      DSR=DSR-ETWEEK
      ETWEEK = 0
      IF(DSR.LE.DWEEK) GO TO 3562
      DWEEK=0
      GO TO 376
 3561 ETWEEK=ETWEEK-DSR
      DSR=0
      GO TO 376
 3562 DWEEK=DWEEK-DSR
      DSR=0
      GO TO 376
  358 WRITE(6,1090) EXCESW,OVRFW,OVRDW
      IF (K .EQ. 10) GO TO 362
      K=K+1
      GO TO 3693
  360 IF(F.LE.1.0) GO TO 364
      F=F-0.2
      GO TO 3693

C  INCREASE THE SIZE OF THE COMPARTMENTS TO REDUCE OVERFLOW
  362 DO 363 J=2,K
      VM(J)=1.25*VM(J)
      AM(J)=1.25*AM(J)
  363 CONTINUE
      K=2
      GO TO 198

  364 WRITE (6,105) AWHP,F,DCUSET
  105 FORMAT (1H0,"OVERDRAFT OCCURED WITH THE MINIMUM CONSUMPTIVE USE",
     1F10.1,F5.3,F10.1)
      GO TO 381

C  THIS SUBSECTION REDUCES THE AREA AND INCREASES THE DEPTH TO INCREASE EF·
C  SINCE THERE IS NO WATER LEFT IN THE RESERVOIRS AFTER EVAPORATION
C  IF THE AREA OF EACH COMPARTMENT HAS BEEN REDUCED TO THE STATED MINIMUM
C  OR TO THE MINIMUM DEPTH THEN THE PROGRAM WILL CONTINUE WITH THE DEFICIT
  366 IF (DETEST .EQ. 1) GO TO 353
      IF(OVRDA.LT.0.10*VTM) GO TO 353
      ATEST = 1
```

```
      DO 369 J=2,K
      IF (AM(J).LT.2000) GO TO 368
      IF(DM(J).GE.6) GO TO 368
      AM(J)=0.80*AM(J)
      DM(J)=DM(J)/0.80*AM(J)
      GO TO 369
  368 ATEST = ATEST+1
  369 CONTINUE
 3692 IF (ATEST .GE.K) GO TO 3694
 3693 J=K
      CALL DISTR(VM,V,VT,STOR1,VOLSAV,J)
      WRITE(6,100)
      DO 3691 J=1,10
 3691 WRITE(6,101) A(J),AM(J),D(J),DM(J),V(J),VM(J),S(J)
      GO TO 3061
 3694 IF (ETST .LE.0) GO TO 360
      IF(AWHP.LE.100) GO TO 360
      AF=AF-0.2
      IF (AF.LE.0) GO TO 360
      AWHP=AWHP*AF
      GO TO 3693

C THIS SECTION DECIDES WHERE DELTAS WILL BE STORED WHEN IT IS POSITIVE
C AND HOW MANY COMPARTMENTS THAT WILL BE REQUIRED TO STORE THE WATER
  370 DSR=DELTAS
      J=K
      PUMPR=DELTAS
  371 IF (J.EQ.0.) GO TO 372
      IF (DSR.GE.(VM(J)-V(J)))GO TO 374
      V(J) = V(J)+DSR
      GO TO 376

  372 IF (DSR .LE.0.) GO TO 375
      V(1)=DSR
      PUMPR=DELTAS-V(1)
      GO TO 376
  374  DSR=DSR-(VM(J)-V(J))
      V(J) =VM(J)
      J=(J-1)
      GO TO 371
  375 WRITE (6,106)
  106 FORMAT (1H0,"DELTAS IS LESS THAN 0")
      STOP

C THIS SUBSECTION DETERMINES IF WATER IS TO BE CONCENTRATED BY PUMPING
  376 J=K
      VT=0
      VTM=0
  377 IF (J.EQ.0.) GO TO 3771
      IF (V(J) .EQ.0.)  GO TO 3772
      VT=VT+V(J)
      VTM = VTM + VM(J)
      J=J-1
      GO TO 377

C CHECK TO SEE IF THE REMAINING VOLUME IN J+1 IS SMALL ENOUGH TO BE
C ACCOMODATED IN THE UNUSED CAPACITY OF COMPARTMENTS J+2, J+3 .....J=10

 3771 IF(V(J+1) .EQ.0) GO TO 380
 3772 J=J+1
```

```
      IF (J.EQ.K) GO TO 380
      VT=VT-V(J)
      VTM=VTM-VM(J)
       IF (V(J) .LT.(VTM-VT)) GO TO 384
      VT=VT+V(J)
      VTM=VTM+VM(J)
      GO TO 380
  384 VT=VT+V(J)
      JSAVE=J
      PUMPW=V(J)
      V(J)=0

C THIS SUBSECTION DISTRIBUTES PUMPED WATER INTO THE COMPARTMENTS
C STARTING WITH COMPARTMENT K FIRST
      J=K
  386 IF (J .EQ. JSAVE) GO TO 380
      IF (PUMPW .LT. 0.) GO TO 390
      IF ((VM(J) -V(J)).GT.PUMPW) GO TO 387
      PUMPW = PUMPW-(VM(J)-V(J))
      V(J) = VM(J)
      J=J-1
      GO TO 386
  387 V(J)=V(J) + PUMPW
      GO TO 380

  380 PUMPRA=PUMPRA+PUMPR
      PUMPRT=PUMPRT+PUMPR
      PUMPWA=PUMPWA+PUMPW
      PUMPWT=PUMPWT+PUMPW
  381 NC=N1+NYEAR1-1
      DCUSET=DCUSET+DWEEK
      DCUSEA=DCUSEA+DWEEK

      IF (MTEST .EQ. 1) GO TO 3801
      ETSA=ETSA+ETWEEK
      ETST=ETST+ETWEEK
      WRITE (6,108) IW,NC,K,QTNW(IW,N1)/DIM,QTWW(IW,N1)/DIM,ETWEEK/DIM,
     1EWEEK/DIM,DWEEK/DIM,PUMPR/DIM,PUMPW/DIM,VT/DIM,V(1)/DIM,V(2)/DIM,
     1V(3)/DIM,V(4)/DIM,V(5)/DIM,V(6)/DIM,V(7)/DIM,V(8)/DIM,V(9)/DIM,
     1V(10)/DIM
  108 FORMAT(3I3,2F7.0,3F6.0,13F7.0)

 3802 IF (EXCESW .GT. 0) GO TO 3810
      IF(OVRFW .GT.0) GO TO 3810
      IF(OVRDW .GT.0) GO TO 3810
      GO TO 390

 3801 ETWEEK=ETW(IW,N1)*AWHP
      ETSA=ETSA+ETWEEK
      ETST=ETST+ETWEEK
      WRITE (6,3108)IW,NC,K,QTNW(IW,N1)/DIM,QTWW(IW,N1)/DIM,ETWEEK/DIM,
     1EWEEK/DIM,DWEEK/DIM,PUMPR/DIM,PUMPW/DIM,TASM/DIM,WIRR/DIM,VT/DIM,
     1V(1)/DIM,V(2)/DIM,V(3)/DIM,V(4)/DIM,V(5)/DIM,V(6)/DIM,V(7)/DIM,
     1V(8)/DIM
 3108 FORMAT(3I3,2F7.0,3F6.0,13F7.0)
      GO TO 3802

 3810 WRITE(6,1090) EXCESW,OVRFW,OVRDW
 1090 FORMAT(1H ,"COMPARTMENT 1 OVERFLOW",F8.1,"TOTAL SYSTEM OVERFLOW",
     1F8.1,"OVERDRAFT",F3.1)
```

```
  390 CONTINUE
      IFW=1

      IF (MTEST .EQ. 1) GO TO 3803
      WRITE (6,1091)
 1091 FORMAT(1HO," YEAR RUNOFFN RUNOFFW   EVAPT    EVAP   DOMESTIC  IN.
     1PUMP  CONC. PUMP TOTAL EXCESS OVERFLOW OVERDRAWN")
  392 WRITE (6,109) NC,QTNA,QTWA,ETSA,ESA,DCUSEA,PUMPRA,PUMPWA,EXCESA,
     1OVRFA,OVRDA
  109 FORMAT (1HO,I3,6F9.1,4F11.1)

 3804 EFFICA = ((ETSA+DCUSEA)/(STOR1-VT+QTNA+QTWA+0.000001))*100
      STOR1 = VT
      WRITE (6,110) N1,EFFICA
  110 FORMAT (1HO,"EFFICIENCY FOR YEAR " ,I2,"EQUALS ",F5.2)
      GO TO 400
 3803 WRITE (6,3091)
 3091 FORMAT(1HO," YEAR RUNOFFN RUNOFFW   EVAPT    EVAP   DOMESTIC  IN.
     1PUMP  CONC. PUMP TOTAL EXCESS OVERFLOW OVERDRAWN   IRRIG    PERC")
      WRITE (6,3109)NC,QTNA,QTWA,ETSA,ESA,DCUSEA,PUMPRA,PUMPWA,EXCESA,
     1OVRFA,OVRDA,WIRRA ,PERCA
 3109 FORMAT (1HO,I3,6F9.1,6F11.1)
      GO TO 3804
  400 CONTINUE

      EFFICT = ((ETST+DCUSET)/(VOLSAV-VT+QTNT+QTWT+0.000001))*100
      IF(MTEST.EQ.1) GO TO 3805
      WRITE (6,1091)
      WRITE(6,112) QTNT/DIM,QTWT/DIM,ETST/DIM,EST/DIM,DCUSET/DIM,
     1PUMPRT/DIM,PUMPWT/DIM,EXCEST/DIM,OVRFT/DIM,OVRDT/DIM
  112 FORMAT (1H ,"PERIOD",6F9.1,5F11.1)
 3806 WRITE (6,114) EFFICT
  114 FORMAT (1HO,"THE EFFICIENCY OF THE SYSTEM FOR THE TOTAL PERIOD WAS
     1 ",F5.2)
      WRITE(6,1121) DIM
 1121 FORMAT(1HO,"ALL OF THE WEEKLY VALUES AND THE TOTAL FOR THE PERIOD
     1HAVE BEEN DIVIDED BY",F6.0)
  403 WRITE (6,100)
      DO 404 J=1,10
  404 WRITE (6,101) A(J),AM(J),D(J),DM(J),V(J),VM(J),S(J)
      GO TO 2061

 3805 WRITE(6,3091)
      WRITE(6,3112)QTNT/DIM,QTWT/DIM,ETST/DIM,EST/DIM,DCUSET/DIM,
     1PUMPRT/DIM,PUMPWT/DIM,EXCEST/DIM,OVRFT/DIM,OVRDT/DIM,WIRRT/DIM
     1,PERCT/DIM
 3112 FORMAT (1H ,"PERIOD",6F9.1,5F11.1)
      GO TO 3806
  405 RETURN
      END
C  THIS SUBROUTINE DISTRIBUTES THE ORIGINAL VOLUME IN THE UPPER TANKS SO
C  THAT OPTCOM CAN BE RERUN UNDER NEW CONSTRAINTS.

      SUBROUTINE DISTR(VM,V,VT,STOR1,VOLSAV,J)
      DIMENSION VM(10),V(10)
      STOR1=VOLSAV
 4040 IF (J.EQ.1) GO TO 4042
      IF (VM(J) .GT.VOLSAV) GO TO 4041
      VOLSAV=VOLSAV-VM(J)
```

```
      V(J)=VM(J)
      J=J-1
      GO TO 4040
 4041 V(J)=VOLSAV
      VOLSAV=0
      J=J-1
      GO TO 4040
 4042 V(1)=0
      VOLSAV=STOR1
      VT=VOLSAV
      RETURN
      END
C  THIS SUBROUTINE WATER HARVESTING AGRISYSTEM KEEPS TRACK OF SOIL
C  MOISTURE, ADDING RAINFALL AND RUNOFF. IT WILL DEDUCT EVAPOTRANSPIR-
C  ATION LOSSES FROM THE SOIL AND CALL FOR AN IRRIGATION FROM THE RES.

      SUBROUTINE WAHAAG (FCAP,WPOINT,SMLEV,ASM,RMCAP,WINR,WIPRA,WIPRT,
     1PW,AWHP,QTWW,ETWEEK,VT,V,TASM,PERCA,PERCT,RSLOPE,RCROSS,
     1 K,VM,STOR1,VOLSAV,NM,IW,N1)
      DIMENSION PW(52,45), QTWW(52,45),V(10)
      DIMENSION ASM(10),SMLEV(10),WPOINT(10),RMCAP(10),FCAP(10)


      NRTM= RSLOPE*IW-RCROSS
      IF(PW(IW,N1) .LE. 0) GO TO 3072
      WATER=PW(IW,N1)*AWHP*0.5*25.4/1000
      IF(QTWW(IW,N1) .GT. 0) GO TO 3076
 3074 CALL STORE(ASM,SMLEV,WPOINT,RMCAP,FCAP,PERCW,PERCA,PERCT,NM,WATER)
 3072 IF(ETWEEK.GT.0) GO TO 9000
      GO TO 6003
 3076 DELETE=0.020*AWHP
      IF(QTWW(IW,N1) .GT. DELETE) GO TO 3078
      WATER=WATER+QTWW(IW,N1)
      QTWW(IW,N1) =0
      GO TO 3074
 3078 RUNON=0.05*(QTWW(IW,N1)-DELETE) +DELETE
      RCAPT=RMCAP(1)+0.5*RMCAP(2)
      IF(RUNON.LT. RCAPT) GO TO 3079
      WATER = WATER+RCAPT
      QTWW(IW,N1)=QTWW(IW,N1) -RCAPT
      GO TO 3074
 3079 WATER=WATER+RUNON
      QTWW(IW,N1)=QTWW(IW,N1)-RUNON
      GO TO 3074

C  THIS SUBSECTION DETERMINES THE NUMBER OF LAYERS DOWN TO ROOT DEPTH
C  AND COMPUTES TOTALS
 9000 TRCAP=0
      TASM=0
      TCAP=0
      DO 9010 NL=1,NRTM
      TASM=TASM+ASM(NL)
      TRCAP=TRCAP+RMCAP(NL)
      TCAP=TCAP+(FCAP(NL)-WPOINT(NL))
 9010 CONTINUE
      IF(TCAP.LE.ETWEEK) GO TO 9050
 9012 IF(TASM .GT.7500.) GO TO 9040

C  WHEN ETWEEK IS GREATER THAN THE AVAILABLE SOIL MOISTURE AN IRRIGATION
C  WILL OCCUR
```

```
      IF((0.9*VT).GT.TRCAP) GO TO 9025
      WATER=0.9*VT
      VT=0
      DO 9015 J=1,K
      V(J)=0
 9015 CONTINUE
 9020 WIRR=WATER
      WIRRA=WIRRA+WATER
      WIRRT=WIRRT+WATER

      CALL STORE(ASM,SMLEV,WPOINT,RMCAP,FCAP,PERCW,PERCA,PERCT,NM,WATER)
      GO TO 9040

C  THIS SECTION REMOVES IRRIGATION,"WATER", PLUS 10 PERCENT LOSES FROM
C  STORAGE AND REDISTRIBUTES THE REMAINING VOLUME IN THE LAST COMPARTMENTS
 9025 WATER=TRCAP
      VT=VT-(WATER/.9)
      STOR2=STOR1
      VOLS2=VOLSAV
      VOLSAV=VT
      J=K
      CALL DISTR(VM,V,VT,STOR1,VOLSAV,J)
      STOR1=STOR2
      VOLSAV=VOLS2
      GO TO 9020

 9040 REMOVE=ETWEEK
      CALL REMOV (FCAP ,RMCAP,ASM,SMLEV,REMOVE,NPTM,WPOINT,ETWEEK)
      GO TO 6003
 9050 WRITE(6,9051)
 9051 FORMAT(1H0,"SOIL MOISTURE CAPACITY IS LESS THAN WEEKS ET.")
 6003 RETURN
      END

C  THIS SUBROUTINE DISTRIBUTES THE RAIN,RUNON OR IRRIGATION WATER THROUGH
C  THE SOIL PROFILE STARTING WITH THE TOP LAYER AND WORKING DOWN.

      SUBROUTINE STORE(ASM,SMLEV,WPOINT,RMCAP,FCAP,PERCW,PERCA,PERCT,NM,
     1WATER)
      DIMENSION ASM(10),SMLEV(10),WPOINT(10),RMCAP(10),FCAP(10)
      NL=1
 1000 ASM(NL)=SMLEV(NL)-WPOINT(NL)
      RMCAP(NL)=FCAP(NL)-SMLEV(NL)
      IF (WATER .GT. RMCAP(NL) ) GO TO 2000
      ASM(NL)=ASM(NL)+WATER
      SMLEV(NL)=SMLEV(NL)+WATER
      RMCAP(NL)=FCAP(NL)-SMLEV(NL)
      WATER=0
      GO TO 4000
 2000 SMLEV(NL)=FCAP(NL)
      ASM(NL)= FCAP(NL)-WPOINT(NL)
      WATER=WATER-RMCAP(NL)
      RMCAP(NL)=0
      IF (NL.EQ.NM) GO TO 3000
      NL=NL+1
      GO TO 1000
 3000 PERCW=WATER
      PERCA=PERCA+PERCW
      PERCT=PERCT+PERCW
 4000 RETURN
```

```
      END

C  THIS SUBROUTINE TAKES ETWEEK FROM THE SOIL BEGINNING WITH NL=1 AND
C  EXTENDING DOWN TO THE DEPTH OF THE ROOTS AS DETERMINED BY THE ROOT
C  FUNCTION OF THE PLANTED CROP.


      SUBROUTINE REMOV (FCAP ,RMCAP,ASM,SMLEV,REMOVE,NRTM,WPOINT,ETWEEK)
      DIMENSION ASM(10),SMLEV(10),WPOINT(10),RMCAP(10),FCAP(10)

      DO 9060 NL=1,NRTM
      IF(ASM(NL).GT.REMOVE) GO TO 9055
      REMOVE= REMOVE-ASM(NL)
      RMCAP(NL)=FCAP(NL)-WPOINT(NL)
      ASM(NL)=0
      SMLEV(NL)=WPOINT(NL)
 9060 CONTINUE
      IF (REMOVE.LE.0) GO TO 9080
      GO TO 9056
 9055 ASM(NL)=ASM(NL)-REMOVE
      SMLEV(NL)=SMLEV(NL)-REMOVE
      RMCAP(NL)=FCAP(NL)-SMLEV(NL)
      REMOVE = 0
      ETWEEK = 0
      GO TO 9081
 9056 WRITE (6,9070) REMOVE
 9070 FORMAT (1H0,"RESERVOIR AND SOIL PROFILE ARE WITHOUT WATER. A WATER
     1DEFICIENCY OF",F8.1," OCCURED")
      ETWEEK=ETWEEK-REMOVE
      GO TO 9081
 9080 REMOVE=0
      ETWEEK = 0
 9081 RETURN
      END


C  THIS SUBROUTINE CONVERTS MONTHLY EVAPORATION TO A WEEKLY ARRAY
      SUBROUTINE EVAP (EW,UNIT)

      DIMENSION EW(52,20),ED(365),E(12)
      INTEGER WRITET
      READ (5,100) IM1,IML,IW1,IWL,IY1,NYT,WRITET
  100 FORMAT(7I4)
      ETT=0
      DO 400 NY=IY1,NYT
      READ(5,210) N1,(E(I),I=1,12)
  210 FORMAT (I4,12F6.3)
      IF (NY.EQ.NYT) GO TO 370
      IF=IM1
      IM1=1
      IL=12
  211 DO 350 I=IF,IL
      E(I)= E(I)/UNIT
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12),I
    1 DO 101 ND=1,31
      ED(ND)=E(1)/31
  101 CONTINUE
      GO TO 350
    2 DO 102 ND=32,59
      ED(ND)=E(1)/28
```

```
102 CONTINUE
    GO TO 350
  3 DO 103 ND=60,90
    ED(ND)=E(3)/31
103 CONTINUE
    GO TO 350
  4 DO 104 ND=91,120
    ED(ND)=E(4)/30
104 CONTINUE
    GO TO 350
  5 DO 105 ND=121,150
    ED(ND)=E(5)/30
105 CONTINUE
    GO TO 350
  6 DO 106 ND=151,181
    ED(ND)=E(6)/31
106 CONTINUE
    GO TO 350
  7 DO 107 ND=182,212
    ED(ND)=E(7)/31
107 CONTINUE
    GO TO 350
  8 DO 108 ND=213,243
    ED(ND)=E(8)/31
108 CONTINUE
    GO TO 350
  9 DO 109 ND=244,273
    ED(ND)=E(9)/30
109 CONTINUE
    GO TO 350
 10 DO 110 ND=274,304
    ED(ND)=E(10)/31
110 CONTINUE
    GO TO 350
 11 DO 111 ND=305,334
    ED(ND)=E(11)/30
111 CONTINUE
    GO TO 350
 12 DO 112 ND=335,365
    ED(ND)=E(12)/31
112 CONTINUE
350 CONTINUE
    GO TO 380
370 IF=1
    IL=IML
    GO TO 211

380 ID1=1
    IF(WRITET .NE. 1) GO TO 381
    WRITE (6,3801)
3801 FORMAT (1H1," DAY  WK  YR  EVAP")
381 DO 390 IW=1,52
    EWT=0
    M2=ID1+6
    DO 385 ND=ID1,M2
    EWT=EWT+ED(ND)
385 CONTINUE
    EW(IW,NY)=EWT
    EAT=EAT+EWT
    ETT=ETT+EWT
```

```
      IF (WRITET .NE. 1) GO TO 387
      WRITE (6,386) ND,IW,N1,EW(IW,NY)
  386 FORMAT (3I4,F6.3)
  387 ID1=ID1+7
  390 CONTINUE

      WRITE(6,391) NY,EAT
  391 FORMAT (1H0,"THE ANNUAL EVAPORATION TOTAL FOR THE YEAR ",I2," IS "
     1,F8.3)
      EAT=0
  400 CONTINUE

      WRITE(6,410) ETT
  410 FORMAT (1H0,"THE TOTAL EVAPORATION FOR THE PERIOD IS ",F8.3)
      RETURN


      END
```

APPENDIX D

OUTPUT FROM CROP-76 FOR SAN FRANCISCO DEL BARREAL, MEXICO, WATER HARVESTING AGRISYSTEM

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	66	3	154.	0.	2.	0.	0.	154.	0.	14972.	0.	24609.	0.	9.	24600.	0.	0.	0.	0.	0.
2	66	3	0.	0.	2.	73.	0.	0.	0.	14969.	0.	24454.	0.	0.	24454.	0.	0.	0.	0.	0.
3	66	3	0.	0.	2.	0.	0.	0.	0.	14967.	0.	24309.	0.	0.	24309.	0.	0.	0.	0.	0.
4	66	3	0.	0.	2.	0.	0.	0.	0.	14972.	0.	24165.	0.	0.	24165.	0.	0.	0.	0.	0.
5	66	3	0.	0.	59.	0.	0.	0.	0.	14969.	0.	24011.	0.	0.	24011.	0.	0.	0.	0.	0.
6	66	3	0.	0.	88.	0.	0.	0.	0.	14911.	0.	23852.	0.	0.	23852.	0.	0.	0.	0.	0.
7	66	3	0.	0.	146.	0.	0.	0.	0.	14823.	0.	23693.	0.	0.	23693.	0.	0.	0.	0.	0.
8	66	3	0.	0.	234.	0.	0.	0.	0.	14677.	0.	23534.	0.	0.	23534.	0.	0.	0.	0.	0.
9	66	3	0.	0.	248.	0.	0.	0.	0.	14443.	0.	23317.	0.	0.	23317.	0.	0.	0.	0.	0.
10	66	3	0.	0.	293.	0.	0.	0.	0.	14195.	0.	23056.	0.	0.	23056.	0.	0.	0.	0.	0.
11	66	3	0.	0.	336.	0.	0.	0.	0.	13903.	0.	22797.	0.	0.	22797.	0.	0.	0.	0.	0.
12	66	3	0.	0.	333.	0.	0.	0.	0.	13565.	0.	22539.	0.	0.	22539.	0.	0.	0.	0.	0.
13	66	3	0.	0.	405.	0.	0.	0.	0.	13183.	0.	22273.	0.	0.	22273.	0.	0.	0.	0.	0.
14	66	3	0.	0.	416.	0.	0.	0.	0.	12778.	0.	21957.	0.	0.	21957.	0.	0.	0.	0.	0.
15	66	3	0.	0.	428.	0.	0.	0.	0.	12362.	0.	21643.	0.	0.	21643.	0.	0.	0.	0.	0.
16	66	3	0.	0.	439.	0.	0.	0.	0.	11934.	0.	21331.	0.	0.	21331.	0.	0.	0.	0.	0.
17	66	3	0.	0.	450.	0.	0.	0.	0.	11495.	0.	21020.	0.	0.	21020.	0.	0.	0.	0.	0.
18	66	3	1068.	1070.	473.	0.	0.	2138.	0.	11802.	0.	22832.	0.	0.	22832.	0.	0.	0.	0.	0.
19	66	3	0.	0.	461.	0.	0.	0.	0.	11329.	0.	22491.	0.	0.	22491.	0.	0.	0.	0.	0.
20	66	3	0.	0.	494.	0.	0.	0.	0.	10899.	0.	22153.	0.	0.	22153.	0.	0.	0.	0.	0.
21	66	3	0.	0.	518.	0.	0.	0.	0.	10413.	0.	21816.	0.	0.	21816.	0.	0.	0.	0.	0.
22	66	3	0.	0.	540.	0.	0.	0.	0.	9898.	0.	21471.	0.	0.	21471.	0.	0.	0.	0.	0.
23	66	3	0.	0.	563.	0.	0.	0.	0.	9358.	0.	21119.	0.	0.	21119.	0.	0.	0.	0.	0.
24	66	3	0.	0.	585.	0.	0.	0.	0.	8811.	0.	20770.	0.	0.	20770.	0.	0.	0.	0.	0.
25	66	3	816.	329.	596.	0.	0.	1146.	0.	8850.	0.	21569.	0.	0.	21569.	0.	0.	0.	0.	0.
26	66	3	196.	0.	1170.	0.	0.	196.	0.	8741.	0.	21412.	0.	0.	21412.	0.	0.	0.	0.	0.
27	66	3	0.	0.	1260.	0.	0.	0.	0.	7571.	0.	21050.	0.	0.	21050.	0.	0.	0.	0.	0.
28	66	3	4018.	2049.	1350.	0.	0.	6067.	0.	7103.	7868.	18079.	0.	0.	18079.	0.	0.	0.	0.	0.
29	66	3	0.	0.	1215.	0.	0.	0.	0.	13622.	0.	17741.	0.	0.	17741.	0.	0.	0.	0.	0.
30	66	3	0.	0.	1148.	0.	0.	0.	0.	12407.	0.	17405.	0.	0.	17405.	0.	0.	0.	0.	0.
31	66	3	160.	0.	1080.	0.	0.	160.	0.	11721.	0.	17286.	0.	0.	17286.	0.	0.	0.	0.	0.
32	66	3	0.	0.	1013.	0.	0.	0.	0.	10641.	0.	17030.	0.	0.	17030.	0.	0.	0.	0.	0.
33	66	3	17736.	5831.	900.	0.	0.	16400.	0.	11135.	0.	33175.	0.	8575.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 7166.6TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
34	66	3	11777.	4103.	720.	205.	0.	15880.	0.	11245.	0.	48553.	0.	23953.	24600.	0.	0.	0.	0.	0.
35	66	3	6989.	2762.	765.	279.	0.	9750.	0.	11401.	0.	57744.	8544.	24600.	24600.	0.	0.	0.	0.	0.
36	66	3	98.	0.	598.	636.	0.	98.	0.	11000.	0.	56990.	8183.	24355.	24452.	0.	0.	0.	0.	0.
37	66	3	0.	0.	608.	603.	0.	0.	0.	10375.	0.	56142.	7824.	24110.	24208.	0.	0.	0.	0.	0.
38	66	3	0.	0.	540.	631.	0.	0.	0.	9768.	0.	55298.	7467.	23867.	23964.	0.	0.	0.	0.	0.
39	66	3	295.	0.	473.	599.	0.	295.	0.	9746.	0.	54751.	7110.	23625.	24016.	0.	0.	0.	0.	0.
40	66	3	0.	0.	450.	526.	0.	0.	0.	9274.	0.	54011.	6797.	23412.	23802.	0.	0.	0.	0.	0.
41	66	3	0.	0.	405.	524.	0.	0.	0.	8824.	0.	53273.	6485.	23200.	23588.	0.	0.	0.	0.	0.
42	66	3	0.	0.	158.	522.	0.	0.	0.	8419.	0.	52538.	6173.	22989.	23376.	0.	0.	0.	0.	0.
43	66	3	0.	0.	135.	521.	0.	0.	0.	8261.	0.	51805.	5863.	22779.	23164.	0.	0.	0.	0.	0.
44	66	3	0.	0.	101.	451.	0.	0.	0.	8126.	0.	51171.	5594.	22597.	22981.	0.	0.	0.	0.	0.
45	66	3	0.	0.	68.	399.	0.	0.	0.	8025.	0.	50609.	5356.	22435.	22818.	0.	0.	0.	0.	0.
46	66	3	0.	0.	45.	398.	0.	0.	0.	7957.	0.	50049.	5118.	22275.	22656.	0.	0.	0.	0.	0.
47	66	3	0.	0.	23.	397.	0.	0.	0.	7912.	0.	49491.	4881.	22115.	22495.	0.	0.	0.	0.	0.
48	66	3	0.	0.	11.	379.	0.	0.	2396.	7890.	0.	48958.	0.	24358.	24600.	0.	0.	0.	0.	0.
49	66	3	0.	0.	9.	141.	0.	0.	0.	7879.	0.	48676.	0.	24217.	24458.	0.	0.	0.	0.	0.
50	66	3	0.	0.	7.	141.	0.	0.	0.	7870.	0.	48394.	0.	24077.	24317.	0.	0.	0.	0.	0.
51	66	3	0.	0.	5.	140.	0.	0.	0.	7863.	0.	48113.	0.	23936.	24177.	0.	0.	0.	0.	0.
52	66	3	0.	0.	2.	140.	0.	0.	0.	7905.	0.	47833.	0.	23797.	24036.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
66	43305.3	21199.4	22506.8	7644.4	0.0	52282.4	2396.3	7166.6	0.0	0.0	0.0	7868.3	360.7

EFFICIENCY FOR YEAR 1EQUALS 54.53

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	67	3	0.	0.	2.	140.	0.	0.	0.	7903.	0.	47551.	0.	23656.	23895.	0.	0.	0.	0.	0.
2	67	3	308.	0.	2.	140.	0.	308.	0.	8542.	0.	47579.	0.	23516.	24063.	0.	0.	0.	0.	0.
3	67	3	0.	0.	2.	140.	0.	0.	0.	8540.	0.	47298.	0.	23376.	23922.	0.	0.	0.	0.	0.
4	67	3	0.	0.	2.	139.	0.	0.	0.	8537.	0.	47018.	0.	23237.	23781.	0.	0.	0.	0.	0.
5	67	3	0.	0.	59.	149.	0.	0.	0.	8535.	0.	46721.	0.	23089.	23632.	0.	0.	0.	0.	0.
6	67	3	0.	0.	88.	153.	0.	0.	0.	8477.	0.	46413.	0.	22936.	23477.	0.	0.	0.	0.	0.
7	67	3	0.	0.	146.	153.	0.	0.	0.	8389.	0.	46105.	0.	22783.	23322.	0.	0.	0.	0.	0.
8	67	3	0.	0.	234.	153.	0.	0.	0.	8243.	0.	45798.	0.	22630.	23168.	0.	0.	0.	0.	0.
9	67	3	243.	0.	243.	223.	0.	243.	0.	8473.	0.	45594.	0.	22407.	23186.	0.	0.	0.	0.	0.
10	67	3	0.	0.	293.	275.	0.	0.	0.	8225.	0.	45040.	0.	22133.	22908.	0.	0.	0.	0.	0.
11	67	3	0.	0.	338.	273.	0.	0.	0.	7933.	0.	44490.	0.	21859.	22630.	0.	0.	0.	0.	0.
12	67	3	1100.	818.	333.	272.	0.	1919.	0.	8401.	0.	45860.	0.	21587.	24273.	0.	0.	0.	0.	0.
13	67	3	0.	0.	405.	255.	0.	0.	0.	8018.	0.	45276.	0.	21302.	23973.	0.	0.	0.	0.	0.
14	67	3	0.	0.	416.	371.	0.	0.	0.	7613.	0.	44516.	0.	20932.	23584.	0.	0.	0.	0.	0.
15	67	3	0.	0.	428.	295.	0.	0.	0.	7197.	7774.	35169.	0.	10983.	24206.	0.	0.	0.	0.	0.
16	67	3	0.	0.	439.	293.	0.	0.	0.	14544.	0.	34505.	0.	10490.	23815.	0.	0.	0.	0.	0.
17	67	3	0.	0.	450.	290.	0.	0.	0.	14105.	0.	33827.	0.	10400.	23427.	0.	0.	0.	0.	0.
18	67	3	0.	0.	473.	259.	0.	0.	0.	13655.	0.	33199.	0.	10131.	23068.	0.	0.	0.	0.	0.
19	67	3	0.	0.	461.	263.	0.	0.	0.	13183.	0.	32583.	0.	9968.	22715.	0.	0.	0.	0.	0.
20	67	3	0.	0.	424.	251.	0.	0.	0.	12722.	0.	31971.	0.	9607.	22364.	0.	0.	0.	0.	0.
21	67	3	0.	0.	518.	299.	0.	0.	0.	12238.	0.	31363.	0.	9347.	22016.	0.	0.	0.	0.	0.
22	67	3	0.	0.	540.	271.	0.	0.	0.	11783.	0.	30728.	0.	9076.	21652.	0.	0.	0.	0.	0.
23	67	3	0.	0.	563.	279.	0.	0.	0.	11243.	0.	30073.	0.	8797.	21276.	0.	0.	0.	0.	0.
24	67	3	0.	0.	585.	277.	0.	0.	0.	10680.	0.	29423.	0.	8520.	20903.	0.	0.	0.	0.	0.
25	67	3	0.	0.	596.	275.	0.	0.	0.	10127.	0.	28778.	0.	8245.	20532.	0.	0.	0.	0.	0.
26	67	3	0.	0.	1170.	271.	0.	0.	0.	9530.	0.	28140.	0.	7974.	20166.	0.	0.	0.	0.	0.
27	67	3	0.	0.	1260.	263.	0.	0.	0.	8391.	0.	27521.	0.	7711.	19810.	0.	0.	0.	0.	0.
28	67	3	0.	0.	1350.	0.	0.	0.	0.	7131.	7840.	18464.	0.	0.	18464.	0.	0.	0.	0.	0.
29	67	3	0.	0.	1215.	0.	0.	0.	0.	13819.	0.	18121.	0.	0.	18121.	0.	0.	0.	0.	0.
30	67	3	0.	0.	1149.	0.	0.	0.	0.	12604.	0.	17780.	0.	0.	17780.	0.	0.	0.	0.	0.
31	67	3	0.	0.	1080.	0.	0.	0.	0.	11457.	0.	17489.	0.	0.	17489.	0.	0.	0.	0.	0.
32	67	3	0.	0.	1013.	0.	0.	0.	0.	10377.	0.	17220.	0.	0.	17220.	0.	0.	0.	0.	0.
33	67	3	15217.	4561.	900.	0.	0.	16400.	0.	10445.	0.	33351.	0.	8751.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW				4676.6TOTAL SYSTEM OVERFLOW						0.0OVERDRAFT		0.0								
34	67	3	0.	0.	720.	216.	0.	0.	0.	9564.	0.	32826.	0.	8535.	24290.	0.	0.	0.	0.	0.
35	67	3	20685.	5137.	765.	203.	0.	16400.	0.	10002.	0.	48731.	0.	24131.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW				9421.4TOTAL SYSTEM OVERFLOW						0.0OVERDRAFT		0.0								
36	67	3	219.	0.	698.	250.	0.	219.	0.	9583.	0.	48449.	0.	23881.	24568.	0.	0.	0.	0	0.
37	67	3	0.	0.	603.	249.	0.	0.	0.	8901.	0.	47948.	0.	23633.	24316.	0.	0.	0.	0.	0.
38	67	3	2173.	977.	540.	248.	0.	3150.	0.	9053.	0.	50600.	1400.	24600.	24600.	0.	0.	0.	0.	0.
39	67	3	0.	0.	473.	595.	0.	0.	0.	8513.	0.	49753.	1057.	24348.	24348.	0.	0.	0.	0.	0.
40	67	3	0.	0.	450.	451.	0.	0.	354.	8087.	0.	49112.	0.	24512.	24600.	0.	0.	0.	0.	0.
41	67	3	3.	0.	405.	191.	0.	3.	0.	7698.	0.	48732.	0.	24320.	24412.	0.	0.	0.	0.	0.
42	67	3	2295.	2179.	158.	191.	0.	4475.	0.	8116.	0.	52825.	3625.	24600.	24600.	0.	0.	0.	0.	0.
43	67	3	825.	1106.	135.	459.	0.	1931.	0.	8670.	0.	54105.	4905.	24600.	24600.	0.	0.	0.	0.	0.
44	67	3	0.	0.	101.	420.	0.	0.	0.	8535.	0.	53512.	4659.	24426.	24426.	0.	0.	0.	0.	0.
45	67	3	0.	0.	68.	386.	0.	0.	0.	8433.	0.	52965.	4433.	24266.	24266.	0.	0.	0.	0.	0.
46	67	3	0.	0.	45.	385.	0.	0.	0.	8366.	0.	52420.	4207.	24107.	24107.	0.	0.	0.	0.	0.
47	67	3	0.	0.	23.	384.	0.	0.	0.	8321.	0.	51877.	3982.	23948.	23948.	0.	0.	0.	0.	0.
48	67	3	0.	0.	11.	388.	0.	0.	0.	8293.	0.	51328.	3754.	23787.	23787.	0.	0.	0.	0.	0.
49	67	3	0.	0.	9.	399.	0.	0.	0.	8287.	0.	50765.	3520.	23622.	23622.	0.	0.	0.	0.	0.
50	67	3	0.	0.	7.	398.	0.	0.	0.	8325.	0.	50202.	3287.	23458.	23458.	0.	0.	0.	0.	0.
51	67	3	0.	0.	5.	397.	0.	0.	0.	8318.	0.	49642.	3054.	23294.	23294.	0.	0.	0.	0.	0.
52	67	3	0.	0.	2.	396.	0.	0.	1352.	8314.	0.	49083.	0.	24483.	24600.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
67	44070.7	19576.0	22505.8	13037.0	0.0	45048.9	1706.5	14100.1	0.0	0.0		15614.3	0.0

EFFICIENCY FOR YEAR 2EQUALS 36.01

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	68	3	0.	0.	2.	121.	0.	0.	0.	8311.	0.	48840.	0.	24361.	24478.	0.	0.	0.	0.	0.
2	68	3	0.	0.	2.	121.	0.	0.	0.	8501.	0.	48597.	0.	24240.	24357.	0.	0.	0.	0.	0.
3	68	3	0.	0.	2.	121.	0.	0.	0.	8498.	0.	48355.	0.	24119.	24236.	0.	0.	0.	0.	0.
4	68	3	0.	0.	2.	121.	0.	0.	0.	8494.	0.	48114.	0.	23999.	24115.	0.	0.	0.	0.	0.
5	68	3	0.	0.	59.	126.	0.	0.	0.	8494.	0.	47858.	0.	23871.	23987.	0.	0.	0.	0.	0.
6	68	3	0.	0.	55.	133.	0.	0.	0.	8498.	0.	47592.	0.	23738.	23854.	0.	0.	0.	0.	0.
7	68	3	0.	0.	146.	133.	0.	0.	0.	8512.	0.	47327.	0.	23606.	23721.	0.	0.	0.	0.	0.
8	68	3	84.	0.	234.	132.	0.	84.	0.	8560.	0.	47146.	0.	23473.	23673.	0.	0.	0.	0.	0.
9	68	3	8781.	4949.	248.	174.	0.	13770.	0.	9341.	0.	60567.	11367.	24600.	24600.	0.	0.	0.	0.	0.
10	68	3	3333.	3190.	293.	527.	0.	5033.	0.	9731.	0.	64862.	15652.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					1539.8TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
11	68	3	0.	0.	339.	545.	0.	0.	0.	9439.	0.	64122.	15332.	24390.	24390.	0.	0.	0.	0.	0.
12	68	3	0.	0.	383.	538.	0.	0.	0.	9131.	0.	63364.	15033.	24190.	24190.	0.	0.	0.	0.	0.
13	68	3	0.	0.	405.	577.	0.	0.	0.	8719.	0.	62563.	14651.	23956.	23956.	0.	0.	0.	0.	0.
14	68	3	0.	0.	416.	816.	0.	0.	0.	8314.	0.	61430.	14152.	23639.	23639.	0.	0.	0.	0.	0.
15	68	3	0.	0.	428.	912.	0.	0.	0.	7898.	0.	60302.	13655.	23324.	23324.	0.	0.	0.	0.	0.
16	68	3	0.	0.	439.	321.	0.	0.	0.	7470.	7501.	48558.	0.	24279.	24279.	0.	0.	0.	0.	0.
17	68	3	0.	0.	450.	319.	0.	0.	0.	14533.	0.	47921.	0.	23960.	23960.	0.	0.	0.	0.	0.
18	68	3	0.	0.	473.	400.	0.	0.	0.	14083.	0.	47121.	0.	23560.	23560.	0.	0.	0.	0.	0.
19	68	3	0.	0.	461.	411.	0.	0.	0.	13610.	0.	46299.	0.	23150.	23150.	0.	0.	0.	0.	0.
20	68	3	0.	0.	484.	408.	0.	0.	0.	13149.	0.	45484.	0.	22742.	22742.	0.	0.	0.	0.	0.
21	68	3	0.	0.	518.	405.	0.	0.	0.	12655.	0.	44675.	0.	22337.	22337.	0.	0.	0.	0.	0.
22	68	3	0.	0.	540.	378.	0.	0.	0.	12148.	0.	43918.	0.	21959.	21959.	0.	0.	0.	0.	0.
23	68	3	0.	0.	563.	356.	0.	0.	0.	11608.	0.	43201.	0.	21601.	21601.	0.	0.	0.	0.	0.
24	68	3	0.	0.	585.	356.	0.	0.	0.	11045.	0.	42409.	0.	21245.	21245.	0.	0.	0.	0.	0.
25	68	3	0.	0.	596.	354.	0.	0.	0.	10450.	0.	41782.	0.	20891.	20891.	0.	0.	0.	0.	0.
26	68	3	0.	0.	1170.	347.	0.	0.	0.	9864.	0.	41083.	0.	20544.	20544.	0.	0.	0.	0.	0.
27	68	3	0.	0.	1250.	323.	0.	0.	0.	8694.	0.	40442.	0.	20221.	20221.	0.	0.	0.	0.	0.
28	68	3	34933.	10379.	1350.	321.	0.	16400.	0.	9258.	0.	56200.	7000.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					26412.2TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
29	68	3	0.	0.	1215.	851.	0.	0.	0.	7903.	0.	55001.	6497.	24252.	24252.	0.	0.	0.	0.	0.
30	68	3	0.	0.	1148.	327.	0.	0.	0.	6693.	6278.	45128.	0.	20676.	24252.	0.	0.	0.	0.	0.
31	68	3	33342.	8146.	2030.	277.	0.	16400.	0.	14972.	0.	60955.	11755.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					25125.7TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
32	68	3	0.	0.	1013.	696.	0.	0.	0.	13892.	0.	59983.	11335.	24323.	24323.	0.	0.	0.	0.	0.
33	68	3	16119.	5027.	900.	693.	0.	5064.	0.	14094.	0.	64079.	14879.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					15032.2TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
34	68	3	2554.	1013.	723.	738.	0.	1521.	0.	13931.	0.	64616.	15416.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					2045.7TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
35	68	3	8742.	5022.	795.	635.	0.	994.	0.	14550.	0.	64713.	15513.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					12777.2TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
36	68	3	0.	0.	638.	463.	0.	0.	0.	13832.	0.	64073.	15232.	24421.	24421.	0.	0.	0.	0.	0.
37	68	3	25955.	11768.	608.	459.	0.	-1168.	0.	14972.	0.	64664.	15404.	24600.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					36527.9TOTAL SYSTEM OVERFLOW					0.0OVERDRAFT		0.0								
38	68	3	0.	0.	540.	463.	0.	0.	0.	14383.	0.	63965.	15123.	24421.	24421.	0.	0.	0.	0.	0.
39	68	3	0.	0.	473.	459.	0.	0.	0.	13840.	0.	63327.	14843.	24242.	24242.	0.	0.	0.	0.	0.
40	68	3	0.	0.	450.	511.	0.	0.	0.	13357.	0.	62619.	14531.	24043.	24043.	0.	0.	0.	0.	0.
41	68	3	0.	0.	435.	539.	0.	0.	0.	12917.	0.	61915.	14221.	23845.	23845.	0.	0.	0.	0.	0.
42	68	3	1069.	1045.	198.	507.	0.	2116.	0.	13236.	0.	63322.	14122.	24600.	24600.	0.	0.	0.	0.	0.
43	68	3	0.	0.	135.	510.	0.	0.	0.	13079.	0.	62612.	13812.	24400.	24400.	0.	0.	0.	0.	0.
44	68	3	0.	0.	101.	426.	0.	0.	0.	12944.	0.	62020.	13554.	24233.	24233.	0.	0.	0.	0.	0.
45	68	3	0.	0.	68.	353.	0.	0.	0.	12842.	0.	61515.	13333.	24091.	24091.	0.	0.	0.	0.	0.
46	68	3	0.	0.	45.	352.	0.	0.	0.	12775.	0.	61011.	13113.	23949.	23949.	0.	0.	0.	0.	0.
47	68	3	0.	0.	23.	341.	0.	0.	0.	12730.	0.	60508.	12893.	23807.	23807.	0.	0.	0.	0.	0.
48	68	3	0.	0.	11.	355.	0.	0.	0.	12707.	0.	60014.	12678.	23668.	23668.	0.	0.	0.	0.	0.
49	68	3	0.	0.	9.	340.	0.	0.	0.	12695.	0.	59541.	12471.	23535.	23535.	0.	0.	0.	0.	0.
50	68	3	0.	0.	7.	339.	0.	0.	0.	12687.	0.	59059.	12264.	23402.	23402.	0.	0.	0.	0.	0.
51	68	3	0.	0.	5.	339.	0.	0.	0.	12790.	0.	58598.	12058.	23270.	23270.	0.	0.	0.	0.	0.
52	68	3	0.	0.	2.	338.	0.	0.	0.	12785.	0.	56128.	11853.	23138.	23138.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFH	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
68	139994.3	56955.6	22506.8	20981.1	0.0	62540.4	0.0	125013.6	0.0	0.0	0.0	15779.4	541.0

EFFICIENCY FOR YEAR 3EQUALS 12.17

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	69	3	1343.	1751.	2.	317.	0.	3094.	0.	13591.	0.	60781.	11660.	24521.	24600.	0.	0.	0.	0.	0.
2	69	3	0.	0.	2.	320.	0.	0.	0.	13588.	0.	60334.	11467.	24394.	24473.	0.	0.	0.	0.	0.
3	69	3	0.	0.	2.	319.	0.	0.	0.	13586.	0.	59887.	11275.	24267.	24346.	0.	0.	0.	0.	0.
4	69	3	0.	0.	2.	319.	0.	0.	0.	13584.	0.	59442.	11083.	24141.	24219.	0.	0.	0.	0.	0.
5	69	3	0.	0.	59.	337.	0.	0.	0.	13582.	0.	58970.	10879.	24006.	24085.	0.	0.	0.	0.	0.
6	69	3	0.	0.	88.	351.	0.	0.	0.	13523.	0.	58479.	10668.	23867.	23945.	0.	0.	0.	0.	0.
7	69	3	0.	0.	146.	351.	0.	0.	0.	13435.	0.	57989.	10456.	23728.	23805.	0.	0.	0.	0.	0.
8	69	3	0.	0.	234.	350.	0.	0.	0.	13289.	0.	57501.	10245.	23589.	23666.	0.	0.	0.	0.	0.
9	69	3	0.	0.	248.	520.	0.	0.	0.	13055.	0.	56775.	9932.	23383.	23460.	0.	0.	0.	0.	0.
10	69	3	0.	0.	293.	645.	0.	0.	0.	12809.	0.	55873.	9542.	23127.	23204.	0.	0.	0.	0.	0.
11	69	3	0.	0.	338.	643.	0.	0.	0.	12515.	0.	54975.	9154.	22872.	22948.	0.	0.	0.	0.	0.
12	69	3	0.	0.	383.	640.	0.	0.	0.	12178.	0.	54081.	8768.	22618.	22694.	0.	0.	0.	0.	0.
13	69	3	0.	0.	405.	651.	0.	0.	0.	11795.	0.	53172.	8375.	22361.	22436.	0.	0.	0.	0.	0.
14	69	3	0.	0.	416.	728.	0.	0.	0.	11390.	0.	52156.	7935.	22073.	22148.	0.	0.	0.	0.	0.
15	69	3	0.	0.	478.	724.	0.	0.	0.	11021.	0.	51145.	7497.	21786.	21861.	0.	0.	0.	0.	0.
16	69	3	0.	0.	434.	721.	0.	0.	0.	10593.	0.	50139.	7062.	21501.	21576.	0.	0.	0.	0.	0.
17	69	3	0.	0.	450.	717.	0.	0.	3320.	10159.	0.	49138.	0.	24538.	24600.	0.	0.	0.	0.	0.
18	69	3	0.	0.	473.	398.	0.	0.	0.	9705.	0.	48340.	0.	24139.	24201.	0.	0.	0.	0.	0.
19	69	3	0.	0.	461.	412.	0.	0.	0.	9232.	0.	47516.	0.	23727.	23789.	0.	0.	0.	0.	0.
20	69	3	0.	0.	484.	409.	0.	0.	0.	8771.	0.	46697.	0.	23318.	23379.	0.	0.	0.	0.	0.
21	69	3	0.	0.	518.	405.	0.	0.	0.	8287.	0.	45885.	0.	22912.	22973.	0.	0.	0.	0.	0.
22	69	3	0.	0.	540.	377.	0.	0.	0.	7770.	0.	45132.	0.	22536.	22596.	0.	0.	0.	0.	0.
23	69	3	0.	0.	553.	280.	0.	0.	0.	7230.	7742.	35891.	0.	11649.	24232.	0.	0.	0.	0.	0.
24	69	3	0.	0.	585.	278.	0.	0.	0.	14409.	0.	35237.	0.	11371.	23867.	0.	0.	0.	0.	0.
25	69	3	0.	0.	596.	276.	0.	0.	0.	13824.	0.	34598.	0.	11094.	23504.	0.	0.	0.	0.	0.
26	69	3	2475.	1574.	1170.	276.	0.	4049.	0.	13964.	0.	38009.	0.	13409.	24600.	0.	0.	0.	0.	0.
27	69	3	0.	0.	1250.	303.	0.	0.	0.	12794.	0.	37323.	0.	13106.	24218.	0.	0.	0.	0.	0.
28	69	3	0.	0.	1330.	301.	0.	0.	0.	11534.	0.	36643.	0.	12805.	23838.	0.	0.	0.	0.	0.
29	69	3	0.	0.	1215.	298.	0.	0.	0.	10246.	0.	35968.	0.	12507.	23461.	0.	0.	0.	0.	0.
30	69	3	0.	0.	1149.	296.	0.	0.	0.	9031.	0.	35297.	0.	12211.	23086.	0.	0.	0.	0.	0.
31	69	3	0.	0.	1080.	279.	0.	0.	0.	7884.	0.	34664.	0.	11932.	22732.	0.	0.	0.	0.	0.
32	69	3	0.	0.	1013.	187.	0.	0.	0.	6908.	8064.	25161.	0.	917.	24244.	0.	0.	0.	0.	0.
33	69	3	0.	0.	900.	186.	0.	0.	0.	13959.	0.	24621.	0.	731.	23890.	0.	0.	0.	0.	0.
34	69	3	14597.	4137.	720.	184.	0.	16400.	0.	14104.	0.	40485.	0.	15885.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW					2384.0TOTAL SYSTEM OVERFLOW					0.0TOVERDRAFT		0.0								
35	69	3	0.	0.	755.	284.	0.	0.	0.	13500.	0.	39864.	0.	15602.	24262.	0.	0.	0.	0.	0.
36	69	3	0.	0.	698.	243.	0.	0.	0.	12735.	0.	39333.	0.	15359.	23974.	0.	0.	0.	0.	0.
37	69	3	0.	0.	608.	241.	0.	0.	0.	12037.	0.	38804.	0.	15118.	23686.	0.	0.	0.	0.	0.
38	69	3	5095.	3077.	540.	240.	0.	8172.	0.	12463.	0.	46450.	0.	21850.	24600.	0.	0.	0.	0.	0.
39	69	3	0.	0.	473.	276.	0.	0.	0.	11923.	0.	45883.	0.	21573.	24309.	0.	0.	0.	0.	0.
40	69	3	0.	0.	450.	198.	0.	0.	0.	11482.	0.	45476.	0.	21375.	24101.	0.	0.	0.	0.	0.
41	69	3	0.	0.	405.	198.	0.	0.	0.	11032.	0.	45070.	0.	21177.	23893.	0.	0.	0.	0.	0.
42	69	3	272.	9.	155.	197.	0.	281.	0.	11234.	0.	44948.	0.	20981.	23967.	0.	0.	0.	0.	0.
43	69	3	0.	0.	135.	196.	0.	0.	0.	11075.	0.	44544.	0.	20784.	23760.	0.	0.	0.	0.	0.
44	69	3	0.	0.	101.	152.	0.	0.	0.	10941.	0.	44231.	0.	20632.	23599.	0.	0.	0.	0.	0.
45	69	3	94.	0.	68.	120.	0.	84.	0.	11066.	0.	44069.	0.	20513.	23557.	0.	0.	0.	0.	0.
46	69	3	0.	0.	45.	119.	0.	0.	0.	10999.	0.	43924.	0.	20393.	23431.	0.	0.	0.	0.	0.
47	69	3	0.	0.	23.	119.	0.	0.	0.	10954.	0.	43579.	0.	20274.	23304.	0.	0.	0.	0.	0.
48	69	3	302.	35.	11.	121.	0.	337.	0.	11602.	0.	43666.	0.	20153.	23513.	0.	0.	0.	0.	0.
49	69	3	0.	0.	9.	128.	0.	0.	0.	11746.	0.	43402.	0.	20025.	23376.	0.	0.	0.	0.	0.
50	69	3	0.	0.	7.	127.	0.	0.	0.	11737.	0.	43139.	0.	19898.	23241.	0.	0.	0.	0.	0.
51	69	3	0.	0.	5.	127.	0.	0.	0.	11730.	0.	42876.	0.	19771.	23105.	0.	0.	0.	0.	0.
52	69	3	0.	0.	2.	127.	0.	0.	0.	11725.	0.	42615.	0.	19644.	22970.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
69	24168.2	14180.7	22506.8	17012.1	0.0	32417.2	3319.7	2384.0	0.0	0.0	15805.6	0.0

EFFICIENCY FOR YEAR 4EQUALS 41.79

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	70	3	0.	0.	2.	113.	0.	0.	0.	11723.	0.	42392.	0.	19532.	22850.	0.	0.	0.	0.	0.
2	70	3	0.	0.	2.	112.	0.	0.	0.	11721.	0.	42149.	0.	19419.	22730.	0.	0.	0.	0.	0.
3	70	3	1640.	1617.	2.	112.	0.	3257.	0.	12280.	0.	45175.	0.	20575.	24600.	0.	0.	0.	0.	0.
4	70	3	851.	1053.	2.	115.	0.	1904.	0.	12469.	0.	46841.	0.	22241.	24600.	0.	0.	0.	0.	0.
5	70	3	0.	0.	59.	126.	0.	0.	0.	12467.	0.	46583.	0.	22115.	24469.	0.	0.	0.	0.	0.
6	70	3	0.	0.	88.	131.	0.	0.	0.	12409.	0.	46316.	0.	21984.	24332.	0.	0.	0.	0.	0.
7	70	3	0.	0.	146.	131.	0.	0.	0.	12321.	0.	46049.	0.	21853.	24196.	0.	0.	0.	0.	0.
8	70	3	0.	0.	234.	130.	0.	0.	0.	12175.	0.	45782.	0.	21723.	24060.	0.	0.	0.	0.	0.
9	70	3	0.	0.	248.	216.	0.	0.	0.	11941.	0.	45341.	0.	21507.	23834.	0.	0.	0.	0.	0.
10	70	3	0.	0.	273.	280.	0.	0.	0.	11693.	0.	44769.	0.	21227.	23542.	0.	0.	0.	0.	0.
11	70	3	0.	0.	338.	278.	0.	0.	0.	11401.	0.	44201.	0.	20949.	23252.	0.	0.	0.	0.	0.
12	70	3	0.	0.	333.	277.	0.	0.	0.	11063.	0.	43636.	0.	20673.	22963.	0.	0.	0.	0.	0.
13	70	3	0.	0.	405.	287.	0.	0.	0.	10681.	0.	43048.	0.	20385.	22663.	0.	0.	0.	0.	0.
14	70	3	0.	0.	416.	360.	0.	0.	0.	10276.	0.	42312.	0.	20025.	22287.	0.	0.	0.	0.	0.
15	70	3	0.	0.	428.	357.	0.	0.	0.	9859.	0.	41582.	0.	19668.	21914.	0.	0.	0.	0.	0.
16	70	3	0.	0.	439.	355.	0.	0.	0.	9432.	0.	40857.	0.	19314.	21543.	0.	0.	0.	0.	0.
17	70	3	0.	0.	450.	352.	0.	0.	0.	8993.	0.	40137.	0.	18962.	21175.	0.	0.	0.	0.	0.
18	70	3	0.	0.	473.	350.	0.	0.	0.	8543.	0.	39401.	0.	18602.	20800.	0.	0.	0.	0.	0.
19	70	3	0.	0.	461.	359.	0.	0.	0.	8071.	0.	38668.	0.	18243.	20425.	0.	0.	0.	0.	0.
20	70	3	0.	0.	484.	356.	0.	0.	0.	7609.	0.	37940.	0.	17887.	20052.	0.	0.	0.	0.	0.
21	70	3	0.	0.	518.	244.	0.	0.	0.	7126.	7846.	28575.	0.	4378.	24198.	0.	0.	0.	0.	0.
22	70	3	0.	0.	540.	218.	0.	0.	0.	14501.	0.	27999.	0.	4160.	23839.	0.	0.	0.	0.	0.
23	70	3	0.	0.	563.	198.	0.	0.	0.	14009.	0.	27475.	0.	3962.	23512.	0.	0.	0.	0.	0.
24	70	3	0.	0.	585.	196.	0.	0.	0.	13595.	0.	26954.	0.	3766.	23188.	0.	0.	0.	0.	0.
25	70	3	0.	0.	595.	195.	0.	0.	0.	13010.	0.	26437.	0.	3572.	22865.	0.	0.	0.	0.	0.
26	70	3	0.	0.	1170.	194.	0.	0.	0.	12523.	0.	25920.	0.	3377.	22542.	0.	0.	0.	0.	0.
27	70	3	0.	0.	1260.	200.	0.	0.	0.	11353.	0.	25388.	0.	3178.	22210.	0.	0.	0.	0.	0.
28	70	3	0.	0.	1350.	198.	0.	0.	0.	10093.	0.	24860.	0.	2980.	21880.	0.	0.	0.	0.	0.
29	70	3	0.	0.	1215.	196.	0.	0.	2784.	8847.	0.	24336.	0.	0.	24336.	0.	0.	0.	0.	0.
30	70	3	0.	0.	1148.	0.	0.	0.	0.	7694.	0.	23993.	0.	0.	23993.	0.	0.	0.	0.	0.
31	70	3	0.	0.	1030.	0.	0.	0.	0.	6547.	8425.	14329.	0.	0.	14329.	0.	0.	0.	0.	0.
32	70	3	0.	0.	1013.	0.	0.	0.	0.	13892.	0.	14020.	0.	0.	14020.	0.	0.	0.	0.	0.
33	70	3	0.	0.	930.	0.	0.	0.	0.	12879.	0.	13714.	0.	0.	13714.	0.	0.	0.	0.	0.
34	70	3	0.	0.	720.	0.	0.	0.	0.	11979.	0.	13409.	0.	0.	13409.	0.	0.	0.	0.	0.
35	70	3	0.	0.	795.	0.	0.	0.	0.	11259.	0.	13126.	0.	0.	13126.	0.	0.	0.	0.	0.
36	70	3	0.	0.	698.	0.	0.	0.	0.	10494.	0.	12893.	0.	0.	12893.	0.	0.	0.	0.	0.
37	70	3	107.	0.	608.	0.	0.	107.	0.	10167.	0.	12767.	0.	0.	12767.	0.	0.	0.	0.	0.
38	70	3	219.	0.	540.	0.	0.	219.	0.	9874.	0.	12755.	0.	0.	12755.	0.	0.	0.	0.	0.
39	70	3	2570.	1621.	473.	0.	0.	4191.	0.	10354.	0.	16714.	0.	0.	16714.	0.	0.	0.	0.	0.
40	70	3	0.	0.	450.	0.	0.	0.	0.	9882.	0.	16519.	0.	0.	16519.	0.	0.	0.	0.	0.
41	70	3	0.	0.	405.	0.	0.	0.	0.	9432.	0.	16324.	0.	0.	16324.	0.	0.	0.	0.	0.
42	70	3	0.	0.	158.	0.	0.	0.	0.	9027.	0.	16130.	0.	0.	16130.	0.	0.	0.	0.	0.
43	70	3	0.	0.	135.	0.	0.	0.	0.	8869.	0.	15937.	0.	0.	15937.	0.	0.	0.	0.	0.
44	70	3	0.	0.	101.	0.	0.	0.	0.	8734.	0.	15766.	0.	0.	15766.	0.	0.	0.	0.	0.
45	70	3	0.	0.	68.	0.	0.	0.	0.	8633.	0.	15613.	0.	0.	15613.	0.	0.	0.	0.	0.
46	70	3	0.	0.	45.	0.	0.	0.	0.	8555.	0.	15460.	0.	0.	15460.	0.	0.	0.	0.	0.
47	70	3	0.	0.	23.	0.	0.	0.	0.	8520.	0.	15308.	0.	0.	15308.	0.	0.	0.	0.	0.
48	70	3	0.	0.	11.	0.	0.	0.	0.	8498.	0.	15161.	0.	0.	15161.	0.	0.	0.	0.	0.
49	70	3	0.	0.	9.	0.	0.	0.	0.	8487.	0.	15024.	0.	0.	15024.	0.	0.	0.	0.	0.
50	70	3	0.	0.	7.	0.	0.	0.	0.	8479.	0.	14887.	0.	0.	14887.	0.	0.	0.	0.	0.
51	70	3	0.	0.	5.	0.	0.	0.	0.	8471.	0.	14752.	0.	0.	14752.	0.	0.	0.	0.	0.
52	70	3	0.	0.	2.	0.	0.	0.	0.	8466.	0.	14616.	0.	0.	14616.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
70	5337.0	5752.5	22506.8	6643.9	0.0	9579.2	2783.6	0.0	0.0	0.0		16270.5	0.0

EFFICIENCY FOR YEAR 5EQUALS 57.51

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	71	3	0.	0.	2.	0.	0.	0.	0.	8464.	0.	14468.	0.	0.	14468.	0.	0.	0.	0.	0.
2	71	3	0.	0.	2.	0.	0.	0.	0.	8462.	0.	14320.	0.	0.	14320.	0.	0.	0.	0.	0.
3	71	3	0.	0.	2.	0.	0.	0.	0.	8460.	0.	14173.	0.	0.	14173.	0.	0.	0.	0.	0.
4	71	3	0.	0.	2.	0.	0.	0.	0.	8457.	0.	14026.	0.	0.	14026.	0.	0.	0.	0.	0.
5	71	3	0.	0.	59.	0.	0.	0.	0.	8455.	0.	13871.	0.	0.	13871.	0.	0.	0.	0.	0.
6	71	3	0.	0.	88.	0.	0.	0.	0.	8397.	0.	13710.	0.	0.	13710.	0.	0.	0.	0.	0.
7	71	3	0.	0.	146.	0.	0.	0.	0.	8309.	0.	13549.	0.	0.	13549.	0.	0.	0.	0.	0.
8	71	3	0.	0.	234.	0.	0.	0.	0.	8163.	0.	13389.	0.	0.	13389.	0.	0.	0.	0.	0.
9	71	3	0.	0.	248.	0.	0.	0.	0.	7929.	0.	13185.	0.	0.	13185.	0.	0.	0.	0.	0.
10	71	3	0.	0.	293.	0.	0.	0.	0.	7681.	0.	12948.	0.	0.	12948.	0.	0.	0.	0.	0.
11	71	3	0.	0.	338.	0.	0.	0.	0.	7389.	7583.	4341.	0.	0.	4341.	0.	0.	0.	0.	0.
12	71	3	0.	0.	383.	0.	0.	0.	0.	14634.	0.	4161.	0.	0.	4161.	0.	0.	0.	0.	0.
13	71	3	0.	0.	405.	0.	0.	0.	0.	14252.	0.	3978.	0.	0.	3978.	0.	0.	0.	0.	0.
14	71	3	0.	0.	415.	0.	0.	0.	0.	13847.	0.	3774.	0.	0.	3774.	0.	0.	0.	0.	0.
15	71	3	0.	0.	428.	0.	0.	0.	0.	13430.	0.	3573.	0.	0.	3573.	0.	0.	0.	0.	0.
16	71	3	0.	0.	439.	0.	0.	0.	0.	13003.	0.	3373.	0.	0.	3373.	0.	0.	0.	0.	0.
17	71	3	0.	0.	450.	0.	0.	0.	0.	12564.	0.	3174.	0.	0.	3174.	0.	0.	0.	0.	0.
18	71	3	0.	0.	473.	0.	0.	0.	0.	12114.	0.	2960.	0.	0.	2960.	0.	0.	0.	0.	0.
19	71	3	0.	0.	481.	0.	0.	0.	0.	11704.	0.	2745.	0.	0.	2745.	0.	0.	0.	0.	0.
20	71	3	627.	261.	484.	0.	0.	888.	0.	11847.	0.	3420.	0.	0.	3420.	0.	0.	0.	0.	0.
21	71	3	0.	0.	515.	0.	0.	0.	0.	11363.	0.	3201.	0.	0.	3201.	0.	0.	0.	0.	0.
22	71	3	0.	0.	540.	0.	0.	0.	0.	10846.	0.	3009.	0.	0.	3009.	0.	0.	0.	0.	0.
23	71	3	0.	0.	563.	0.	0.	0.	0.	10306.	0.	2837.	0.	0.	2837.	0.	0.	0.	0.	0.
24	71	3	0.	0.	585.	0.	0.	0.	0.	9790.	0.	2667.	0.	0.	2667.	0.	0.	0.	0.	0.
25	71	3	0.	0.	596.	0.	0.	0.	0.	9276.	0.	2498.	0.	0.	2498.	0.	0.	0.	0.	0.
26	71	3	1929.	752.	1170.	0.	0.	2690.	0.	9383.	0.	5019.	0.	0.	5018.	0.	0.	0.	0.	0.
27	71	3	0.	0.	1260.	0.	0.	0.	0.	8218.	0.	4814.	0.	0.	4814.	0.	0.	0.	0.	0.
28	71	3	0.	0.	1350.	0.	0.	0.	0.	7062.	4333.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	71	3	0.	0.	1215.	0.	0.	0.	0.	10045.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	71	3	0.	0.	1148.	0.	0.	0.	0.	8830.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	71	3	4428.	2414.	1080.	0.	0.	6842.	0.	8588.	0.	6842.	0.	0.	6842.	0.	0.	0.	0.	0.
32	71	3	0.	0.	1013.	0.	0.	0.	0.	7570.	0.	6664.	0.	0.	6664.	0.	0.	0.	0.	0.
33	71	3	29745.	10850.	500.	0.	0.	16400.	0.	8495.	0.	22887.	0.	0.	22887.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 24195.7TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
34	71	3	0.	0.	720.	0.	0.	0.	0.	7585.	0.	22623.	0.	0.	22623.	0.	0.	0.	0.	0.
35	71	3	0.	0.	765.	0.	0.	0.	0.	6865.	8106.	13403.	0.	0.	13403.	0.	0.	0.	0.	0.
36	71	3	0.	0.	698.	0.	0.	0.	0.	14269.	0.	13199.	0.	0.	13199.	0.	0.	0.	0.	0.
37	71	3	3260.	2213.	608.	0.	0.	5494.	0.	14388.	0.	18490.	0.	0.	18490.	0.	0.	0.	0.	0.
38	71	3	0.	0.	540.	0.	0.	0.	0.	13780.	0.	18261.	0.	0.	18261.	0.	0.	0.	0.	0.
39	71	3	0.	0.	473.	0.	0.	0.	0.	13240.	0.	18032.	0.	0.	18032.	0.	0.	0.	0.	0.
40	71	3	765.	458.	450.	0.	0.	1224.	0.	13508.	0.	19119.	0.	0.	19119.	0.	0.	0.	0.	0.
41	71	3	13699.	8445.	405.	0.	0.	16400.	0.	14890.	0.	35379.	0.	10779.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 5744.6TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
42	71	3	4895.	3702.	198.	115.	0.	8596.	0.	14972.	0.	43705.	0.	19105.	24600.	0.	0.	0.	0.	0.
43	71	3	0.	0.	135.	140.	0.	0.	0.	14814.	0.	43409.	0.	18965.	24444.	0.	0.	0.	0.	0.
44	71	3	0.	0.	101.	149.	0.	0.	0.	14679.	0.	43095.	0.	18816.	24279.	0.	0.	0.	0.	0.
45	71	3	0.	0.	68.	155.	0.	0.	0.	14578.	0.	42768.	0.	18661.	24107.	0.	0.	0.	0.	0.
46	71	3	0.	0.	45.	154.	0.	0.	0.	14510.	0.	42442.	0.	18506.	23936.	0.	0.	0.	0.	0.
47	71	3	0.	0.	23.	154.	0.	0.	0.	14465.	0.	42117.	0.	18352.	23765.	0.	0.	0.	0.	0.
48	71	3	0.	0.	11.	148.	0.	0.	0.	14443.	0.	41805.	0.	18204.	23600.	0.	0.	0.	0.	0.
49	71	3	0.	0.	9.	134.	0.	0.	0.	14432.	0.	41521.	0.	18070.	23451.	0.	0.	0.	0.	0.
50	71	3	0.	0.	7.	134.	0.	0.	0.	14423.	0.	41239.	0.	17936.	23302.	0.	0.	0.	0.	0.
51	71	3	0.	0.	5.	133.	0.	0.	0.	14494.	0.	40957.	0.	17803.	23154.	0.	0.	0.	0.	0.
52	71	3	0.	0.	2.	133.	0.	0.	0.	14489.	0.	40676.	0.	17670.	23006.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
71	59369.6	34023.5	22506.8	1549.9	0.0	58534.6	0.0	29940.4	0.0	0.0	0.0	20022.2	277.6

EFFICIENCY FOR YEAR 6EQUALS 33.43

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	72	3	0.	0.	2.	137.	0.	0.	0.	14487.	0.	40387.	0.	17533.	22854.	0.	0.	0.	0.	0.
2	72	3	0.	0.	2.	137.	0.	0.	0.	14485.	0.	40098.	0.	17396.	22702.	0.	0.	0.	0.	0.
3	72	3	0.	0.	2.	136.	0.	0.	0.	14483.	0.	39810.	0.	17260.	22551.	0.	0.	0.	0.	0.
4	72	3	0.	0.	2.	136.	0.	0.	0.	14480.	0.	39524.	0.	17124.	22399.	0.	0.	0.	0.	0.
5	72	3	0.	0.	59.	144.	0.	0.	0.	14478.	0.	39220.	0.	16980.	22240.	0.	0.	0.	0.	0.
6	72	3	0.	0.	88.	149.	0.	0.	0.	14420.	0.	38964.	0.	16831.	22073.	0.	0.	0.	0.	0.
7	72	3	0.	0.	146.	149.	0.	0.	0.	14332.	0.	38590.	0.	16682.	21908.	0.	0.	0.	0.	0.
8	72	3	0.	0.	234.	148.	0.	0.	0.	14186.	0.	38276.	0.	16533.	21742.	0.	0.	0.	0.	0.
9	72	3	0.	0.	248.	161.	0.	0.	0.	13952.	0.	37935.	0.	16372.	21563.	0.	0.	0.	0.	0.
10	72	3	0.	0.	293.	170.	0.	0.	0.	13704.	0.	37576.	0.	16202.	21373.	0.	0.	0.	0.	0.
11	72	3	0.	0.	338.	170.	0.	0.	0.	13412.	0.	37217.	0.	16032.	21185.	0.	0.	0.	0.	0.
12	72	3	0.	0.	333.	169.	0.	0.	0.	13074.	0.	36860.	0.	15863.	20996.	0.	0.	0.	0.	0.
13	72	3	0.	0.	405.	156.	0.	0.	0.	12692.	0.	36466.	0.	15677.	20789.	0.	0.	0.	0.	0.
14	72	3	0.	0.	416.	291.	0.	0.	0.	12287.	0.	35850.	0.	15386.	20464.	0.	0.	0.	0.	0.
15	72	3	0.	0.	428.	289.	0.	0.	0.	11870.	0.	35236.	0.	15097.	20142.	0.	0.	0.	0.	0.
16	72	3	0.	0.	439.	287.	0.	0.	0.	11443.	0.	34630.	0.	14809.	19821.	0.	0.	0.	0.	0.
17	72	3	0.	0.	450.	286.	0.	0.	0.	11004.	0.	34026.	0.	14524.	19503.	0.	0.	0.	0.	0.
18	72	3	0.	0.	473.	240.	0.	0.	0.	10554.	0.	33519.	0.	14284.	19235.	0.	0.	0.	0.	0.
19	72	3	0.	0.	461.	231.	0.	0.	0.	10082.	0.	33030.	0.	14053.	18977.	0.	0.	0.	0.	0.
20	72	3	0.	0.	484.	230.	0.	0.	0.	9623.	0.	32544.	0.	13823.	18721.	0.	0.	0.	0.	0.
21	72	3	0.	0.	515.	229.	0.	0.	0.	9137.	0.	32061.	0.	13595.	18466.	0.	0.	0.	0.	0.
22	72	3	0.	0.	540.	238.	0.	0.	0.	8619.	0.	31556.	0.	13356.	18200.	0.	0.	0.	0.	0.
23	72	3	0.	0.	563.	245.	0.	0.	0.	8079.	0.	31036.	0.	13111.	17925.	0.	0.	0.	0.	0.
24	72	3	0.	0.	585.	244.	0.	0.	0.	7517.	0.	30520.	0.	12867.	17653.	0.	0.	0.	0.	0.
25	72	3	0.	0.	596.	0.	0.	0.	0.	6932.	8040.	21293.	0.	0.	21293.	0.	0.	0.	0.	0.
26	72	3	0.	0.	1170.	0.	0.	0.	0.	14375.	0.	21009.	0.	0.	21009.	0.	0.	0.	0.	0.
27	72	3	0.	0.	1260.	0.	0.	0.	0.	13205.	0.	20768.	0.	0.	20768.	0.	0.	0.	0.	0.
28	72	3	0.	0.	1350.	0.	0.	0.	0.	11945.	0.	20529.	0.	0.	20529.	0.	0.	0.	0.	0.
29	72	3	0.	0.	1215.	0.	0.	0.	0.	10595.	0.	20290.	0.	0.	20290.	0.	0.	0.	0.	0.
30	72	3	0.	0.	1146.	0.	0.	0.	0.	9380.	0.	20053.	0.	0.	20053.	0.	0.	0.	0.	0.
31	72	3	0.	0.	1030.	0.	0.	0.	0.	8233.	0.	19793.	0.	0.	19793.	0.	0.	0.	0.	0.
32	72	3	0.	0.	1013.	0.	0.	0.	0.	7153.	7819.	10886.	0.	0.	10886.	0.	0.	0.	0.	0.
33	72	3	0.	0.	900.	0.	0.	0.	0.	13959.	0.	10667.	0.	0.	10667.	0.	0.	0.	0.	0.
34	72	3	0.	0.	720.	0.	0.	0.	0.	13059.	0.	10450.	0.	0.	10450.	0.	0.	0.	0.	0.
35	72	3	0.	0.	720.	0.	0.	0.	0.	12339.	0.	10242.	0.	0.	10242.	0.	0.	0.	0.	0.
36	72	3	0.	0.	696.	0.	0.	0.	0.	11621.	0.	10055.	0.	0.	10055.	0.	0.	0.	0.	0.
37	72	3	544.	90.	608.	0.	0.	624.	0.	11534.	0.	10492.	0.	0.	10492.	0.	0.	0.	0.	0.
38	72	3	25790.	8591.	540.	0.	0.	16400.	0.	12578.	0.	26703.	0.	2103.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 17981.0TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
39	72	3	206.	0.	473.	142.	0.	206.	0.	12587.	0.	26509.	0.	1961.	24548.	0.	0.	0.	0.	0.
40	72	3	0.	0.	450.	85.	0.	0.	0.	12130.	0.	26269.	0.	1876.	24393.	0.	0.	0.	0.	0.
41	72	3	0.	0.	405.	85.	0.	0.	0.	11680.	0.	26029.	0.	1792.	24238.	0.	0.	0.	0.	0.
42	72	3	0.	0.	158.	84.	0.	0.	0.	11275.	0.	25790.	0.	1707.	24083.	0.	0.	0.	0.	0.
43	72	3	3526.	2714.	135.	84.	0.	6239.	0.	12007.	0.	31792.	0.	7192.	24600.	0.	0.	0.	0.	0.
44	72	3	0.	0.	101.	110.	0.	0.	0.	11872.	0.	31516.	0.	7082.	24434.	0.	0.	0.	0.	0.
45	72	3	0.	0.	65.	114.	0.	0.	0.	11771.	0.	31229.	0.	6967.	24262.	0.	0.	0.	0.	0.
46	72	3	0.	0.	45.	114.	0.	0.	0.	11704.	0.	30943.	0.	6853.	24090.	0.	0.	0.	0.	0.
47	72	3	0.	0.	23.	114.	0.	0.	0.	11659.	0.	30658.	0.	6740.	23918.	0.	0.	0.	0.	0.
48	72	3	0.	0.	11.	109.	0.	0.	0.	11636.	0.	30384.	0.	6630.	23754.	0.	0.	0.	0.	0.
49	72	3	0.	0.	9.	99.	0.	0.	0.	11625.	0.	30135.	0.	6531.	23604.	0.	0.	0.	0.	0.
50	72	3	0.	0.	7.	99.	0.	0.	0.	11616.	0.	29888.	0.	6433.	23455.	0.	0.	0.	0.	0.
51	72	3	0.	0.	5.	98.	0.	0.	0.	11609.	0.	29641.	0.	6334.	23306.	0.	0.	0.	0.	0.
52	72	3	0.	0.	2.	98.	0.	0.	0.	11605.	0.	29394.	0.	6236.	23158.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
72	30065.9	13772.7	22506.8	6237.1	0.0	23469.1	0.0	17981.0	0.0	0.0	0.0	15858.6	0.0

EFFICIENCY FOR YEAR 7EQUALS 40.83

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	73	3	0.	0.	2.	101.	0.	0.	0.	11602.	0.	29141.	0.	6136.	23005.	0.	0.	0.	0.	0.
2	73	3	53.	0.	2.	100.	0.	53.	0.	11894.	0.	28941.	0.	6035.	22906.	0.	0.	0.	0.	0.
3	73	3	0.	0.	2.	100.	0.	0.	0.	11891.	0.	28689.	0.	5935.	22754.	0.	0.	0.	0.	0.
4	73	3	0.	0.	2.	100.	0.	0.	0.	11889.	0.	28438.	0.	5835.	22602.	0.	0.	0.	0.	0.
5	73	3	0.	0.	59.	106.	0.	0.	0.	11887.	0.	28172.	0.	5730.	22442.	0.	0.	0.	0.	0.
6	73	3	0.	0.	88.	110.	0.	0.	0.	11828.	0.	27895.	0.	5620.	22275.	0.	0.	0.	0.	0.
7	73	3	0.	0.	146.	109.	0.	0.	0.	11741.	0.	27619.	0.	5511.	22109.	0.	0.	0.	0.	0.
8	73	3	0.	0.	234.	109.	0.	0.	0.	11704.	0.	27345.	0.	5402.	21943.	0.	0.	0.	0.	0.
9	73	3	0.	0.	248.	118.	0.	0.	0.	11470.	0.	27046.	0.	5284.	21763.	0.	0.	0.	0.	0.
10	73	3	0.	0.	293.	125.	0.	0.	0.	11222.	0.	26731.	0.	5159.	21572.	0.	0.	0.	0.	0.
11	73	3	0.	0.	338.	124.	0.	0.	0.	10930.	0.	26418.	0.	5035.	21383.	0.	0.	0.	0.	0.
12	73	3	0.	0.	383.	124.	0.	0.	0.	10592.	0.	26105.	0.	4911.	21194.	0.	0.	0.	0.	0.
13	73	3	0.	0.	409.	136.	0.	0.	0.	10210.	0.	25761.	0.	4775.	20986.	0.	0.	0.	0.	0.
14	73	3	0.	0.	416.	213.	0.	0.	0.	9805.	0.	25222.	0.	4562.	20660.	0.	0.	0.	0.	0.
15	73	3	0.	0.	428.	211.	0.	0.	0.	9388.	0.	24687.	0.	4351.	20336.	0.	0.	0.	0.	0.
16	73	3	0.	0.	439.	209.	0.	0.	4142.	8961.	0.	24156.	0.	0.	24156.	0.	0.	0.	0.	0.
17	73	3	0.	0.	450.	0.	0.	0.	0.	8522.	0.	23810.	0.	0.	23810.	0.	0.	0.	0.	0.
18	73	3	0.	0.	473.	0.	0.	0.	0.	8072.	0.	23520.	0.	0.	23520.	0.	0.	0.	0.	0.
19	73	3	0.	0.	461.	0.	0.	0.	0.	7600.	0.	23240.	0.	0.	23240.	0.	0.	0.	0.	0.
20	73	3	0.	0.	434.	0.	0.	0.	0.	7138.	7833.	14304.	0.	0.	14304.	0.	0.	0.	0.	0.
21	73	3	0.	0.	516.	0.	0.	0.	0.	14488.	0.	14073.	0.	0.	14073.	0.	0.	0.	0.	0.
22	73	3	0.	0.	540.	0.	0.	0.	0.	13970.	0.	13814.	0.	0.	13814.	0.	0.	0.	0.	0.
23	73	3	0.	0.	563.	0.	0.	0.	0.	13430.	0.	13535.	0.	0.	13535.	0.	0.	0.	0.	0.
24	73	3	0.	0.	585.	0.	0.	0.	0.	12868.	0.	13258.	0.	0.	13258.	0.	0.	0.	0.	0.
25	73	3	4509.	3258.	596.	0.	0.	7797.	0.	13296.	0.	20779.	0.	0.	20779.	0.	0.	0.	0.	0.
26	73	3	0.	0.	1170.	0.	0.	0.	0.	12700.	0.	20460.	0.	0.	20460.	0.	0.	0.	0.	0.
27	73	3	160.	0.	1240.	0.	0.	160.	0.	11992.	0.	20336.	0.	0.	20336.	0.	0.	0.	0.	0.
28	73	3	0.	0.	1300.	0.	0.	0.	0.	10732.	0.	20053.	0.	0.	20053.	0.	0.	0.	0.	0.
29	73	3	0.	0.	1215.	0.	0.	0.	0.	9382.	0.	19772.	0.	0.	19772.	0.	0.	0.	0.	0.
30	73	3	1835.	652.	1148.	0.	0.	2486.	0.	8839.	0.	21978.	0.	0.	21978.	0.	0.	0.	0.	0.
31	73	3	0.	0.	1080.	0.	0.	0.	0.	7691.	0.	21692.	0.	0.	21692.	0.	0.	0.	0.	0.
32	73	3	1259.	1335.	1013.	0.	0.	2594.	0.	7522.	0.	24005.	0.	0.	24005.	0.	0.	0.	0.	0.
33	73	3	36279.	10947.	900.	0.	0.	16400.	0.	8442.	0.	40111.	0.	15511.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 30826.1TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
34	73	3	0.	0.	720.	247.	0.	0.	0.	7542.	0.	39566.	0.	15264.	24303.	0.	0.	0.	0.	0.
35	73	3	0.	0.	755.	180.	0.	0.	0.	6926.	8045.	30165.	0.	5847.	24318.	0.	0.	0.	0.	0.
36	73	3	0.	0.	698.	155.	0.	0.	0.	14207.	0.	29769.	0.	5693.	24076.	0.	0.	0.	0.	0.
37	73	3	21304.	8157.	608.	154.	0.	16400.	0.	14972.	0.	45773.	0.	21173.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 13061.0TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
38	73	3	0.	0.	540.	229.	0.	0.	0.	14380.	0.	45301.	0.	20945.	24356.	0.	0.	0.	0.	0.
39	73	3	1471.	624.	473.	228.	0.	2095.	0.	14572.	0.	46926.	0.	22326.	24600.	0.	0.	0.	0.	0.
40	73	3	0.	0.	450.	194.	0.	0.	0.	14289.	0.	46530.	0.	22132.	24398.	0.	0.	0.	0.	0.
41	73	3	0.	0.	405.	193.	0.	0.	0.	13839.	0.	46136.	0.	21939.	24197.	0.	0.	0.	0.	0.
42	73	3	1970.	1949.	158.	192.	0.	3919.	0.	14252.	0.	49662.	462.	24600.	24600.	0.	0.	0.	0.	0.
43	73	3	0.	0.	135.	474.	0.	0.	190.	14095.	0.	48986.	0.	24398.	24588.	0.	0.	0.	0.	0.
44	73	3	0.	0.	101.	211.	0.	0.	0.	14022.	0.	48563.	0.	24187.	24376.	0.	0.	0.	0.	0.
45	73	3	0.	0.	68.	218.	0.	0.	0.	13921.	0.	48128.	0.	23970.	24158.	0.	0.	0.	0.	0.
46	73	3	0.	0.	45.	217.	0.	0.	0.	13854.	0.	47694.	0.	23753.	23941.	0.	0.	0.	0.	0.
47	73	3	0.	0.	23.	216.	0.	0.	0.	13809.	0.	47261.	0.	23537.	23724.	0.	0.	0.	0.	0.
48	73	3	0.	0.	11.	195.	0.	0.	0.	13786.	0.	46870.	0.	23342.	23528.	0.	0.	0.	0.	0.
49	73	3	0.	0.	9.	145.	0.	0.	0.	13775.	0.	46580.	0.	23197.	23383.	0.	0.	0.	0.	0.
50	73	3	0.	0.	7.	144.	0.	0.	0.	13766.	0.	46291.	0.	23053.	23238.	0.	0.	0.	0.	0.
51	73	3	0.	0.	5.	144.	0.	0.	0.	13759.	0.	46003.	0.	22909.	23094.	0.	0.	0.	0.	0.
52	73	3	0.	0.	2.	144.	0.	0.	0.	13833.	0.	45716.	0.	22766.	22950.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
73	68340.5	32177.9	22506.8	5972.8	0.0	51904.9	4331.9	43887.1	0.0	0.0	0.0	15379.3	151.2

EFFICIENCY FOR YEAR BEQUALS 26.57

WK	YR	K	RUNOFF MATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	74	3	0.	0.	2.	166.	0.	0.	0.	13831.	0.	45354.	0.	22600.	22784.	0.	0.	0.	0.	0.
2	74	3	0.	0.	2.	165.	0.	0.	0.	13828.	0.	45053.	0.	22435.	22618.	0.	0.	0.	0.	0.
3	74	3	0.	0.	2.	165.	0.	0.	0.	13826.	0.	44723.	0.	22270.	22453.	0.	0.	0.	0.	0.
4	74	3	0.	0.	2.	164.	0.	0.	0.	13895.	0.	44395.	0.	22106.	22288.	0.	0.	0.	0.	0.
5	74	3	0.	0.	59.	174.	0.	0.	0.	13884.	0.	44047.	0.	21933.	22114.	0.	0.	0.	0.	0.
6	74	3	0.	0.	88.	181.	0.	0.	0.	13826.	0.	43685.	0.	21752.	21933.	0.	0.	0.	0.	0.
7	74	3	0.	0.	146.	190.	0.	0.	0.	13738.	0.	43325.	0.	21572.	21753.	0.	0.	0.	0.	0.
8	74	3	0.	0.	234.	179.	0.	0.	0.	13592.	0.	42965.	0.	21393.	21573.	0.	0.	0.	0.	0.
9	74	3	0.	0.	248.	237.	0.	0.	0.	13358.	0.	42491.	0.	21156.	21335.	0.	0.	0.	0.	0.
10	74	3	0.	0.	293.	279.	0.	0.	0.	13110.	0.	41932.	0.	20877.	21055.	0.	0.	0.	0.	0.
11	74	3	0.	0.	338.	278.	0.	0.	0.	12818.	0.	41376.	0.	20599.	20777.	0.	0.	0.	0.	0.
12	74	3	0.	0.	383.	276.	0.	0.	0.	12480.	0.	40823.	0.	20323.	20500.	0.	0.	0.	0.	0.
13	74	3	0.	0.	405.	256.	0.	0.	0.	12098.	0.	40251.	0.	20038.	20213.	0.	0.	0.	0.	0.
14	74	3	0.	0.	416.	350.	0.	0.	0.	11693.	0.	39550.	0.	19688.	19862.	0.	0.	0.	0.	0.
15	74	3	0.	0.	428.	367.	0.	0.	0.	11275.	0.	38854.	0.	19341.	19513.	0.	0.	0.	0.	0.
16	74	3	0.	0.	439.	345.	0.	0.	0.	10849.	0.	38163.	0.	18996.	19167.	0.	0.	0.	0.	0.
17	74	3	0.	0.	450.	342.	0.	0.	0.	10410.	0.	37477.	0.	18653.	18824.	0.	0.	0.	0.	0.
18	74	3	0.	0.	473.	378.	0.	0.	0.	9960.	0.	36719.	0.	18275.	18444.	0.	0.	0.	0.	0.
19	74	3	0.	0.	461.	381.	0.	0.	0.	9488.	0.	35955.	0.	17894.	18061.	0.	0.	0.	0.	0.
20	74	3	0.	0.	434.	378.	0.	0.	0.	9026.	0.	35197.	0.	17516.	17682.	0.	0.	0.	0.	0.
21	74	3	0.	0.	519.	375.	0.	0.	0.	8543.	0.	34446.	0.	17140.	17305.	0.	0.	0.	0.	0.
22	74	3	0.	0.	546.	360.	0.	0.	0.	8025.	0.	33725.	0.	16781.	16944.	0.	0.	0.	0.	0.
23	74	3	0.	0.	563.	210.	0.	0.	0.	7485.	7486.	24792.	0.	597.	24195.	0.	0.	0.	0.	0.
24	74	3	0.	0.	535.	209.	0.	0.	389.	14409.	0.	24182.	0.	0.	24182.	0.	0.	0.	0.	0.
25	74	3	0.	0.	596.	0.	0.	0.	0.	13824.	0.	23780.	0.	0.	23780.	0.	0.	0.	0.	0.
26	74	3	0.	0.	1170.	0.	0.	0.	0.	13228.	0.	23384.	0.	0.	23384.	0.	0.	0.	0.	0.
27	74	3	0.	0.	1200.	0.	0.	0.	0.	12162.	0.	23008.	0.	0.	23008.	0.	0.	0.	0.	0.
28	74	3	0.	0.	1350.	0.	0.	0.	0.	11296.	0.	22634.	0.	0.	22634.	0.	0.	0.	0.	0.
29	74	3	0.	0.	1215.	0.	0.	0.	0.	10277.	0.	22263.	0.	0.	22263.	0.	0.	0.	0.	0.
30	74	3	0.	0.	1145.	0.	0.	0.	0.	9052.	0.	21895.	0.	0.	21895.	0.	0.	0.	0.	0.
31	74	3	0.	0.	1080.	0.	0.	0.	0.	7915.	0.	21554.	0.	0.	21554.	0.	0.	0.	0.	0.
32	74	3	10476.	3474.	1013.	0.	0.	13950.	0.	7795.	0.	35175.	0.	10575.	24600.	0.	0.	0.	0.	0.
33	74	3	0.	0.	900.	186.	0.	0.	0.	6783.	8189.	25542.	0.	1291.	24252.	0.	0.	0.	0.	0.
34	74	3	0.	0.	720.	184.	0.	0.	0.	14163.	0.	25012.	0.	1106.	23906.	0.	0.	0.	0.	0.
35	74	3	27952.	8193.	765.	165.	0.	16400.	0.	14972.	0.	40937.	0.	16337.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 19744.9TOTAL SYSTEM OVERFLOW 0.0OVERDRAFT 0.0																				
36	74	3	0.	0.	698.	174.	0.	0.	0.	14207.	0.	40514.	0.	16143.	24371.	0.	0.	0.	0.	0.
37	74	3	0.	0.	603.	193.	0.	0.	0.	13509.	0.	40094.	0.	15950.	24144.	0.	0.	0.	0.	0.
38	74	3	0.	0.	540.	192.	0.	0.	0.	12964.	0.	39675.	0.	15758.	23917.	0.	0.	0.	0.	0.
39	74	3	0.	0.	473.	191.	0.	0.	0.	12656.	0.	39257.	0.	15566.	23691.	0.	0.	0.	0.	0.
40	74	3	0.	0.	450.	191.	0.	0.	0.	12183.	0.	38841.	0.	15375.	23466.	0.	0.	0.	0.	0.
41	74	3	0.	0.	405.	190.	0.	0.	0.	11733.	0.	38427.	0.	15185.	23242.	0.	0.	0.	0.	0.
42	74	3	0.	0.	158.	189.	0.	0.	0.	11328.	0.	38015.	0.	14996.	23019.	0.	0.	0.	0.	0.
43	74	3	0.	0.	135.	188.	0.	0.	0.	11171.	0.	37604.	0.	14808.	22796.	0.	0.	0.	0.	0.
44	74	3	0.	0.	131.	164.	0.	0.	0.	11082.	0.	37246.	0.	14644.	22603.	0.	0.	0.	0.	0.
45	74	3	0.	0.	63.	146.	0.	0.	0.	10981.	0.	36928.	0.	14498.	22430.	0.	0.	0.	0.	0.
46	74	3	0.	0.	45.	145.	0.	0.	0.	10914.	0.	36610.	0.	14352.	22258.	0.	0.	0.	0.	0.
47	74	3	0.	0.	23.	145.	0.	0.	0.	10869.	0.	36294.	0.	14207.	22087.	0.	0.	0.	0.	0.
48	74	3	0.	0.	11.	131.	0.	0.	0.	10862.	0.	36007.	0.	14076.	21931.	0.	0.	0.	0.	0.
49	74	3	0.	0.	9.	98.	0.	0.	0.	10851.	0.	35793.	0.	13978.	21815.	0.	0.	0.	0.	0.
50	74	3	0.	0.	7.	98.	0.	0.	0.	10842.	0.	35578.	0.	13879.	21649.	0.	0.	0.	0.	0.
51	74	3	0.	0.	5.	98.	0.	0.	0.	10835.	0.	35365.	0.	13782.	21583.	0.	0.	0.	0.	0.
52	74	3	0.	0.	2.	98.	0.	0.	0.	11110.	0.	35155.	0.	13684.	21471.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
74	38431.1	13972.1	22506.8	9590.8	0.0	30353.6	389.4	19744.9	0.0	0.0	0.0	15674.9	86.3

EFFICIENCY FOR YEAR 9EQUALS 35.75

WK	YR	K	RUNOFF NATRL	RUNOFF HARVST	EVAPT AGRIC	EVAP WATER	DMSTIC WATERC	WATER V(1)	PUMPED CONC	SOIL MOISTURE	IRRIG	TOTAL VOLUME	1	2	3	4	5	6	7	8
1	75	3	0.	0.	2.	127.	0.	0.	0.	11123.	0.	34878.	0.	13557.	21321.	0.	0.	0.	0.	0.
2	75	3	0.	0.	2.	127.	0.	0.	0.	11121.	0.	34601.	0.	13430.	21171.	0.	0.	0.	0.	0.
3	75	3	0.	0.	2.	126.	0.	0.	0.	11119.	0.	34326.	0.	13304.	21021.	0.	0.	0.	0.	0.
4	75	3	0.	0.	2.	126.	0.	0.	0.	11116.	0.	34051.	0.	13179.	20872.	0.	0.	0.	0.	0.
5	75	3	0.	0.	59.	133.	0.	0.	0.	11114.	0.	33760.	0.	13045.	20715.	0.	0.	0.	0.	0.
6	75	3	0.	0.	88.	139.	0.	0.	0.	11055.	0.	33458.	0.	12907.	20551.	0.	0.	0.	0.	0.
7	75	3	0.	0.	146.	138.	0.	0.	0.	10963.	0.	33157.	0.	12769.	20387.	0.	0.	0.	0.	0.
8	75	3	0.	0.	234.	137.	0.	0.	0.	10821.	0.	32856.	0.	12632.	20224.	0.	0.	0.	0.	0.
9	75	3	0.	0.	248.	212.	0.	0.	0.	10587.	0.	32393.	0.	12420.	19973.	0.	0.	0.	0.	0.
10	75	3	0.	0.	293.	267.	0.	0.	0.	10340.	0.	31810.	0.	12153.	19656.	0.	0.	0.	0.	0.
11	75	3	0.	0.	338.	255.	0.	0.	0.	10047.	0.	31230.	0.	11889.	19342.	0.	0.	0.	0.	0.
12	75	3	0.	0.	353.	253.	0.	0.	0.	9710.	0.	30655.	0.	11625.	19029.	0.	0.	0.	0.	0.
13	75	3	0.	0.	405.	270.	0.	0.	0.	9327.	0.	30084.	0.	11356.	18708.	0.	0.	0.	0.	0.
14	75	3	0.	0.	416.	319.	0.	0.	0.	8922.	0.	29366.	0.	11037.	18329.	0.	0.	0.	0.	0.
15	75	3	0.	0.	428.	316.	0.	0.	0.	8506.	0.	28674.	0.	10721.	17953.	0.	0.	0.	0.	0.
16	75	3	0.	0.	439.	313.	0.	0.	0.	8079.	0.	27987.	0.	10407.	17579.	0.	0.	0.	0.	0.
17	75	3	0.	0.	450.	311.	0.	0.	0.	7640.	0.	27306.	0.	10097.	17209.	0.	0.	0.	0.	0.
18	75	3	0.	0.	473.	0.	0.	0.	0.	7190.	7782.	18311.	0.	0.	18211.	0.	0.	0.	0.	0.
19	75	3	0.	0.	461.	0.	0.	0.	0.	14499.	0.	17969.	0.	0.	17969.	0.	0.	0.	0.	0.
20	75	3	0.	0.	464.	0.	0.	0.	0.	14038.	0.	17630.	0.	0.	17630.	0.	0.	0.	0.	0.
21	75	3	147.	0.	518.	0.	0.	147.	0.	13970.	0.	17441.	0.	0.	17441.	0.	0.	0.	0.	0.
22	75	3	0.	0.	540.	0.	0.	0.	0.	13453.	0.	17084.	0.	0.	17084.	0.	0.	0.	0.	0.
23	75	3	0.	0.	563.	0.	0.	0.	0.	12913.	0.	16714.	0.	0.	16714.	0.	0.	0.	0.	0.
24	75	3	0.	0.	535.	0.	0.	0.	0.	12350.	0.	16347.	0.	0.	16347.	0.	0.	0.	0.	0.
25	75	3	0.	0.	596.	0.	0.	0.	0.	11963.	0.	15982.	0.	0.	15982.	0.	0.	0.	0.	0.
26	75	3	0.	0.	1170.	0.	0.	0.	0.	11367.	0.	15633.	0.	0.	15633.	0.	0.	0.	0.	0.
27	75	3	0.	0.	1260.	0.	0.	0.	0.	10197.	0.	15355.	0.	0.	15355.	0.	0.	0.	0.	0.
28	75	3	10475.	3503.	1350.	0.	0.	13980.	0.	9931.	0.	29058.	0.	4458.	24600.	0.	0.	0.	0.	0.
29	75	3	442.	302.	1215.	201.	0.	744.	0.	9250.	0.	29269.	0.	4669.	24600.	0.	0.	0.	0.	0.
30	75	3	442.	296.	1148.	202.	0.	738.	0.	8641.	0.	29473.	0.	4873.	24600.	0.	0.	0.	0.	0.
31	75	3	0.	0.	1080.	0.	0.	0.	0.	7493.	7478.	20886.	0.	0.	20886.	0.	0.	0.	0.	0.
32	75	3	1259.	1336.	1013.	0.	0.	2594.	0.	14802.	0.	23217.	0.	0.	23217.	0.	0.	0.	0.	0.
33	75	3	36279.	11025.	900.	0.	0.	16400.	0.	14972.	0.	39343.	0.	14743.	24600.	0.	0.	0.	0.	0.
COMPARTMENT 1 OVERFLOW 30903.7TOTAL SYSTEM OVERFLOW 0.0 OVERDRAFT 0.0																				
34	75	3	0.	0.	720.	230.	0.	0.	0.	14072.	0.	38831.	0.	14512.	24318.	0.	0.	0.	0.	0.
35	75	3	0.	0.	765.	227.	0.	0.	0.	13456.	0.	38325.	0.	14285.	24040.	0.	0.	0.	0.	0.
36	75	3	0.	0.	698.	222.	0.	0.	0.	12691.	0.	37832.	0.	14063.	23769.	0.	0.	0.	0.	0.
37	75	3	0.	0.	608.	221.	0.	0.	0.	11993.	0.	37341.	0.	13842.	23499.	0.	0.	0.	0.	0.
38	75	3	0.	0.	540.	220.	0.	0.	0.	11386.	0.	36852.	0.	13623.	23230.	0.	0.	0.	0.	0.
39	75	3	0.	0.	473.	218.	0.	0.	0.	10846.	0.	36366.	0.	13404.	22962.	0.	0.	0.	0.	0.
40	75	3	0.	0.	450.	217.	0.	0.	0.	10373.	0.	35884.	0.	13187.	22696.	0.	0.	0.	0.	0.
41	75	3	0.	0.	405.	216.	0.	0.	0.	9923.	0.	35404.	0.	12972.	22432.	0.	0.	0.	0.	0.
42	75	3	0.	0.	158.	214.	0.	0.	0.	9518.	0.	34926.	0.	12757.	22169.	0.	0.	0.	0.	0.
43	75	3	0.	0.	135.	213.	0.	0.	0.	9552.	0.	34451.	0.	12544.	21907.	0.	0.	0.	0.	0.
44	75	3	0.	0.	101.	177.	0.	0.	0.	9417.	0.	34057.	0.	12367.	21690.	0.	0.	0.	0.	0.
45	75	3	0.	0.	68.	149.	0.	0.	0.	9316.	0.	33724.	0.	12218.	21506.	0.	0.	0.	0.	0.
46	75	3	0.	0.	45.	149.	0.	0.	0.	9248.	0.	33392.	0.	12069.	21323.	0.	0.	0.	0.	0.
47	75	3	0.	0.	23.	148.	0.	0.	0.	9203.	0.	33062.	0.	11921.	21141.	0.	0.	0.	0.	0.
48	75	3	0.	0.	11.	133.	0.	0.	0.	9181.	0.	32765.	0.	11788.	20977.	0.	0.	0.	0.	0.
49	75	3	0.	0.	9.	96.	0.	0.	0.	9169.	0.	32550.	0.	11692.	20859.	0.	0.	0.	0.	0.
50	75	3	0.	0.	7.	95.	0.	0.	0.	9160.	0.	32337.	0.	11596.	20741.	0.	0.	0.	0.	0.
51	75	3	3735.	2384.	5.	96.	0.	6090.	0.	10065.	0.	38213.	0.	13613.	24600.	0.	0.	0.	0.	0.
52	75	3	0.	0.	2.	101.	0.	0.	0.	10309.	0.	37986.	0.	13513.	24474.	0.	0.	0.	0.	0.

YEAR	RUNOFFN	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
75	52751.5	23090.4	22506.8	7333.0	0.0	40693.5	0.0	30903.7	0.0	0.0	0.0	15259.6	673.2

EFFICIENCY FOR YEAR 10EQUALS 30.83

YEAR	RUNOFFW	RUNOFFW	EVAPT	EVAP	DOMESTIC	IN. PUMP	CONC. PUMP	TOTAL	EXCESS	OVERFLOW	OVERDRAWN	IRRIG	PERC
PERIOD	503384.2	234800.8	225067.5	96002.0	0.0	406922.8	14927.3	291121.4	0.0	0.0	0.0	154632.0	2090.4

THE EFFICIENCY OF THE SYSTEM FOR THE TOTAL PERIOD WAS 31.05

ALL OF THE WEEKLY VALUES AND THE TOTAL FOR THE PERIOD HAVE BEEN DIVIDED BY 1.

A(J)	AM(J)	D(J)	DM(J)	V(J)	VM(J)	S(J)
0.	9352.	0.0	1.9	0.	16400.	2.0
4712.	5944.	0.0	5.7	13513.	24600.	2.0
5918.	5944.	0.0	5.7	24474.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0
0.	5944.	0.0	5.7	0.	24600.	2.0

THE LAST GIVEN DESIGN WILL SATISFY THE GIVEN CONSUMPTIVE USE FOR THE ENTIRE PERIOD

APPENDIX E

COMPARTMENTED RESERVOIR PROGRAM FOR HP-25 CALCULATOR

HP-25 Program Form

Title COMPARTMENTED RESERVOIR PROGRAM Dec 29, 1975 Page 1 of 1

Switch to PRGM mode, press [f] [PRGM], then key in the program. C. Brent Cluff

DISPLAY LINE	DISPLAY CODE	KEY ENTRY	X	Y	Z	T	COMMENTS
00			Enter	Am			RecordΣV Enter Am
01		STO 5					
02		R/S	Enter	Em			Enter Em
03		X					
04		STO 4					
05		STO+6					
06		STO-7					
07		RCL 2					
08		STO+1					
09		STO-7					
10		RCL 7					
11		GTO 00					
12		RCL 4					
13		RCL 2					
14		+					
15		RCL 0					
16		÷					
17		R/X					Enter next stage
18		RCL 7					Volume
19		-					
20		↑ ↓					
21		÷					
22		STO 3					
23		RCL 0					
24		-					
25		Pause					Read date pumped
26		RCL 3					
27		RCL 0					
28		÷					
29		STO 3					
30		RCL 2					
31		X					
32		STO-1					
33		STO+7					
34		RCL 4					
35		RCL 3					
36		X					
37		STO-6					
38		STO+7					
39		RCL 6					
40		RCL 5					
41		STO 4					
42		÷					
43		R/S					Enter area of next
44		STOx4					stage
45		X					
46		Pause					Read amount of
47		Pause					water pumped
48		RCL 3					
49		STOx4					

REGISTERS	
R_0	30
R_1	ΣCU
R_2	CU m
R_3	
R_4	AmxEm
R_5	Am
R_6	ΣE
R_7	ΣV

HEWLETT hp PACKARD

Instructions for Compartmented Reservoir Program for HP-25

1. Key in Am, Hit R/S. (Am = area of reservoir in m^2 corresponding to the volume.)
2. Key in Em, Hit R/S. (Em - monthly evaporation loss in meters.)
3. Record ΣV. (ΣV = remaining volume in reservoir at the end of the monthly period.)
4. RCL 6 - Record ΣE. (ΣE = total evaporation loss up to the end of the period.)
5. RCL 1 - Record ΣC.U. (C.U. = consumptive use.)
6. Repeat above sequence until ΣV is less than the volume of the remaining compartments, then proceed to step 7.
7. Key in GTO 12, Hit R/S.
8. Key in total volume of remaining compartments. Hit R/S.
9. Pause - Read date of pumping. It will always be negative.
10. Key in surface area in m^2 of remaining compartments. Hit R/S.
11. Pause - Read amount of pumping in m^3.
12. RCL 2 then hit x then STO 3, RCL 1, record C.U. up to time of pumping.
13. RCL 7, record ΣV up to time of pumping.
14. RCL 6 and record ΣE up to time of pumping.
15. RCL 3 STO + 1, Sto - 7.
16. RCL 1 and record C.U. up to end of the month.
17. RCL 4 STO - 7 and then STO + 6.
18. RCL 7 (record as ΣV to end of month).
19. RCL 6 (record as ΣE to end of month).