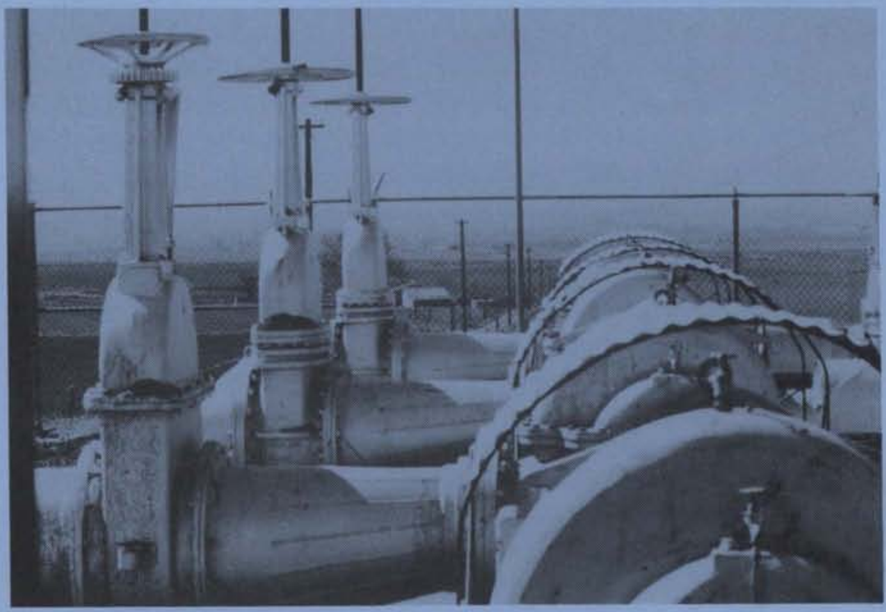
MANAGEMENT, MAINTENANCE AND OPERATION OF PUMP SUPPLIED IRRIGATION PROJECTS



by

R.D. Wells, C.E. Brockway, and J.R. Busch
with contributions by
R.G. Allen and M.W. Beus

Idaho Water and Energy Resources Research Institute
University of Idaho
Moscow, Idaho
January, 1983

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OF

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Submitted to the

United States Department of Agriculture

Agricultural Research Service

Washington, D.C. 20242

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Idaho Water Resources Research Institute

University of Idaho

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ABSTRACT

Ten pump supplied irrigation projects in the Pacific Northwest cooperated in this study. Water use data was collected. Pumping systems were tested for their energy efficiency on each project and data are presented. Special problems were studied and solutions were developed.

Methodologies were developed to aid in systematically critiquing pump supplied irrigation systems and the cooperating irrigation projects were critiqued. A methodology was developed to access the attitides of management on a variety of subjects and the managers of each project participated by answering a standard set of questions. Four computer routines were developed to supply management with some tools to use in planning and analysis. The routines were used to study project operation. Real situations are described in a set of case studies.

GENERAL COMMENTS

This FINAL REPORT consists of four parts. Part I is a set of user's guides for computer programs useful as water management tools. Part II is a description of methods and procedures of measuring (pump) irrigation project performance, analyzing the data, and presenting the results. Part III is a set of five case studies where the tools of Part I and the procedures of Part II were applied to real situations. Appendix D, the forth part, is a set of data from pump tests which were conducted during this study.

The original version of the FINAL REPORT has been bound as a single volume but has been written so that each of the parts can stand alone. The final report binding is removable so that the single volume may be separated if necessary. This report structure will allow especially Parts I and III and the pump test data in the appendix to Part III to be made available to users with specific intrests.

ACKNOWLEDGEMENTS

The principle investigators for this project were Dr. John Busch and Dr. Charles Brockway. Dr. Busch is a professor of Agricultural Engineering and is director of the Water and Energy Resources Research Institute at the University of Idaho in Moscow. Dr. Brockway is a professor of Civil and Agricultural Engineering at Kimberly. Both individuals acted as advisors and reviewers for this study.

USDA liaison at Kimberly was Jim Bondurant who also reviewed material and supplied constructive remarks throughout the study.

Robin Wells, research associate at Kimberly, performed the majority of the field work and wrote the final report.

Richard Allen, research associate at Kimberly, provided constructive remarks and supplied one of the computer routines described in the report.

Michael Beus, graduate student, assisted with field work.

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MANAGEMENT, MAINTENANCE AND OPERATION

OF

PUMP SUPPLIED IRRIGATION PROJECTS

FINAL REPORT: PART ONE

WATER MANAGEMENT COMPUTER AIDS

THREE DESCRIPTIONS AND USER'S GUIDES

by

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OVERVIEW

This FINAL REPORT consists of four parts. Part I is a set of user's guides for computer programs useful as water management tools. Part II is a description of methods and procedures of measuring (pump) irrigation project performance, analyzing the data, and presenting the results. Part III is a set of five case studies where the tools of Part I and the procedures of Part II were applied to real situations. The Appendix, the forth part, is a set of data from pump tests which were conducted during this study.

Part I has been written in three sections. Part I-A is a description of program RULE which can be used to find the most energy efficient combination of multiple, parallel pumps operating under constraints to deliver a specified total station discharge. Part I-B is a description of program WATER which can be used to calculate the consumptive irrigation requirements of up to nine crops, the seasonal irrigation schedules for each crop, and the 15 day total irrigation demand for the study area under mutiple crops. Part I-C is a description of programs HPOW and HWTR; these programs are essentially data formatters that put irrigation water delivery records and pumping energy cost and use in the same format as the output format of the predictive procedure described in Part I-B.

The three sections of Part I were intended to be stand alone reports. They each include a listing of the computer routine, a description of how to use and interpret the results, and an example application.

FINAL REPORT PART I-A:

COMPUTER AIDED DEVELOPMENT OF OPTIMAL OPERATING RULES FOR MULTIPLE, PARALLEL UNIT PUMPING PLANTS

A Description and User's Guide

This study was supported by funds authorized by Cooperative Agreement 58-9AHZ-9-395 as amended, between the ARS-USDA and the Idaho Water Resources Research Institute

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C. E. Brockway

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January, 1983

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INTRODUCTION

This is a report on one aspect of a study conducted by the University of Idaho and funded by the United States Department of Agriculture. The study entitled, "Management, Maintenance, and Operation of Pump Supplied Irrigation Projects", involved the evaluation and testing of irrigation water supply pumping systems on ten projects in the Northwest (Busch, et al, 1980). Most of these pumps were ganged in parallel with adjacent pumps. Methods of controlling total station discharge were valving, spilling, pump cycling, and combining ("blending") individual units in a single station. The primary objective at each pumping station was to maintain a dependable, controlled discharge to meet the discharge and pressure requirements of the irrigation demand. Three of the projects were faced with high power costs due to high lifts and/or power rates and were therefore concerned with energy efficiency. One project turned its pumps off early in 1980 to avoid going into debt and possible bankruptcy.

During the pump testing program, a "range of logic" was detected in observing the operation of multiple parallel pumps. Some stations were maintained and operated very well while others were not. For example, at one station, the most energy efficient pump was used reluctantly because the motor ventilation fan was noisy.

When the pump testing phase of the University's study was near completion, a set of "operating rules" or guidelines was manually developed for one project's pump station. This single station contained five pumps in parallel and the total energy consumption varied ten percent as a function of station operation alone. Another project operated 22 parallel unit stations with options of valving, spilling, and pump "blending". The same project often replaced units during the water season on short notice; in addition, the operators were not necessarily long time employees. The latter project operated a computer in its office so that development of a computer aid to generate station operation guidelines or rules seemed a reasonable step.

GENERAL

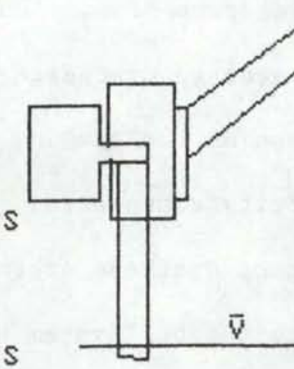
Output from the procedure described in this section intended as an aid in constructing a comprehensive set of guidelines for energy conscious pump operators. Input to the program allows the user to delete undesirable ranges of operation in a steady state flow situation. The input format also allows the analyst to change the system head and individual unit head requirements without changing the shape of the original system head curve. This feature is useful, especially when pump test data are available. The ability to specify locations of valves including alternative valve placement combinations is included.

Some definitions are made here to clarify discussion. Pump stations operate under "constraints" which affect the method of station operation. Within these constraints, the objective of project management is to operate the station as energy efficiently as possible. A set of guidelines to meet all objectives within the constraints are "Operating Rules". Another term, "Spilling" is the practice of returning water from the discharge to the pump intake in order to control net station

FLOW CHART PROGRAM RULE

DATA INPUT:

1. DESCRIPTIVE LABEL
2. NUMBER OF PUMPS
3. MANIFOLD LOSSES
4. VALVE FLAGS
5. PUMP CHARACTERISTICS
6. SYSTEM CHARACTERISTICS
7. FACTORS FOR:
   INCREMENT SIZE
   WINDOW SIZE
   SCALING FACTOR
8. BOUNDS AND CONSTRAINTS



DATA VERIFICATION

INPUT STATION FLOWS

CONST. "G" ARRAYS

CALL SUBROUTINE INTRP:

INTERPOLATES BETWEEN DISCRETE POINTS FOR PUMP AND SYSTEM HEAD, POWER, AND DISCHARGE

CALL SUBROUTINE CNSTN:

APPLIES SPECIFIED CONSTRAINTS

CALL SUBROUTINE DYNAI:

LOOPS THROUGH RANGE OF STA. FLOW

1. SOLVES FOR "F" AND "ID" VALUES
2. CONSIDERS POSSIBILITY OF SPILL
3. CONSIDERS BOUNDS AND CONSTRAINTS
4. SELECTS OPTIMUM COMBINATION
5. PRINTS SUMMARY TABULAR VALUES

CALL SUBROUTINE SPILL:

END *END* *END*

FIGURE 1. PROGRAM ORDER

discharge. "Valving" is the practice of throttling pump discharge by increasing pump head. "Pump Cycling" requires storage to produce a reduced average discharge and is not treated here. "System Head" is the total head on the pumping units and includes the static lift, friction and velocity components. "Pumping Head" is the pressure head generated by the pump upstream of the main valve and must always be greater than the distribution "System Head".

PROGRAM MECHANICS

The optimal operating rules for a pumping station are developed by a computer routine, RULE, and four subroutines shown in Figure 1. Program RULE is a FORTRAN routine that solves for the most energy efficient combination of parallel pumping units in a pumping station. The demand on the total station is specified and pump settings are generated. The solution is obtained using a dynamic programming procedure that involves simple comparisons of the relative magnitude of many single pairs of power values.

The purpose of the main program, RULE, is to read in necessary data for each pump and the pumping system, to generate a "power" array for the pumping station and to call necessary subroutines. Data are input describing the number of pumps in the plant, manifold losses for each pump and the plant and whether or not each pump is fitted with a valve for throttling flow. Pump head and power characteristics, and system head characteristics are input as functions of flow rate. These parameters may be input either as polynomial functions or as discrete data points. Three parameters, increment (K), window (WNDO), and a scaling factor (FACP), are also input. "K" is the number of increments the station flow is broken into for the dynamic programming analysis. "WNDO" describes the allowable range of individual pump head for a given system head, and "FACP" relates discharge and pump head to the appropriate units of power. (These terms are described in detail later.)

If desired, all input data may be printed for verification. A range of pumping station flows are then selected for which optimal solutiuons are desired.

A major function of the main program is to construct a power array for each pump; these arrays are named the "G" arrays. Power required for each pump is computed for each increment of station flow rate; these values fill the "G" array. Single pump units are "constrained" from consideration when the system head is greater than the pump head. Very large numbers (10E35) are assigned to the "G" array so that the unit can not be selected as an optimum performer at that excluded level. Similarly, very large power values are assigned to a pump at flows that produce pump heads greater than system heads and when the pump is not valved. Valved pumps may operate against heads greater than the system head. Additional constraints may be intentionally applied. Subroutine CNSTN, called from MAIN, assigns more large numbers to exclude ranges of flow within total range of the pump as prescribed by lower and upper bound data from the input. Prescribed constraints may remove a pump from consideration when pressure, power, vibration or even water supply is critical but not obvious in the pump characteristics. Up to three sets of bounds per pump may be specified. After all of the constraints are determined for the "G" power array, it is passed to subroutine DYNAI that makes inter-pump comparisons.

Subroutine DYNAI is a dynamic programming procedure based on the "stage coach" problem presented by Gillett (1976). At each increment of discharge this subroutine compares the power requirements of a pump under consideration to the best combination (i.e., requiring the least power) of a previously considered group of pumps. As each new "challenging" pump is considered, it must compete against a "defending" group. DYNAI keeps score on the individual incremental comparisons of power values supplied by the "G" power array in the "F" power array and the "ID" flow increment array. If the challenging unit loses, the number zero is assigned to the "ID" array and the "F" array is assigned the power value from the defending group. If it wins, the challenger is awarded an appropriate number of flow increments in the "ID" array, and the new pump's power value from the "G" array is included in the new "F" value. In other words, the "F" array is the accumulated power requirements of the winners at increasing levels of output. There as many challenges to an incumbent "F" value as there are flow increments for each new pump considered. Not only does the challenger compete for its total capacity, but it also competes for any incremental portion. By building each new "F" value on the best incumbent, the number of necessary challenges are greatly reduced thereby reducing computer time. All incremental flow and pump combinations have been considered when the last "F" value is determined. Therefore, the last "F" value of the last pump considered is the lowest power value necessary to deliver the total station flow rate under all imposed constraints. Consequently the last number in the "ID" array of the very last pump corresponds to the number of flow increments supplied (won) by that pump. Similarly, on the next to last pump, the flow assignment is the number recorded in the position of the ID array representing the total station flow less the last pump's assignment, etc. DYNAI performs the comparison procedure, identifies the optimum flows from each unit, writes out the results, and augments the results with diagnostic statements.

Subroutine SPILL is called from DYNAI and double checks each unit's "G" power array for a greater flow as identified by DYNAI being produced for the same or less power. If this is the case, the appropriate changes incorporating a spill situation are made. A diagnostic statement is generated, identifying and numbering these "curve anomolies" or a statement that there were no anomolies. Curve anomolies may appear due to an error in data input involving an improper selection of a digitized value on a flat power curve. When such anomalies do occur, a pump may physically operate in an undesirable "hunting" mode. Such a situation requires interpretation of pump characteristic curves in conjunction with the results generated.

EXAMPLE PROBELM

A sample problem is presented here to demonstrate one application and clarify the function of variables in the data set. FIGURE 2 represents a fictitious station called Pillar Falls with nine unique pumps, two of which are valved, and all of which have some manifold losses (PML) inherent in the system. A station head loss of 4 feet has been specified.

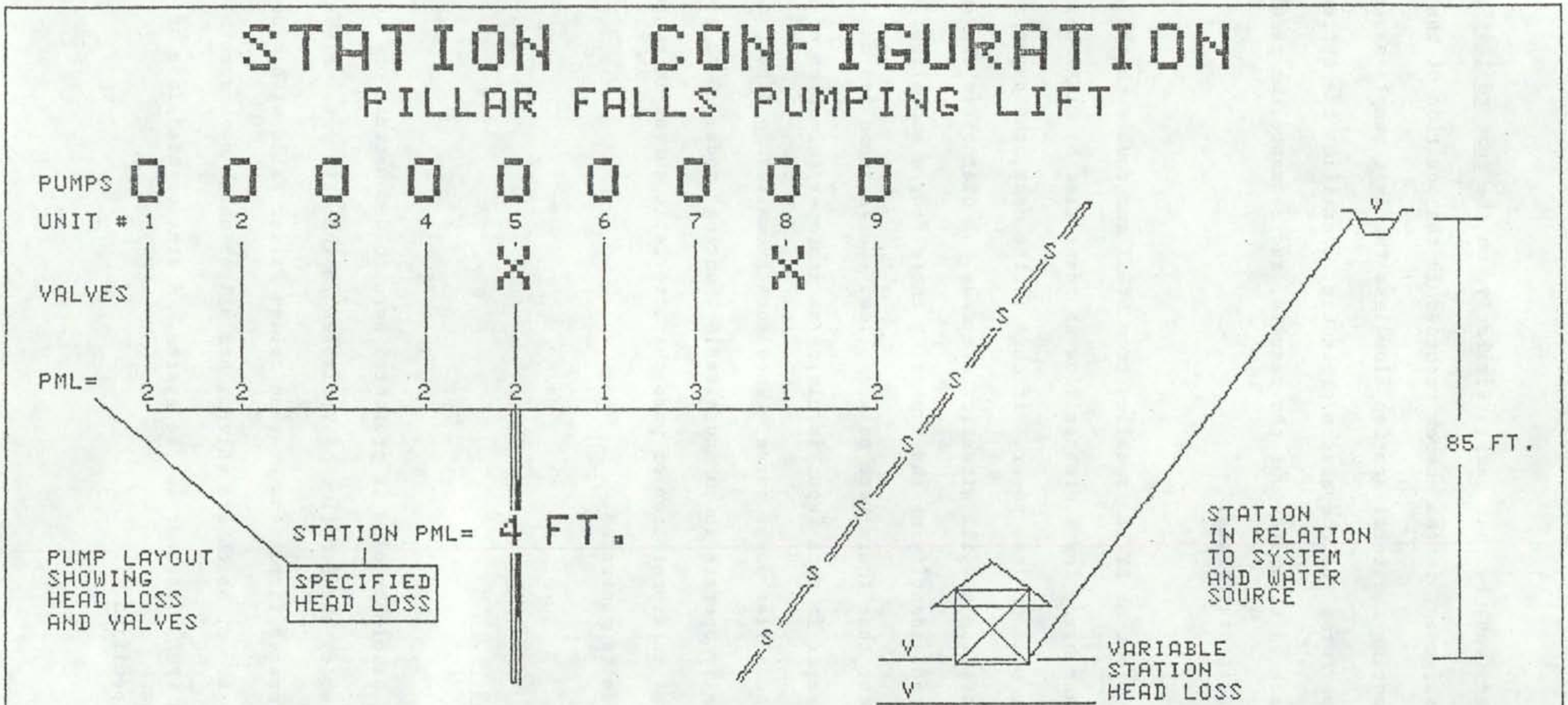


FIGURE 2. PUMP AND VALVE LOCATION, AND HEAD LOSSES

```
01-PILLAR FALLS WATER COMPANY:9 PUMPS, MIXED TYPES, VALVES, HEAD LOSSES
02-GPM       FEET     SFT-HP                             (LABL                dimensions)
03- 9 2 2                                                (N,IHQP,ISYS         no.pumps,type of data)
04- 2  2  2  2  1  3  1  2  4                            (PML(I) I=1,N+1      manifold losses)
05- 0  0  0  1  0  0  1  0                               (IV(I)  I=1,N        valve flag)
06-4.3 034.2 034.1 034.0 030.5 020.0 010.8 000.1  (H(1,J) J=2,9 .... unit head characteristics)
07-4.0 111.0 108.0 099.0 086.0 069.0 045.0 000.1
08-0.0 135.0 130.0 124.0 115.0 100.0 062.0 000.1
09-4.0 142.0 139.0 129.0 121.0 115.0 095.0 000.1          (N=9)        (no. of pumps)
10-7.0 176.0 168.0 150.0 130.0 105.0 075.0 000.1          (IHQP=2)     (indicates discrete data)
11-7.0 144.0 138.0 130.0 115.0 091.0 078.0 000.1 (line number preceding dash
12-3.0 136.0 125.0 114.0 106.0 085.0 055.0 000.1 is not part of the data)
13-8.0 177.0 176.0 171.0 150.0 130.0 115.0 050.0
14-0.0 144.0 136.0 120.0 096.0 070.0 000.2 000.1  (H(N,J))...................................
15-01. 0050. 0150. 0400. 0800. 1200. 1400. 1600.  (QA(1,J) J=2,9 ... unit flow characteristics)
16-01. 0080. 0160. 0240. 0320. 0400. 0480. 0560.
17-01. 0100. 0200. 0300. 0400. 0500. 0700. 0900.
18-01. 0200. 0400. 0600. 0700. 0800. 1000. 1700.          (N=9)        (a ´1´ would indicate
19-01. 0200. 0500. 0700. 0900. 1100. 1200. 1400.          (IHQP=2)     cubic equATION
20-01. 0400. 0800. 1200. 1600. 1900. 2000. 2100.                       unit input data)
21-01. 0600. 1200. 1600. 1800. 2200. 2600. 3000.
22-01. 0050. 0150. 0400. 0800. 1600. 3200. 6400.
23-01. 0500. 1000. 1250. 1500. 1750. 3500. 6000.  (QA(N,J))..................................
24-2.9 012.8 012.7 012.6 011.0 008.5 007.0 005.0  (P(1,J)........... unit power characteristics)
25-2.0 005.5 007.4 008.3 010.0 010.5 009.0 007.0
26-8.0 009.0 012.0 014.0 017.0 018.0 018.5 012.0
27-9.0 015.0 020.0 025.0 027.0 028.0 032.0 017.0          (N=9)
28-3.0 018.0 030.0 035.0 040.0 044.0 040.0 020.0          (IHQP=2)     (ISYS=1 would indicate
29-0.0 032.0 040.0 049.0 055.0 058.0 055.0 035.0                       cubic eq. system
30-7.0 037.5 050.0 058.0 060.0 059.0 058.0 040.0                       characteristics)
31-8.0 065.0 066.7 065.0 080.0 090.0 116.0 130.0
32-6.0 032.0 044.0 048.0 049.0 046.0 050.0 060.0  (P(N,J)............(see ISYS=2)...............
33-5.0 088.0 098.0 105.0 118.0 125.0 135.0 137.0  (SS(1,J)...........system head characteristics)
34-01. 2600. 4950. 5010. 6950. 7010. 9000. 10800. (QS(1,J) J=2,9 ... system flow characteristics)
35-0  0.033  3957.                                (K,WNDO,FACP.......incre.,window,& conv.factor
36-  6  0000 0000 0000 0000 0000 0000             (M,(LBND(M,J)......unit no, and...............
37-  8  0000 0000 0000 0000 0000 0000                    ,UBND(M,J))  constraints................
38-  9  0000 0000 0000 0000 0000 0000              ..  J=1,3 ..........bounds)...................
39-  -1 0000 0000 0000 0000 0000 0000             (end of file flag)
```

FIGURE 3. DATA SET FOR EXAMPLE PROBLEM

FIGURE 3 is an annotated input data set for the example Pillar Falls Pumping Lift Station. (A list of all input variables and definitions is contained in Appendix A-I.) Note that option two has been selected to specify the type of input for both unit pump and system head characteristics to be input as discrete data points. The options are specified on line 3. The number of lines read in the block of data specifying H-Q-P characteristics is controlled by the number of pumps specified and the data option specified. The data option specification affects lines 6 through 34 in this case. Option two requires discrete data discharge (line 15 through 23 and line 34) related to discrete head and power values (lines 6 through 14, lines 24 through 32, and line 34). Option two requires eight input values per line while option one requires four, corresponding to coefficients of a cubic polynomial ($X1 + X2 \cdot Q^1 + X3 \cdot Q^2 + X4 \cdot Q^3$) to describe the head versus flow and power versus flow relationships. Note that each pump is unique and that unit number one would never be selected because it could never deliver water against the total system head shown in FIGURE 2. Also note that the discharge characteristics do not begin on zero and do end on values within the working range of the pump. The system head characteristics shown may sometimes be quite erratic when turbulence problems occur in the system. Lines 33 and 34 show discrete points describing the head characteristics of such a system.

The data in line 35 of Figure 3 specify values for K, WNDO, and FACP. FACP relates flow rate (gpm or cfs) and head (feet or meters) to the desired power term in the relationship FACP=HQ/POWER.

Lines 36 through 38 have been included to show where pumping unit constraints belong. These values are entered as consecutive pairs of flow values, three pairs to a pump with a lower and upper value to each pair. An end of file flag is the negative number in the pump identification position in the constraints block. All zeros or no entry at all in the constraints section results in no imposed constraints.

RULE requires operator input during execution. The first response specifies whether data input is to be displayed for operator verification or output. The second response requires the range of station flows and the increment between each flow on which RULE operates. These values correspond to a FORTRAN "DO" specification.

FIGURE 4 is sample output data for one of several runs spanning the flow range for the pumping plant. The flow specified for this run of program RULE is 7100 gpm. FIGURE 5 is a compilation of results from 15 runs of RULE as determined by the increment size. Note that the unvalved number two unit and the valved number five unit supply the lower flows, but that the number two unit is eliminated at the higher station demand and system head while unit five will operate with the valve open and run at very near full capacity. The station is at its capacity pumping 7100 gpm. Output interpretation is discussed in more detail later in the section under that title.

PROGRAM OPERATION

A successful run of DYNAI is dependent on the selection of values specified for Q, PML,IV, K, and WNDO and their relationship to the pump

PILLAR FALLS WATER COMPANY:9 PUMPS, MIXED TYPES, VALVES, HEAD LOSSES
************************************ RESULTS ************************************
TOTAL STATION TARGET DISCHARGE IS 7100 BROKEN INTO 300 INCREMENTS OF 23.67 UNITS
DISCHARGE IS IN GPM , HEAD IS IN FEET , AND UNITS OF POWER ARE IN SFT-HP
NO POWER ANOMALIES
CONSIDER VALVING OR CONTROLLING HEADS ON UNITS NOT VALVED
LOOK AT THE POTENTIAL HEADS BELOW OR SLIGHTLY ABOVE THE SYSTEM HEAD

>>>>>>>> TOTAL STATION VALUES

STATION DISCHARGE	SYSTEM HEAD	TOTAL POWER	DISCHARGE AT POTENTIAL	STA. HEAD AT POTENTIAL	STA. POWER AT POTENTIAL
7100.	129.45	315.31	7147.33	129.69	316.50

>>>>>>>> INDIVIDUAL UNIT VALUES

#	UNIT DISCHARGE	UNIT HEAD	UNIT POWER	UNIT Q AT POTENTIAL	UNIT HEAD AT POTENTIAL	UNIT POWER AT POTENTIAL
1	0.	34.40	0.00	0.00	34.40	0.00
2	0.	114.10	0.00	0.00	114.10	0.00
3	237.	127.80	12.73	236.67	127.80	12.73
4	615.	127.77	25.31	615.33	127.77	25.31
5	852.	134.80	38.80	899.33	130.07	39.98
6	1278.	127.07	50.17	1278.00	127.07	50.17
7	1018.	128.34	46.20	1017.67	128.34	46.20
8	1988.	126.36	96.31	1988.00	126.36	96.31
9	1112.	128.81	45.80	1112.33	128.81	45.80

>>>33>>> REFERENCE INFORMATION

#	VALVE CONDITION	HD.LOSS SPECIFIED	HD.LOSS DEVELOPED	POWER LOSSES	WATER POWER	POWER EFFICIENCY
1	0	2.	0.	0.	0.	0.
2	0	2.	0.	0.	0.	0.
3	0	2.	0.	0.	8.	60.
4	0	2.	0.	0.	20.	79.
5	1	2.	7.	2.	29.	75.
6	0	1.	-1.	-0.	41.	82.
7	0	3.	2.	0.	33.	71.
8	1	1.	-2.	-1.	63.	66.
9	0	2.	1.	0.	36.	79.
TOTAL STA.		4.000	44.452	80.	232.	74.

****

FIGURE 4. OUTPUT FROM SAMPLE PROBLEM

PRELIMINARY SUMMARY FIRST ALTERNATIVE FLOW RECOMMENDATIONS, PILLAR FALLS WATER COMPANY

Station Discharge (GPM)	Power Required (HP)	Unit Flow: (gpm) #1	2	3	4	5	6	7	8	9
500	27.8	0	302	0	0	198	0	0	0	0
1000	90.2	0	0	0	1000	0	0	0	0	0
1500	90.7	0	295	0	1035	170	0	0	0	0
2000	91.3	0	0	0	0	0	0	2000	0	
2500	91.9	0	0	517	0	0	0	1983	0	0
3000	93.7	0	0	0	970	0	0	2030	0	0
3500	95.8	0	0	525	992	0	0	1983	0	0
4000	98.0	0	0	0	0	0	0	0	4000	0
4500	100.1	0	0	465	0	0	0	0	4035	0
5000	107.8	0	0	450	883	0	0	0	3667	0
5500	112.3	0	0	403	0	0	1650	0	3447	0
6000	115.6	0	0	340	800	0	1560	0	3300	0
6500	119.0	0	0	0	758	0	1560	0	2903	1278
7000	127.8	0	0	0	630	653	1330	1097	2147	1143
7100	129.5	0	0	237	615	852	1278	1018	1988	1112

FIGURE 5. OUTPUT RESULTS, A SUMMARY OF MULTIPLE RUNS

curve characteristics. An appropriate combination of these numbers will give a numerically correct and usable combination of pump settings to achieve an optimum solution that complies with all constraints.

The number of increments into which the station flow, Q, is divided is specified by K. Obviously, a smaller K value will result in a relatively larger change between adjacent numbers in the "G" array. A good trial value is 30 times the number of pumps in the analysis, but as K increases, so does the program execution time. If the pump head exactly matches the system head with no valve on the pump, then a solution is possible. However, this seldom occurs and "margin of consideration" about the system head value allows the production of a practical solution. It also occasionally causes contradictory values to appear in the reference information output section such as small insignificant negative power values. WNDO controls the number of flow increments above and below the fully open valve condition allowed in the "G" power array for a given value of Q. Realistically, as system head increases, WNDO should decrease as it is used to calculate a percentage of a total head value. A good starting value is 0.05 which means that 5% above and 5% below the system head at specified Q will remain unconstrained. An examination of potential values in the output would help in selecting a more restrictive value if necessary.

Variables describing unit and station characteristics are PML and IV, both of which operate on head values and control power values. When IV=1, a valve on a single unit is indicated, and unit head is allowed to exceed system head. When the pump is not valved or when IV=0, the unit is constrained from lower flows and higher heads. In this version of

RULE, there are as many values for IV as there are pumps. There is no valve on the total station. (It is assumed that the station IV=0).

Manifold friction, turbulence, and elevation losses may be approximated by adjusting pump and station heads using PML values. If one unit is observed to lose 0.5 feet of head due to its valve, intake, or elevation, it may be specified. Usually, friction and turbulence losses vary with flow but practically, the losses are within a range of some reasonable value. In addition, system heads are subject to significant variations due to changes in stage of the station water supply or general lift requirements. This shift in system head is many times a function of the season and not the station discharge. There are as many PML values as pumps, plus one for the total station.

OUTPUT INTERPRETATION

The output of RULE is in four general parts and it is important to recognize the function of each and its limitations. The parts are messages, lumped station values, itemized unit within-station values, and reference information. For the most part, labeling, diagnostic and warning messages are self-explanatory.

The "reference information" functions to make each run of program RULE unique as shown in Figure 4. Note that a number is imbedded in the arrow flags of this section. This number is 1000 times WNDO. The first and second columns are the specified value and head loss numbers from the input data. The third column is the total dynamic head loss developed in addition to the system head specified in the input. The total station value includes the turbulence and friction generated in the pipe. "Power losses" result from specified head losses, losses across valves, and the coarseness of the analysis. The total station value can account for pipe friction. The "water power" column indicates the amount of water power each unit generates, and the total station value is the amount of water power delivered from the station. The "power efficiency" value is the water power fraction of each unit and total station, respectively. Turbulence and friction losses account for the difference between the units' weighted mean and the overall station value.

Station and unit values are divided into two parts. The first set of three values under both headings is self-explanatory. The second set of "potential" values is important when the station capacity falls short of the demand. The system head used to obtain these values is the one resulting from the specified station demand. The values are the sum of all individual unit discharge and power values operating against a fixed system head. The program does not take into account that the system head would be different at the summed potential discharge. When the station can meet its demand, the potential values are useful in adjusting the size of K and WNDO. When the station cannot meet its demand, they are helpful in identifying reasons and remedies.

DISCUSSION

Program RULE may be used to reduce the tedious task of examining pump characteristics in detail. Its use requires judgment and some adjustment on program controls, as discussed earlier, to effect a practical solution.

A sample of data input and results is included in Figure 3 and 4 in addition to a program listing at the end of the paper. The program listing is dimensioned to accommodate ten parallel pumps with up to 300 flow increments.

The major strength of this algorithm is the versatility which each unit within a station may be described and constrained without using complex step functions. Another positive characteristic is the valve and head loss specification for individual units and the control on how tightly the analysis is to proceed according to choices of Q, K, and WNDO. In addition, with the exception of values displayed in the output under "Reference Information", the head and power units need not be in consistent units for DYNAI to run successfully as only the relative magnitudes are important in obtaining optimal solutions. For example, head can be in feet and discharge in cubic meters per week. If the relationship between "H" and "Q" can be reconciled with power in the number "FACP", all data output will be understandable and dimensionally coherent.

The major weakness in this program is in the procedure for constraining single units based on a single system head value. For example, when Q = 10, the system head is the same definite number throughout, and unless K is small and WNDO large enough, the possibility of pumping eleven and spilling one to achieve the goal of ten may not be considered, even though doing so may require less energy. If the pump head at a specified station discharge misses the "window" around the system by a little or a lot, the effect is the same: a prediction of failure of the unit to meet the requirements. This situation is the major reason for including the "potential values" in the output data.

In its present form, RULE solves the steady state flow situation from a bank of parallel pumps delivering flow to a single system. The technique may be extended to solve a problem of banks of pumps in parallel pumping to stations in series or parallel by assuming a variable station PML value and keeping track of the power requirements at varying discharges.

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FINAL REPORT PART I-B:

COMPUTER AIDS USEFUL IN DEVELOPING CROP WATER REQUIREMENTS AND SCHEDULES FOR MIXED CROPS UNDER IRRIGATION

A Description and User's Guide

This study was supported by funds authorized by Cooperative Agreement 58-9AHZ-9-395 as amended, between the ARS-USDA and the Idaho Water Resources Research Institute

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January, 1983

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INTRODUCTION

The manager of an irrigation project has an obligation to deliver specified amounts of water. Ultimately, the source of that demand is the irrigator or farm operator who pays for the delivery service. The irrigator bases his water order "demand" on many factors not all of which have to do with crop requirements. For the most part and during the major part of the growing season, the timing and magnitude of the total water demand is directly related to the needs of the growing crop. If the system managers and irrigators know, in advance, the approximate quantity and date of required water application, they may be able to anticipate water demand and plan schedules more effectively.

The procedures in FINAL REPORT: PART IC were designed to produce a convenient record of cost, energy use, and water demand from records. Timewise, this a backward looking approach. The procedure in this section, PART IB, produces estimates of water requirements for any mixture of crops and is not dependent on historical cropping patterns. It can be used to predict water demand at varying levels of water use efficiency. Timewise, this is a forward looking approach.

For irrigation projects dealing with expensive or fixed peak water delivery rates, this computer routine could be a valuable management tool in planning operating budgets, evaluating the cost effectiveness of system maintenance, and reviewing water delivery policy.

GENERAL

Program "WATER" calculates a water balance for a variety of crops. Single crop consumptive use information is presented along with estimated irrigation dates and the water requirement necessary to replace depleted soil moisture. The unit area water demand estimate is used to calculate the volume of water the total project will require and the period within which that demand will occur. The relative proportions of crop areas may be changed to reflect a trend or current situation. Significant growing season dates affected by climate and cultural practices may be specified. Water delivery and irrigation efficiencies may be used to estimate total project demand. In general, the routine offers a systematic procedure to evaluate the effects of many different factors on the timing and the magnitude of the water demand. The project demand estimates have been put into a format that is compatible with the "historical" type records presented in PART IC.

DISCUSSION

Accuracy of the results of a water balance procedure are dependent on the assumptions and data used to generate the results. Irrigation scheduling has been used widely, especially in the west, and there is sufficient experience and data to justify trust in an irrigation scheduling procedure.

Evapotranspiration. The evapotranspiration data (ET) used in the program data tables are 15 day averages based on 14 years of record at Kimberly, Idaho. Standard deviation values associated with each 15 day value which indicate year to year variation. In areas other than south central Idaho, some method must be selected to generate the reference ET estimates. The Penman equation has been tested and gives good results over a wide range of conditions, but the detailed data required is often not available. Jensen (1974) evaluated 15 different methods for estimating the consumptive use of water. The Blaney-Criddle method has been modified by Doorenbos and Pruitt (1977) to include factors of humidity, sunshine hours, and daytime wind. This "FAO Blaney-Criddle" method is being used in world wide applications.

Crop coefficients. The coefficients relating many crops to a standard reference crop are less likely to change from area to area than the actual consumptive use estimates. The reference crop used in this routine is alfalfa. The coefficients were developed at Kimberly, Idaho by Wright (1982) and should be valid for temperate areas. The climate at Kimberly is mild, and the area may be described as mountain valley with 138 frost free days beginning approximately May 12 and ending September 27th. The growing season daily minimum and maximum relative humidity ranges between 30% and 90% respectively and mean precipitation is 9.6 inches. The Kimberly weather station is at 3960 feet.

Modifications to the crop coefficients used in program WATER will require changing a data statement in the program listed in Appendix B-I. Recommendations for selection and adjustment of crop coefficients are included in the publication by Doorenbos and Pruitt (1977). Crop coefficients presented are for use with an alfalfa reference. They should not be used with equations predicting ET for grass because an underestimation may result. Coefficients are presented in a format allowing variations in crop development stages.

Extra evaporation. One of the refinements of the procedure here produces estimates of evaporation not included in ET estimates. After every irrigation, there is a certain amount of evaporation from the soil surface which is not accounted for by the crop coefficient. An estimate for this "loss" is labeled "extra evaporation per irrigation" in Part A of the output. As the growing crop shades a greater portion of the ground surface, the amount of water lost to evaporation becomes less. The reference crop ET accounts for normal evaporative moisture loss, but if the crop is other than the reference and lags the development of the reference, and if the soil surface is wetted by irrigation, an unaccounted evaporation component will occur. In addition, the evaporation opportunity time for soils is affected by soil type. Wright (1981) has measured these effects and based on his work, the following relationship has been implemented in program WATER. The evaporation opportunity time for sand, silt, and clay under growing crops is assumed to be 3, 5, and 7 days respectively. When the crop coefficient is less than 1.0, extra evaporation has been observed to occur. An upper limit on potential evaporation per irrigation is specified in the data file and calculated in the program and the lower value prevails.

Precipitation. Including an estimate for precipitation would make this analysis more area specific than it is presently. Calculated irrigation demand differs from the field water requirement values by a component called effective precipitation. Just as there is an evaporative loss at irrigation, there is a similar loss during storm events. If growing season precipitation is significant, a correction should be applied to the ET values entered in lines 3 thru 6 in Figure 1. The appropriate correction value is <u>effective</u> precipitation.

<u>Field capacity</u>. The amount of water in the soil at the beginning of a growing season is never the same. Therefore some assumptions concerning initial moisture levels must be made in order to calculate a water balance; there must be a starting point. Here are the assumptions used in program WATER concerning initial moisture used in program WATER concerning initial moisture levels: (1) Dormant season precipitation builds soil moisture to field capacity. (2) Spring seed bed preparation results in a loss of moisture <u>in the layer of disturbance</u>. (3) Alfalfa, pasture, and winter wheat "green-up" is assumed to occur at 100% field moisture capacity. (4) Potatoes are planted at 90% field capacity. (5) Beans, corn, peas, sugarbeets, and spring grain are planted at 75% field capacity.

<u>Utility</u>. Program WATER is intended to be used as a planning and long-term-operating management tool. There are more appropriate short-term-operating management tools which use nearer to real time estimates of ET, although there is no reason not to update WATER's input data file during the season. Program WATER does not include separate growing season precipitation estimates, inter-season soil moisture corrections, or direct computation of ET from meterological data. The best use of this routine is in showing the magnitude and duration of the water requirements. With these estimates, costs may be attached to operating losses that were previously assumed to be normal and unavoidable. This computer routine, as it is, may be used under the conditions specified in this report and the documentation in the program

source listing. Modifications for other conditions will require only minor changes to the computer routine data statements and appropriate changes in labels.

PROGRAM MECHANICS

Program WATER is written in FORTRAN. It contains a data statement that specifies crop coefficients relating consumptive use of nine crops to that of alfalfa at Kimberly, Idaho based on actual field (lysimeter) measurments. The relationship between alfalfa and other crops is not as likely to change as the actual amount of evapotranspiration, or "ET" (Wright,1981, 1982). Half-monthly values of measured or calculated ET are read from a data file along with the standard deviations of the measurements or calculations for each period.

Within the same data file, described in the EXAMPLE APPLICATION, is information on crops of interest, including planting-growing-harvesting data, the fraction of total areas planted to each crop, and a range of expected irrigation efficiencies. The file must also includes soil and root depth information so that the amount of moisture available to the crop can be calculated.

The routine calculates the water requirements for each crop by multiplying coefficients by the alfalfa reference ET. This water requirement is added to soil moisture depletion in the zone of root growth. When the declining soil moisture content reaches the specified allowable moisture depletion level, an irrigation is specified. The time in days to reach that point from the date of initial "field capacity" or from the date of last irrigation is printed. The procedure cycles through the season and ends at harvest for each crop.

When all crop requirements have been determined, the total water requirement for all crops based on the area of each crop is calculated for the 100% efficiency level. Requirements for subsequent efficiencies are then determined. These are enhanced with a bar graph. All available input-output options, ET alfalfa reference, crop, and soil information are required in a single data file. A description of that file is in the following section.

EXAMPLE APPLICATION

A set of input and output data is presented for one of the cooperating water projects. The project delivering water to the area described in the data file did have a low project efficiency of water use and because records were sketchy, there was a need to quantify crop requirements and identify the source and magnitude of water losses. Soil data for the analysis were obtained from SCS soil survey maps. Crop information was obtained from local sources. Evapotranspiration data were Kimberly, Idaho values.

Figure 1 is an annotated input data file for program WATER. This file may be considered in two sections; the first section includes the first eight lines. The flag on line 1 specifies whether to include (1), or not include (0) Part A of the output. Line 2 gives the total acres of all crops in the file and also a scaling factor for the bar graph shown in Figure 4. Lines 3 and 4 are the half-monthly values of average

```
1234567890123456789012345678901234567890123456789012345678901234567890112

                    (block 1)
 1.                                      (IO=0  eliminates output PART A)
    1359.       50.                   (total crop acres & bar graph scale)
 4.10 4.74 5.79 6.45 6.79 7.75 7.94 7.71  (fourteen,15-day evapotrans..)
 7.38 6.35 5.51 4.53 3.58 2.67            ...(estimates, April thru October)
 0.70 1.03 0.68 0.74 0.89 1.07 0.52 0.66  (standard deviation of.......
 0.61 0.90 0.62 0.64 0.34 0.41            ............ evapotran. estimates)
  5 100. 80.0 60.0 40.0 30.0             (five irrigation efficiencies in %)
  .5  3.  100.                                              (*see below)
                    (block 2)

ALFALFA - SANDY SOILS, SPRINKLER, GREEN UP APRIL 15        (label,crop # 1)
  1  4 15  5 01 10 01  3 15  8 10  2.5  2.5  1.7  55. .22      (data # 1)
  3                                        ..................(three cuttings)
  6 15  8 15  9 15                         ......................(cut dates)
PASTURE - SANDY SOILS, SPRINKLER, GREEN UP APRIL 15              (label # 4)
  4  4 15  5 01 10 15  3 15  7 15  2.5  2.5  1.7  55. .16       (data # 4)
SPRING GRAIN - SANDY SOILS. SPRINKLER, PLANT MARCH 15            (label # 8)
  8  3 15  6 15  8 01  4 01  7 01  0.5  2.5  1.7  50. .15       (data # 8)
SILAGE CORN - SANDY SOILS, SPRINKLER, PLANT MAY 01               (label # 3)
  3  5 01  7 10  9 15  5 08  7 20  0.5  2.5  1.7  50. .04       (data # 3)
DRY BEANS - SANDY SOILS, SPRINKLER, PLANT MAY 15                 (label # 2)
  2  5 15  7 15  9 01  5 18  7 20  0.3  2.5  1.7  50. .05       (data # 2)
POTATOES - SANDY SOILS, SPRINKLER, PLANT APRIL 15                (label # 6)
  6  4 15  7 05 10 15  4 17  7 20  0.5  2.5  1.7  45. .38       (data # 6)
END
END
                           (variables)
1234567890123456789012345678901234567890123456789012345678901234567890112
(dec).    .    .    .    .    .    .    .    .    .    ....crop fraction
(%)  .    .    .    .    .    .    .    .    .    allow'd moist.deplet'n
 .    .    .    .    .    .    .    .    .   avaliable moisture (in/ft)
 .    .    .    .    .    .    .    .   maximum root depth (ft)
 .    .    .    .    .    .    .   minimum root depth (ft)
 .    .    .    .    .    .   date of maximum root (Mo.& Day)
 .    .    .    .    .   date of minimum root (Mo.& Day)
 .    .    .   date of harvest (Mo.& Day)
 .    .   date of effective cover (Mo.& Day)
 .   date of plantinf (Mo.& Day)
 crop number
```

*THREE VALUES:

1. maximum evaporation per irrigation (in.)
2. evaporation opportunity time (Days)
3. percent surface wetted at irrigation

FIGURE 1. INPUT DATA FILE USED BY PROGRAM WATER.

reference evapotransporation for April through October; there are 14 values. Lines 5 and 6 are the standard deviations of the values in the previous lines. These values were obtained from 14 years of reference ET estimates at Kimberly. Values in line 5 and 6 can be set to zero if no value of standard deviation are available. Line 7 specifies the number of water application efficiency levels of interest and their value. In this particular application, the total demand at the canal turnout was desired. Line 8 specifies the maximum extra evaporation occuring after irrigation, the evaporation opportunity time, and the percentage of soil surface wetted by irrigation (Wright,1981).

Up to nine crops may be included in the analysis; however, a separate computer run must be used to consider the same type of crop under modified conditions. For example, the present version of this routine cannot consider two crops of beans with different planting dates. The crops of interest here were specified in lines 9 through the end; this is the second section of the data file. The format for all of the crop information with the exception of alfalfa is the same. Alfalfa is different with the addition of two extra lines specifying the number of expected cuttings and the cutting dates. The labels are informational only. The significant dates and values are described in the figure. The order of the crops is arbitrary but the crop number identifying the crop is not. The format for data read statements in the program are mixed and may be obtained from the program listing in the Appendix.

PROGRAM OPERATION and OUTPUT INTREPRETATION

The output of program WATER may be of interest from several viewpoints; therefore its output has been grouped into three sets labeled A, B, and C. These are results from input data shown in Figure 1.

Part A. Figure 2 is a listing of output data for dry beans. For every crop specified in the input data file, there is a full page listing and summary of data pertinent to that crop. The first block of information in Figure 1 echoes data from the input file and labels it for clarity.

The second block contains the consumptive use by date, through the growing season; for example, month 5 and period 2 is the last 16 days of May and all period 1´s represent 15 days. The average crop coefficient relates the consumptive use of water for the specified crop to that of an alfalfa reference with no cutting effects. This is a simple multiplier coefficient. A four column set of data labeled "EVAPOTRANS. FOR PERIOD" gives the amount of alfalfa reference ET and the specified crop ET. The average consumptive requirement is, in reality, the quantity which will not be exceeded 50% of the time. The 80% and 20% values are also listed. The average requirement was used in calculating total acreage water requirements. The 80% and 20% values are included if the 50% risk is not appropriate.

After every irrigation, there is an evaporation loss not accounted for by the crop coefficient. There is a potential extra evaporation limit set for each irrigation shown. There may be more than one irrigation per period and usually the "potential" evaporation is not realized especially if the crop ET is high using all available evaporative energy for transpiration (Wright,1981). The estimated

FIGURE 2: CONSUMPTIVE USE & EVAPORATION ESTIMATES FOR BEANS. ONE OF SIX CROPS.

HALF-MONTHLY CONSUMPTIVE USE ESTIMATES FOR KIMBERLY IDAHO..14 YEARS OF RECORD (EJLW)
DRY BEANS - SANDY SOILS, SPRINKLER, PLANT MAY 15

```
CROP NUMBER          2
DATE OF PLANTING        5/ 15
DATE OF EFF.COV.        7/ 15
DATE OF HARVEST         9/  1
DATE OF MIN ROOT        5/ 18
DATE OF MAX ROOT        7/ 20       (block 1)              P A R T   A
MIN. ROOT DEPTH,FT     .30
MAX. ROOT DEPTH,FT    2.50
AVAIL.MOIST.,IN/FT    1.70
ALLOW. DEPLETION,%   50.00
ALLOW. DEPL.,IN/FT     .85
```

C O N S U M P T I V E   U S E   A N D   E V A P O R A T I O N   E S T I M A T E S   (INCHES)

MONTH	PERIOD (15 DAY)	AVE CROP COEF	EVAPOTRANS FOR PERIOD REF	ACTUAL	80%	20%	EXTRA EVAP PER IRR	NO. OF IRR	TOTAL EVAP	ROOT DEPTH	TOTALS, PERIOD AND MONTH REF	ACTUAL	80%	20%
4	1	0.000	2.42	0.00	0.00	0.00	.26	0	0.00	.30		0.00	0.00	0.00
4	2	0.000	2.80	0.00	0.00	0.00	.30	0	0.00	.30		0.00	0.00	0.00
											5.22	T0.00	T0.00	T0.00
5	1	.010	3.42	.03	.04	.03	.36	0	0.00	.30		.03	.04	.03
5	2	.160	4.06	.65	.71	.59	.34	1	.34	.50		.99	1.06	.93
											7.48	T1.03	T1.09	T .96
6	1	.251	4.01	1.00	1.12	.89	.32	1	.32	1.03		1.33	1.44	1.21
6	2	.554	4.58	2.53	2.83	2.24	.22	2	.44	1.56		2.97	3.27	2.67
											8.59	T3.98	T4.39	T3.57
7	1	.878	4.69	4.12	4.34	3.89	.06	2	.12	2.08		4.24	4.47	4.01
7	2	.949	4.86	4.61	4.94	4.27	.03	3	.08	2.48		4.68	5.02	4.35
											9.55	T8.80	T9.36	T8.23
8	1	.813	4.36	3.54	3.79	3.29	.09	1	.09	2.50		3.63	3.88	3.38
8	2	.394	4.00	1.58	1.76	1.39	.24	1	.24	2.50		1.82	2.01	1.63
											8.36	T5.36	T5.80	T4.92
9	1	.014	3.25	.05	.05	.04	.34	0	0.00	2.50		.05	.05	.04
9	2	0.000	2.68	0.00	0.00	0.00	.29	0	0.00	2.50		0.00	0.00	0.00
											5.93	T .05	T .05	T .04
10	1	0.000	2.11	0.00	0.00	0.00	.23	0	0.00	2.50		0.00	0.00	0.00
10	2	0.000	1.68	0.00	0.00	0.00	.17	0	0.00	2.50		0.00	0.00	0.00
											3.80	T0.00	T0.00	T0.00

(^^^ block 2)

(block 3 >>>)

```
*****************************************************
SEASONAL TOTAL FOR SINGLE CROP
DRY BEANS - SANDY SOILS, SPRINKLER, PLANT MAY 15
 N O T E:  ET FOR DRY SOIL SURFACE THROUGHOUT SEASON
INCLUDES SOIL EVAPORATION PRIOR TO PLANTING AFTER
HARVEST. EXTRA EVAP IS DUE TO IRRIGATED WET SURFACE.
TOTAL REFERENCE ET   48.92 INCHES
ACTUAL CROP ET       18.11
80 %   CROP ET       19.59
20 %   CROP ET       16.63
NO. OF IRRIGATIONS   11
TOTAL EXTRA EVAP.     1.63
*****************************************************
```

evaporative loss is based on soil type and degree of surface wetting by irrigation and is shown in the column labeled "TOTAL EVAP.". The depth of the zone of soil water depletion at the end of the period is labeled "ROOT DEPTH".

The final four column set of data in block 2 labeled "TOTAL, PERIOD AND MONTH". This column gives the total ET and evaporative loss estimates for 15 day periods and the totals for each month. The third block, in Part A, shows seasonal totals abstracted from the second block.

Part B. Figure 3 is a listing of Part B of the output for beans. The date and amount of irrigation required at 100% application efficiency is listed on the following page. For potatoes and other shallow rooted or high use crops, the number of irrigations tends to be rather high. For every listing of Part A (6 in this case), there is a Part B.

Part C. Figure 4 is a listing of Part C for the total project operating at 40% efficiency. This section is a summary of all the calculated component project water requirements. For every irrigation efficiency specified, there is a repeat of the data in this section that has been adjusted to that efficiency.

The first block specifies the weighting assigned to the crop requirements specified in Part A based on areas of each crop, and the total irrigated acres. The second block lists the crop requirements and indicated irrigation efficiencies. These values are weighted sums extracted from block two of Part A. The "AVE.", "20%", and "80%" columns are in inches and the final value is in acre feet.

P A R T B

I R R I G A T I O N S C H E D U L E F O R C A S T

IRRIGATION DATES FOR MEAN CONSUMPTIVE USE REQUIREMENTS
DRY BEANS - SANDY SOILS, SPRINKLER, PLANT MAY 15

IRR. DATE	DAYS SINCE LAST IRR.	AMOUNT (IN.)
5 / 25	0 DAYS	.42
6 / 10	16 DAYS	.88
6 / 19	9 DAYS	1.32
6 / 26	7 DAYS	1.32
7 / 3	7 DAYS	1.77
7 / 9	6 DAYS	1.77
7 / 17	8 DAYS	2.11
7 / 24	7 DAYS	2.11
7 / 31	7 DAYS	2.11
8 / 9	9 DAYS	2.13
8 / 21	12 DAYS	2.13

TOTAL NO. IRRIGATIONS = 11 TOTAL REQ. = 18.06

THIS DATA INCLUDES WET SOIL EVAPORATION FOR
3 DAYS FOLLOWING IRRIGATION.

THE SEASONAL IRRIGATION REQUIREMENT IS REDUCED BY
ALLOWABLE DEPLETION NEAR THE SEASON END.

FIGURE 3. IRRIGATION SCHEDULE FOR DRY BEANS. ONE OF SIX CROPS.

P A R T   C

W A T E R   R E Q U I R E M E N T   S U M M A R Y   F O R   C R O P   D I S T R I B U T I O N

CROP DISTRIBUTION

ALFALFA	22.00 %
BEANS	5.00 %
CORN	4.00 %
PASTURE	16.00 %
PEAS	0.00 %
POTATOES	38.00 %
SUGAR BEETS	0.00 %
SPRING GRAIN	15.00 %
WINTER WHEAT	0.00 %

TOTAL PROJECT ACRES = 1359.

(block 1)

THE HALF-MONTHLY WATER REQUIREMENTS FOR THIS CROP DISTRIBUTION
FOR *** 40.% *** APPLICATION EFFICIENCY ARE:

MONTH	PERIOD	AVE	20%	80%	AC.FT.
4	1	.34	.30	.38	95.74
4	2	2.76	2.26	3.25	780.13
5	1	5.00	4.55	5.46	1416.33
5	2	6.82	6.19	7.45	1930.98
6	1	7.90	7.07	8.73	2236.82
6	2	9.06	8.07	10.05	2564.73
7	1	10.60	10.03	11.17	3000.99
7	2	10.40	9.67	11.13	2945.13
8	1	8.18	7.63	8.74	2316.83
8	2	6.18	5.47	6.89	1750.15
9	1	5.58	5.07	6.10	1581.13
9	2	2.96	2.60	3.31	836.92
10	1	1.44	1.34	1.55	409.06
10	2	0.00	0.00	0.00	0.00
SEASONAL TOTALS		77.23	70.25	84.20	8745.97

(block 2)

MONTHLY SUMMARY OF ESTIMATED IRRIGATION DEMAND

	MONTH	AVE.AC.FT.	EACH I EQUALS 50.0 ACRE FEET DELIVERED	% W TOTAL
*	1	0.	>	0.00
*	2	0.	>	0.00
*	3	0.	>	0.00
*	4	83.	>II	1.01
*	5	1470.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	17.87
*	6	1849.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	22.47
*	7	2224.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	27.03
*	8	1474.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	17.92
*	9	769.	>IIIIIIIIIIIIIII	9.35
*	10	357.	>IIIIIII	0.00
*	11	0.	>	0.00
*	12	0.	>	0.00

(block 3)

FIGURE 4: CONSUMPTIVE USE, EVAPORATIVE LOSSES, AND IRRIGATION DEMAND SHOWING WEIGHTED TOTALS OF SIX CROPS AT 40% EFFICIENCY.

The <u>third block</u>, different from the second block, is a sum of the monthly irrigation demand and are weighted sums from Part B. Note that the total seasonal irrigation requirement is less than the total crop water requirements. This is a result of the assumption that the soil is dryer at harvest than at planting for most crops. The format of this block is the same as data presented in the formatted water and power records in "FINAL REPORT: PART IC.

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FINAL REPORT PART I-C:

COMPUTER AIDS USEFUL IN FORMATTING AND DISPLAYING WATER, COST, AND ENERGY USE FROM IRRIGATION PROJECT RECORDS

A Description and Users Guide

This study was supported by funds authorized by Cooperative Agreement 58-9AHZ-9-395 as amended, between the ARS-USDA and the Idaho Water Research Institute

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January, 1983

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INTRODUCTION

Irrigation project managers tend to spend most of their time in making the project function on a daily basis. Their intimate knowledge of the operation allows them to make decisions and recommendations and to be correct most of the time. The manager's own understanding of the state of the project might be clearer if the project records were put in a well organized, standard format. In addition, the managers ability to inform, persuade, and educate may control his freedom to act in the interest of the project because the board of directors and the water users define the framework in which the manager functions. The assumption here is that good information will result in equally good management decisions and project policy.

During this study, the records from ten irrigation projects were examined. As might be expected, the condition of some water and power records were good and others were not so good. If poor records exist, their lack of utility may be due to the format in which they are kept even though they are thoroughly and completely collected and documented.

Three of the water projects kept excellent records in an understandable format. The goal of this section is to provide some specific examples and a few resource ideas on how energy and water records might be collected and stored so that they can be retrieved, augmented or modified and presented quickly.

GENERAL

The greatest asset of an automated data processing system may not be the speed at which it operates; rather, it may be the systematic and complete records that are prerequisite to system operation. The records of interest in this study are monthly (electric) energy billing and water delivery records but could be other types of records as well, with appropriate modifications.

Program HPOW and HWTR format power and water records so that the final result displays periods of record that synchronize (monthly). From a project wide standpoint, this may offer a critical perspective especially where cash flow or water availability is a problem.

HPOW offers options that can produce daily and/or monthly average energy use and charges from information printed on a utility power bill. Since these bills are usually associated with a single (kilowatt hour) meter, the location or duty of the pump and its cost of operation may be isolated from other (meters) pumps. Options are offered to select daily averages or accumulating daily averages. Tabular output is enhanced with a "quasi-graphical" output. Monthly fractions of the yearly total are printed in tabular form.

The output format of HWTR water records is similar to the output format of HPOW power records. In the example application, individual water user records are supplied that contain a water user number, acres irrigated, user location (optional), and water use by month. The high, low, average, and non-use patrons may be identified if desired.

The "graphical" output produced in HPOW and HWTR is similar to a bar chart and simulates a histogram. The subroutine that generates the printed bar is brief and does not require graphics software. The records used to generate the output need not represent the full year's record; only the record to date.

PROGRAM MECHANICS

HPOW and HWTR are written in FORTRAN. The programs read and store data, request output option specification interactively, and write to devices as specified. Refer to the program listing for a description of the logical unit input-output devices used and their function.

In order to synchronize power and water records, an average cost in dollars and energy use is calculated for the billing interval for each pump (meter). The total daily project charges for the pumps of interest are calculated, then the monthly values are determined. This procedure should produce estimates of energy flow at least as representative as the water flow estimates. The advantage of having synchronized water and power records does justify the data manipulation, as will be shown in the example problem.

The two programs use modifications on the same principle to generate the bar graph output. Subroutine DFILL constructs an array of print characters. The number of characters assigned to an initially blank array is controlled by the number of times a factoring number can be subtracted from a base value. After the array is constructed, it is printed. A judious selection of print characters creates the impression of a draftsman's bar graph and may even allow one "bar" to be superimposed on another.

In an effort to make the two programs versatile, options of output listing have been provided. The same basic information may be sent to the operator's terminal for preview, or to file storage for later use or to a printer. Subroutine DFILL prints and overlays characters and utilizes line feed controls. The intent in writing the routine was to produce output that was similar line for line (month by month) between energy and water data. The format selected produces the graphical portion only on a printer where line supression can be utilized.

PROGRAM OPERATION, OUTPUT INTREPRETATION and DISCUSSION

When water and power input files are available, the operator is required to select output options and provide labels for the data. The options are specified by the operator so that multiple runs producing different sets of formatted data may be produced rapidly without changing or re-reading an input data file. Some applications for different options are suggested.

Program HPOW may produce daily average energy and cost figures and can be used to produce the current day or the accumulated daily total values. Either option selected presents a listing and graph for 366 days. The uses of this particular option may be to keep track of the rate at which the water project is using up a "block" of power specified in a negotiated power contract or billing rate structure. It may also be used to graphically show how fast the operating budget is being depleted by energy charges. The ability to select from one or the sum of three groups of pumps may give the manager a means to compare the performance of one group against another or one group against the same group during a previous year. Both from energy dollar and water accounting view point, having current information should be quite valuable. It may also cause the policy making body of the project to take a critical look at when and how much water is being used and the cost of delivering that water to the project.

Program HWTR can be used to calculate the project average and identify who and where the high, low and non water users operate on the project. Estimates of the remaining water and power seasonal requirement may be closer to reality if the crops and individuals whose water use habits are known can be produced and correlated.

If the operators of water projects use records to manage, they are dependent on their own ability to correlate, compare, and extrapolate. The type of results presented in the example application may inspire some ideas not presented here.

EXAMPLE APPLICATION

A set of input data and output is presented for a water company that operates three groups of pumps. Surface water storage in a lake was supplemented with pumped groundwater in order to build up reserves for heavy growing season demand. Each year, the decision has to be made of when to start the groundwater pumps, and how long to operate them. There are two other pump groups one to deliver the irrigation demanded and another to pump drainage water.

The energy records were obtained from power utility billing invoices. The invoices were sorted into groups by meter number and arranged in a chronological order. The water records were copied without alteration from water records kept routinely by the company. The power records have been used by the company to keep track of costs and not to estimate quantities of pumped water. Water records have been used as the estimator of lake reserves and project demand. No definite relationships have been developed to relate variables of total dynamic head, pump discharge, and energy consumption.

HPOW input data file is listed in Figure 1 and HWTR data is in Figure 2. The files are annotated so that the order and format should be clear. Both files are read with an unformatted read statement; however, for clerical reasons, it may be convenient to format the listing. Basically, both files present the same kind of information but in a different order. The power data is presented in a block that represents the total year's record using additional lines for new billing records while the water data requires one line per user per year.

On the first line of the power data, the pump identifier and function is specified. Up to three types of pump functions may be specified. In Figure 1, pumps coded -100 are delivery pumps, -200 are drainage return pumps, and -300 are water supply pumps. With each coding is the capacity to identify 99 pumps; ie., -301, -399, etc. On the same line, the second character specifies the size of the pumping unit (75 horsepower, perhaps) and the unit's location (in this case, a range and section number). The size and location numbers are not used in HPOW. Each successive line after the first line within a block contains four values. They are month and day, peak kilowatts of demand, kilowatt hours, and dollar charges. (The peak kilowatts value in the data set is not used in HPOW.) The second line in the block specifies the first day of seasonal operation. Successive blocks begin with new pump identifiers and the file ends with a large positive number in the pump identifier position.

On the first line and each successive line of water delivery data listed in Figure 2, the water user number, acre allotment, location (range and section number) monthly totals and yearly total are specified. The location number is not used in HWTR . In this case, monthly totals begin with the fourth month and end with the ninth month, and the last number represents the yearly total. A zero acreage allotment indicates that the operator changed. The end of file mark is a large positive number in the user number position.

Figure 3 is an edited example of the daily accumulated average power cost, and monthly summary values. The daily listing is rather long as it requires one line per day or 366 lines per year; hence, the edited data in the example. In the section pertaining to daily values, the columns of numbers on the left are day number, kilowatt hours, and cost per day followed by superimposed bar graphs with print characters coded as indicate at the beginning of the output. There are 100 spaces between the ">.......<" marks.

Figure 4 are monthly totals of power and water data. The print spacing has been compressed to fit a standard page. Note that there are columns on the right portion of Figure 3 and 4 representing percentage of yearly totals for each month as in the corresponding data in Figure 3. The information present in these figures, less the bar graph, may be stored for later reference without recomputing. The format of the redundant stored data is not shown. In the lower section of Figure 4 is a listing of single water user's statistics (i.e., 4.5 and .5 ft. in Figure 4) are input variables and may be altered in successive runs to make close estimates of high and low user statistics. A listing of the programs HPOW and HWTR is presented in the Appendix C-I and C-II.

```
-201,5,4.22          (drainage pump no. 1; 5 horse power; range 4, sec. 22)
5.01,0,0,0.            *                                                 *
5.27,4,588,59.69       *                                                 *
6.22,4,888,68.62       *                                                 *
6.25,3,120,38.59       *                                                 *
10.24,0,0,21.73        **********(last day pump 1 operates during the year)
-301,135,5.34          (supply pump no. 1; 135 horse power; range 5, sec.34)
3.01,0,0,0.          (March 1.............first day of seasonal operation)
3.21,32,11580.197.02   (highest demand during 1st 21 days, 32 kilowatts)
4.22,36,15120,597.94    *                                                *
5.21,38,22740,990.64    *                                                *
7.22,224,15680,2116.10  *(between 5-21 & 7-22, 15680 & $2116. kwh spent)
9.22,176,103680,3378.97 *************************(last day of operation)
-101,325,4.32        (delivery pump no. 1; 325 horsepower;  range 4, sec.32)
6.23,0,0,0.                *                                  (first day)
7.02,192,40000,1543.46     *                                             *
8.01,200,104000,3862.17    *                                             *
9.03,152,3200,1227.90      *                                             *
10.02,112,1503,105.62      *                                             *
10.29,112,24000,520.89     ***********************************(last day)
-102,525,4.32        (delivery pump no. 2; 525 horsepower;  range 4, sec.32)
5.20,0,0.,0                    *                              (first day)
5.30,262,62720,3449.78         *                                         *
6.01,493,149760,6916.53        *                                         *
8.01,544,215040,8638.84        *                                         *
9.03,352,154880,6010.51        *                                         *
10.02,294,112640,3355.60       *                                         *
10.29,300,131200,2787.31       *******************************(last day)
99999.,000,000,000.0                                        (end of file)
```

FIGURE 1. DATA FILE CONTAINING ENERGY USE AND COST. USED BY PROGRAM HPOW.

```
  1.00  160 4.50   0    0   72    0   70    0  142          (user no. 1)
  2.00   80 4.90   0   42   28   26    0    8  104
   .      .  .     .    .    .    .    .    .    . (loc. by range and sec.)
   . (acres)(loc)  (water demand, may thru oct.&tot.)
   .      .  .     .    .    .    .    .    .    . (wtr dmd in c.f.s. days)
 53.00  160 4.21  39   37   54   44   20    0  194
 57.00  312 4.13   0   28   83    0   80    0  191
   .      .  .     .    .    .    .    .    .    .
   .      .  .    (a    m    j    j    a    s   yr)
   .      .  .     .    .    .    .    .    .    .
 123.0  240 4.13   0   35   18   31   19    8   75
 129.0  668 4.34   0  482  471   70   68  180 1271          (user  129)
 400.0  000 0.     0  000  000   00   00  000 0000          (end of file)
```

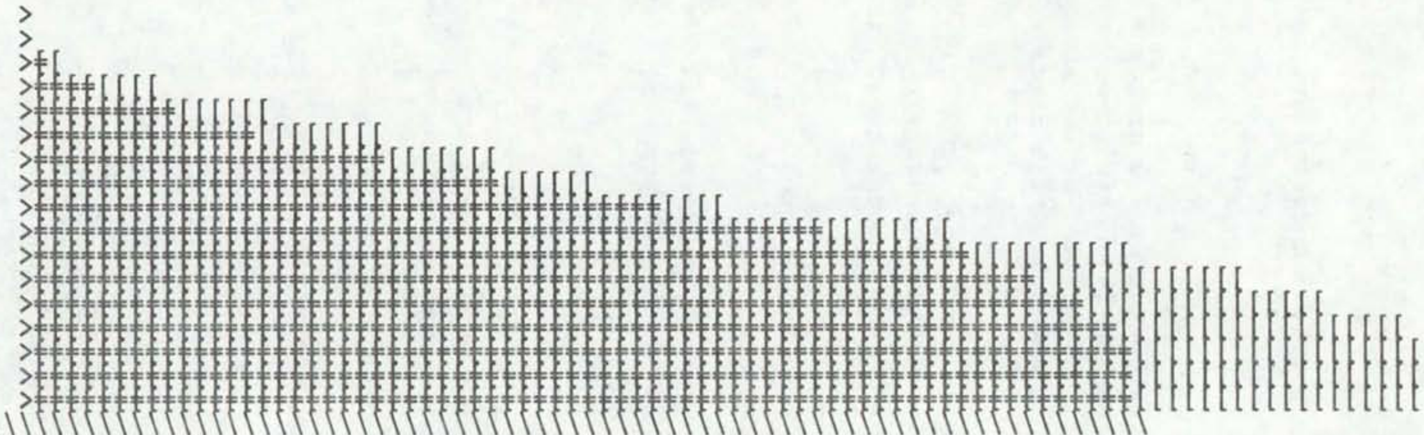
FIGURE 2.   DATA FILE OF WATER USE INFORMATION USED BY PROGRAM HWTR.

THIS IS ENERGY AND POWER COST DATA THAT HAS BEEN MODIFIED TO SYNC WITH MONTHLY WATER RECORDS
KSUM= 3049649 CSUM= 119348.20

THIS IS DAILY ENERGY AND POWER COSTS PROJECT WIDE WITH GRAPHICAL REPRESENTATION OF THE DATA

KWH CODES TO "[[[" AND $CST CODES TO "==="
"[" EQUALS 35000 KWH AND "=" EQUALS 1750. ENERGY DOLLARS

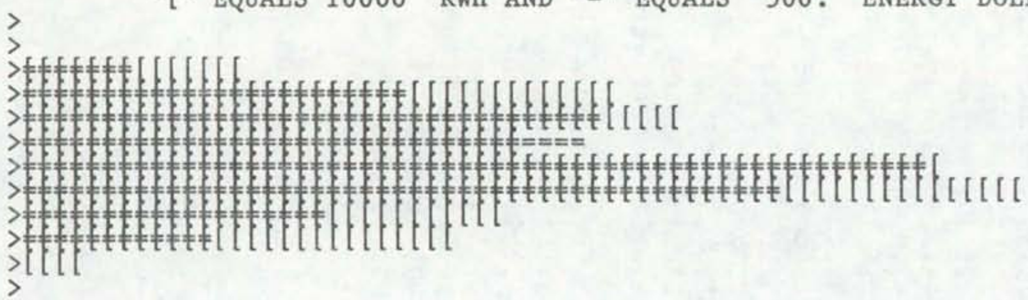
J-DAY	KWH	$CST
1.	0.	0.
1.	0.	0.
81.	8549.	251.
101.	12444.	372.
121.	12815.	455.
141.	17793.	768.
161.	5162.	250.
181.	15122.	893.
201.	14323.	864.
221.	24269.	913.
241.	13043.	505.
261.	11832.	371.
281.	7997.	178.
301.	11208.	244.
321.	925.	36.
341.	0.	0.
366.	0.	0.



MONTHLY SUMMARY ENERGY AND POWER COSTS   OWSLEY CANAL COMPANY, ENERGY AND COST DATA 1980

"[" EQUALS 10000 KWH AND "=" EQUALS 500. ENERGY DOLLARS

MONTH	KWH	$CST	% K TOTAL	% $ TOTAL
1	0	0.00	0.00	0.00<
2	0	0.00	0.00	0.00<
3	144383	3696.79	4.73	3.10<
4	373834	11851.92	12.26	9.93<
5	413961	17961.53	13.57	15.05<
6	313127	17445.23	10.27	14.62<
7	570609	27858.52	18.71	23.34<
8	618879	23445.03	20.29	19.64<
9	303708	9690.89	9.96	8.12<
10	267413	5959.72	8.77	4.99<
11	40958	1329.54	1.34	1.11<
12	2776	109.10	.09	.09<



KSUM= 3049649 CSUM=19348. 100.00 % 100.00 %

FIGURE 3. SAMPLE OUTPUT OF ENERGY USE AND COST FORMATTED BY PROGRAM HPOW

```
MONTHLY SUMMARY PROJECT WATER DELIVERY RECORDS   ACRES:  IRRIGATED = 16819, DRY =   206, TOTAL = 17025
 MONTH      AC.FT                                                                                  % W TOTAL
 -----      -- --                 EACH D EQUALS 100.0 ACRE FEET DELIVERED                          - - -----

   1          0.     >                                                                                  0.00
   2          0.     >                                                                                  0.00
   3          0.     >                                                                                  0.00
   4          0.     >                                                                                  0.00
   5       2416.     >DDDDDDDDDDDDDDDDDDDDDDDD                                                          7.18
   6       7144.     >DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD          21.25
   7      12393.     >DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDX
   8       4629.     >DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD                                   13.77
   9       3041.     >DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD                                                    9.05
  10       4039.     >DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD                                         12.01
  11          0.     >                                                                                  0.00
  12          0.     >                                                                                  0.00

 TOTAL=    33662.                                                                                     100.0 %
```

THE FOLLOWING IS A LISTING OF SINGLE USER STATISTICS FOR THE YEAR OF RECORD;
THEY INCLUDE ONLY THOSE USERS THAT ARE CREDITED WITH AT LEAST ONE UNIT OF DEMAND:

USER NUMBER	USER ACRES	ACRE FEET DELIVERED	ACRE FEET PER ACRE	% TOTAL ACRES	% WATER DELIVERED
THE HIGH WATER USERS. IRRIGATORS APPLYING 4.5 FEET OR MORE:					
3	78.	616.	7.895	.458	1.831
8	160.	754.	4.715	.940	2.244
15	100.	168.	8.415	.012	.501
70	80.	392.	4.900	.470	1.166
93	4.	20.	4.950	.023	.059
SUMMARY	424.	1950.	6.968	2.490	5.580
THE LOW WATER USERS. IRRIGATORS APPLYING .50 FEET OR LESS:					
7	680.	194.	.285	3.994	.577
28	640.	164.	.257	3.759	.489
29	240.	107.	.446	1.410	.318
118	668.	295.	.442	3.923	.877
SUMMARY	2228.	760.	.312	14.302	2.261
THE PROJECT AVERAGE:					
SUMMARY	16819.	33622.	1.999	100.000	100.000
OF THE USERS LISTED THIS YEAR, THE ONES USING NO WATER COMPILED THE FOLLOWING STATISTICS:					
5	2.	0.	0.000	.012	0.000
22	1.	0.	0.000	.006	0.000
24	5.	0.	0.000	.029	0.000
47	8.	0.	0.000	.047	0.000
52	5.	0.	0.000	.029	0.000
90	185.	0.	0.000	1.087	0.000

FIGURE 4. SAMPLE OUTPUT OF WATER USE INFORMATION FORMATTED BY PROGRAM HWTR.

APPENDIX A-I

INPUT VARIABLES AND DEFINITIONS

TITLE: INPUT-OUTPUT USER REFERENCES, 19A4
LABL: FLOW, HEAD, AND POWER UNITS REFERENCE, 34A2
N: NO. OF PUMPS; IHQP and ISYS: PUMP and H-Q-P INPUT DATA TYPE,
1=cubic equation (4 numbers), 2=digital data (8 numbers)
PML(I): LOSSES IN MANIFOLD PRESSURE DUE TO F AND T or ELEVATION,
N+1 values accomodates total station and each individual unit
IV(I): PUMPING UNIT VALVE INDICATOR
1=valve, 0=no valve; there will be N values
H(I,J): PUMP CHARACTERISTIC HEAD VALUES
corresponds to generated (IHQP=1) or specified (IHQP=2)
pump discharge
QA(I,J): PUMP CHARACTERISTIC FLOW VALUES,
omitted when IHQP=1, corresponds to H and P values
P(I,J): PUMP CHARACTERISTIC POWER VALUES
corresponds to generated (IHQP=1) or specified (IHQP=2) pump discharge
PP(I,J): SYSTEM CHARACTERISTIC HEAD VALUES, I=1 interpolator format,
corresponds to generated (ISYS=1) or specified (ISYS=2) system demand
QS(I,J): SYSTEM CHARACTERISTIC FLOW VALUES, omitted when ISYS=1,
corresponds to SS values
K: NO OF INCREMENTS TOTAL PLANT FLOW (Q) IS BROKEN FOR ANALYSIS,
try N=30...then adjust
WNDO: WINDOW, CONTROLS RANGE OF SYSTEM HEAD THAT PUMPS MUST MATCH,
try 0.05, then reduce
FACP: FACTOR RELATING H AND QA TO P, P=HQ/FACP,
LBND(M,J); UBND(M,J): LOWER AND UPPER BOUNDS OF CONSTRAINTS ON QA,
entered in pairs, up to 3 pairs, constraints may overlap,
negative LBND is END OF FILE (EOF) mark

OPERATOR VARIABLES

QP;QH: RANGE OF STATION FLOW
QI: INCREMENT BETWEEN STATION FLOWS (MULTI-SOLUTION PROBLEM)

OUTPUT VARIABLES AND DEFINITIONS

QSPILL: STATION FLOW ABOVE Q WITH NO ENERGY PENALITY

QFND;HSYS;PSUM: TOTAL OPTIMIZED POWER TO PUMP STATION Q
AGAINST SYSTEM HEAD
QPT;HWND;PPT: SUM OF UNIT Q AND POWER OF UNITS
CAPABLE OF PRODUCING WINDOW HEADS, HWND IS THE HIGHEST WINDOW HEAD.
QFND;SPLT;Q: SPLT IS THE DIFFERENCE WHEN STATION CAN PUMP
MORE FLOW THAN SPECIFIED (Q) FOR LESS ENERGY
QEACH(I);E(I);PEACH(I): OPTIMIZED UNIT Q, OPERATING AT "E" HEAD
REQUIRING "PEACH" POWER
QP(I);HP(I);PP(I): UNIT Q AND POWER OF UNITS CAPABLE OF
PRODUCING WINDOW HEADS
IWNDO: 1000WNDO, see input variables
IV;PML: REDUNDANT FROM INPUT
HDD(I): HEAD EACH UNIT PRODUCES
PWR(I): WATER POWER EACH UNIT REQUIRES WHEN PRODUCING QA AT HDD
UPWR(I): USABLE WATER POWER AT PUMP AFTER VALVE
EFF(I): PUMP UNIT EFFICIENCY AFTER VALVE
HDD,PWR,UPWR,EFF: I=N+1, VALUES ACCOUNTING FOR ALL APPURTENANT
TURBULENCE, FRICTION, and ELEVATION

APPENDIX A-II

PROGRAM LISTING

APPENDIX II

```
FTN4
      PROGRAM RULE
C ************************************************************************
C *****              PARALLEL PUMP OPERATION PROGRAM                  *****
C *****                                                               *****
C *****                    UNIVERSITY OF IDAHO                        *****
C *****                           AND                                 *****
C *****          UNITED STATES DEPARTMENT OF AGRICULTURE              *****
C *****                                                               *****
C *****                                     ROBIN D. WELLS            *****
C *****                                     & MIKE W. BEUS            *****
C *****                                                               *****
C *****                                     NOVEMBER 1982             *****
C *****                                                               *****
C *****                                                               *****
C ***** THIS ROUTINE FINDS THE OPTIMUM COMBINATION AND DISCHARGES     *****
C ***** BY UNIT FOR A MULTIPLE UNIT PUMPING STATION DELIVERING A      *****
C ***** SPECIFIED FLOW. OPTIMIZATION IS ON MINIMUM ENERGY INPUT FOR ****
C ***** SPECIFIED OUTPUT. THIS VERSION READS DATA FROM LU 25 AND      *****
C ***** RESULTS ARE WRITTEN TO LU 6                                   *****
C *****                                                               *****
C ************************************************************************
      COMMON G(10,302),LBND(10,5),UBND(10,5),F(10,302),ID(10,302),
     *H(10,10),SS(10,10),QS(10,10),QA(10,10),PML(10),IV(10)
      DIMENSION P(10,10),TITLE(19),LABL(4,3)
   87 FORMAT(1X,4A2,4A2,4A2)
   88 FORMAT(1X,10I5)
   89 FORMAT(1X,10F5.2)
   97 FORMAT(1X,'...........',
     */1X,'>>>>> DO YOU NEED INPUT VERIFICATION?')
   98 FORMAT(/1X,'************************************     RESULTS     '
     *,' ************************************',/)
   99 FORMAT(/1X,'TOTAL STATION TARGET DISCHARGE IS',I5,' BROKEN INTO ',
     *I3,' INCREMENTS OF ',F5.2,' UNITS',/1X,'DISCHARGE IS IN ',4A2,
     *', HEAD IS IN ',4A2,', AND UNITS OF POWER ARE IN ',4A2)
  100 FORMAT(1X,'ENTER THE LOW, HIGH, AND INCREMENTAL STATION FLOWS')
  101 FORMAT('1',19A4)
  102 FORMAT(I5,F5.3,F10.4)
  103 FORMAT(1X,5E10.3,/6X,5E10.3)
  104 FORMAT(1X,I5,3(I10,F10.0))
C ..... DATA READING SECTION .........................................
      READ (25,101) TITLE
```

```
      H(I,10)=H(I,9)/2.
  105 H(I,1)=H(I,2)+0.1
      IF(IHQP.LE.6) GO TO 110
      DO 109 I=1,N
      QA(I,1)=0.0
      READ (25,*) (QA(I,J),J=2,IHQP-1)
  109 QA(I,10)=10.*QA(I,9)
  110 DO 106 I=1,N
      READ (25,*) (P(I,J),J=2,IHQP-1)
      P(I,1)=P(I,2)+0.1
  106 P(I,10)=10.*P(I,9)
      I=1
      READ (25,*) (SS(I,J),J=2,ISYS-1)
      IF(ISYS.GE.6) READ (25,*) (QS(I,J),J=2,ISYS-1)
      SS(I,1)=SS(I,2)
      SS(I,10)=10.*SS(I,9)
      QS(I,1)=0.0
      QS(I,10)=10.*QS(I,9)
      READ (25,*) K,WNDO,FACP
  108 READ (25,*) M,((LBND(M,J),UBND(M,J)),J=1,3)
      IF(M) 107,107,108
  107 CONTINUE
      WRITE (1,97)
      READ (1,*) IFLAG
C ..... DATA VERIFICATION .............................................
      IF(IFLAG.NE.0) GO TO 95
      GO TO 94
   95 WRITE (1,101) TITLE
      WRITE (1,87)  LABL
      WRITE (1,104) N,IHQP,ISYS
      WRITE (1,89) (PML(I),I=1,N+1)
      WRITE (1,88) (IV(I),I=1,N)
      WRITE (1,103) ((H(I,J),J=1,10),I=1,N)
      IF(ISYS.GE.6) WRITE (1,103) ((QA(I,J),J=1,10),I=1,N)
      WRITE (1,103) ((P(I,J),J=1,10),I=1,N)
      WRITE (1,103) ((SS(I,J),J=1,10),I=1,1)
      IF(ISYS.GE.6) WRITE (1,103) ((QS(I,J),J=1,10),I=1,1)
      WRITE (1,102) K,WNDO,FACP
      DO 96 I=1,N
   96 WRITE (1,104) I,((LBND(I,J),UBND(I,J)),J=1,3)
C ..... STATION FLOW SPECIFICATION ....................................
   94 WRITE (1,100)
      READ (1,*) IQL,IQH,IQI
      WRITE(6,101) TITLE
      WRITE(6,98)
      DO 9997 IQ=IQL,IQH,IQI
      Q=IQ
C ..... MAIN COMPUTATIONS .............................................
      KP1=K+1
      QINC=Q/K
      WRITE(6,99) IQ,K,QINC,LABL
      I=1
      BIG=1.0E+35
      SAFH=1.0+WNDO
      SAFV=1.0-WNDO
```

```
      IF (ISYS-7) 112,111,111
  111 CALL INTRP (HSYS,Q,SS,QS,I)
      GO TO 113
  112 HSYS=SS(I,2)+SS(I,3)*Q+SS(I,4)*Q*Q+SS(I,5)*Q*Q*Q
  113 DO 500 I=1,N
  500 G(I,1)=0.
C ..... CONSTRUCTION OF THE G POWER ARRAY ..................................
      DO 600 J=2,KP1+1
      DO 600 I=1,N
      L=J-1
      QTRP=L*QINC
      IF(IHQP-7) 115,114,114
  114 CALL INTRP (G(I,J),QTRP,P,QA,I)
      CALL INTRP (ZZ,QTRP,H,QA,I)
      GO TO 116
  115 G(I,J)=P(I,2)+P(I,3)*QTRP+P(I,4)*QTRP*QTRP+P(I,5)*QTRP**3
      ZZ=H(I,2)+H(I,3)*QTRP+H(I,4)*QTRP*QTRP+H(I,5)*QTRP*QTRP*QTRP
  116 IF((ZZ-PML(I)-PML(N+1))*SAFH.LT.HSYS) G(I,J)=BIG
      IF(IV(I).EQ.0.AND.(ZZ-PML(I)-PML(N+1))*SAFV.GT.HSYS) G(I,J)=BIG
  600 CONTINUE
C ..... CONSTRAINT ASSIGNMENT TO POWER ARRAYS ..........................
      CALL CNSTN (KP1,QINC,N)
C ..... SOLUTION SECTION .............................................
      CALL DYNAI(K,N,QINC,HSYS,Q,IHQP,ISYS,FACP,WNDO)
C ..... INSERT ARRAY CONFORMATION CHECKS HERE IF NECESSARY ............
 9997 CONTINUE
      END
C
C SUBROUTINE: INTERPOLATES DIGITAL INPUTS SSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
C
      SUBROUTINE INTRP(A,Q,B,QA,I)
      DIMENSION B(10,10),QA(10,10)
      J=1
    1 IF(QA(I,J).LE.Q.AND.Q.LE.QA(I,J+1)) GO TO 2
      J=J+1
      GO TO 1
    2 A=B(I,J)+(B(I,J+1)-B(I,J))*(Q-QA(I,J))/(QA(I,J+1)-QA(I,J))
      RETURN
      END
C
C SUBROUTINE: APPLIES SPECIFIED CONSTRAINTS SSSSSSSSSSSSSSSSSSSSSSSSSSSS
C
      SUBROUTINE CNSTN(KP1,QINC,N)
      COMMON G(10,302),LBND(10,5),UBND(10,5)
      BIG=1.0E+35
      DO 10 I=1,N
      DO 10 K=1,3
      DO 10 J=1,KP1
      Q=QINC*(J-1)
      IF (Q.GE.LBND(I,K).AND.Q.LE.UBND(I,K)) G(I,J)=BIG
   10 CONTINUE
      RETURN
      END
C
C SUBROUTINE: FINDS POWER ANOMALIES IN PUMP CHARACTERISTICS SSSSSSSSSSS
```

```
C THIS SUBROUTINE SEARCHES FOR THE CASE WHERE THERE ARE TWO POSSIBLE ...
C FLOWS FOR A SINGLE POWER DEMAND. ALL PUMPS ARE REVIEWED BUT THE MOST .
C LIKELY 'SPILL' SITUATION WILL OCCUR ON THE LAST PUMP CONSIDERED AFTER
C THE STATION DEMAND HAS BEEN SATISFIED................................
C
      SUBROUTINE SPILL (ISTAR,N,K,QINC,ID)
      COMMON G(10,302)
      DIMENSION  ISTAR(10),ID(10,302)
    1 FORMAT (1X,'NO POWER ANOMALIES')
    2 FORMAT (1X,'LOOK FOR ',I2,' POWER ANOMALIES')
    6 FORMAT (1X,'POWER ANOMALY ON PUMP',I3,' AT PUMP-Q=',F5.0,
     *' AND',F5.0)
      IFLAG=0
      KP1=K+1
      BIG=1.0E+35
      DO 10 I=1,N
      IF(ISTAR(I).EQ.0) GO TO 10
      G1=G(I,ISTAR(I)+1)
      DO 9 J=2,KP1
      IK=KP1+2-J
      IF(G(I,IK).LE.G1.AND.G(I,IK).LT.BIG) GO TO 8
      GO TO 9
    8 CONTINUE
      IF(ISTAR(I).GE.IK-1) GO TO 10
      IFLAG=IFLAG+1
      AFLAG=FLOAT(ISTAR(I))*QINC
      BFLAG=FLOAT(IK-1)*QINC
      WRITE(6,6) I,AFLAG,BFLAG
    9 CONTINUE
      ISTAR(I)=ID(I,IK)
   10 CONTINUE
      IF(IFLAG.EQ.0) WRITE(6,1)
      IF(IFLAG.GT.0) WRITE(6,2) IFLAG
      RETURN
      END
C
C SUBROUTINE: OPTIMIZES THE PERFORMANCE WITHIN THE STATION SSSSSSSSSSSS
C THIS IS A DYNAMIC APPROACH TOWARD SOLUTION. WHEN A WINNER IS FOUND, IT
C IS AWARDED AN INCREMENT OF FLOW IN THE ID ARRAY AND THE F ARRAY IS ...
C ASSIGNED AN APPROPRIATE INCREMENT OF POWER FROM THE G ARRAY..........
C THIS SOLUTION IS BASED ON THE "STAGE COACH" PROBLEM PRESENTED
C BY GILLETT (1976)....................................................
C
      SUBROUTINE DYNAI(K,N,QINC,HSYS,Q,IHQP,ISYS,FACP,WNDO)
      DIMENSION ISTAR(10),QEACH(10),E(10),PEACH(10),QP(10),HP(10),PP(10)
     *,HDD(10),PWR(10),UPWR(10),EFF(10)
      COMMON G(10,302),LBND(10,5),UBND(10,5),F(10,302),ID(10,302),
     *H(10,10),SS(10,10),QS(10,10),QA(10,10),PML(10),IV(10)
    1 FORMAT(1X,I2,I8,5F15.0)
   45 FORMAT(/'*','>>>',I2,'>>> REFERENCE INFORMATION',
     */1X,9X,'______________________',
     */7X,'VALVE',9X,'HD.LOSS',8X,'HD.LOSS',9X,'POWER',10X,'WATER',10X,
     *'POWER',/2X,'#',2X,'CONDITION',6X,'SPECIFIED',6X,'DEVELOPED',7X,
     *'LOSSES',9X,' POWER  ',6X,'EFFICIENCY',
     */5X,'---------',6X,'---------',6X,'---------',7X,'------',8X,
```

```
     *'--------',7X,'----------')
  14 FORMAT(1X,'THE STATION CANNOT MEET THE DEMAND UNDER THE PRESCRIBED
     * CONSTRAINTS AT....',F6.0,/1X,'SEE POTENTIAL VALUES FOR ESTIMATE O
     *F STATION CAPACITY SHORTFALL.')
  15 FORMAT(/'*','>>>>>>>> TOTAL STATION VALUES',
     */1X,9X,'____________________',
     */1X,5X,'STATION',9X,'SYSTEM',9X,'TOTAL',7X,'DISCHARGE',6X,
     *'STA. HEAD',6X,'STA. POWER'/1X,4X,'DISCHARGE',9X,'HEAD',10X,
     *'POWER',6X,'AT POTENTIAL',3X,'AT POTENTIAL',3X,'AT POTENTIAL',
     */5X,'---------',9X,'----',10X,'-----',6X,'------------',3X,
     *'------------',3X,'------------',
     */1X,F10.0,5F15.2)
  16 FORMAT(/'*','>>>>>>>> INDIVIDUAL UNIT VALUES',
     */1X,9X,'______________________',
     */1X,7X,'UNIT',11X,'UNIT',11X,'UNIT',9X,'UNIT Q',8X,
     *'UNIT HEAD',5X,'UNIT POWER'/2X,'#',2X,'DISCHARGE',9X,'HEAD',10X,
     *'POWER',6X,'AT POTENTIAL',3X,'AT POTENTIAL',3X,'AT POTENTIAL',
     */5X,'---------',9X,'----',10X,'-----',6X,'------------',3X,
     *'------------',3X,'------------')
  13 FORMAT(1X,I2,F8.0,5F15.2)
  23 FORMAT(1X,3X,'SPECIAL NOTE> PUMP',F6.0,', SPILL',F4.0,',
     *DELIVER,',F6.0)
  24 FORMAT(/1X,'*****************************************************
     *************************************')
  29 FORMAT(1X,'CONSIDER THESE ITEMS IN THE FOLLOWING ORDER:')
  30 FORMAT(5X,'STATION DEMAND IS GREATER THAN SYSTEM CAPACITY')
  31 FORMAT(5X,'IS SPILLING ',F7.2,' AN ACCEPTABLE ALTERNATIVE?')
  35 FORMAT(5X,'EXAMINE THE SPECIFIED CONSTRAINTS')
  36 FORMAT(5X,'REVIEW THE SPECIFIED UNIT AND STATION HEAD LOSSES')
  37 FORMAT(5X,'CONSIDER VALVING ADDITIONAL PUMPS THAT HAVE POTENTIAL H
     *EADS',/7X,' BELOW OR SLIGHTLY ABOVE THE SYSTEM HEAD')
  38 FORMAT(5X,'DECREASE THE INCREMENT SIZE OR INCREASE THE WINDOW SIZE
     *')
  42 FORMAT(1X,'CONSIDER VALVING OR CONTROLLING HEADS ON UNITS NOT VALV
     *ED',/5X,'LOOK AT THE POTENTIAL HEADS BELOW OR SLIGHTLY ABOVE THE S
     *YSTEM HEAD')
  44 FORMAT(/1X,'TOTAL STA.',2F15.3,3F15.0)
     KP1=K+1
     BIG=1.0E35
     F(N+1,1)=0.
     DO 10 IX=2, KP1+1
  10 F(N+1,IX)=BIG
     DO 11 IK=1,N
     I=N-IK+1
     G(I,1)=0.
  11 G(I,KP1+1)=BIG
C ..... ID AND F ARRAY CONSTRUCTION ...................................
     DO 5 IK=1,N
     I=N-IK+1
     F(I,1)=G(I,1)+F(I+1,1)
     JFIX=0
     FLG=0.
     DO 3 IX=2,KP1
     F(I,IX)=F(I+1,IX)
     ID(I,IX)=0
```

```
      DO 2 IZ=2,IX
      IF(G(I,IZ).GE.BIG) GO TO 2
      IF(F(I+1,IX-IZ+1).GE.BIG) GO TO 2
      IF(F(I,IX).LE.G(I,IZ)+F(I+1,IX-IZ+1)) GO TO 2
      F(I,IX)=G(I,IZ)+F(I+1,IX-IZ+1)
      IF(IZ-1.GE.JFIX.AND.FLG+F(I+1,IX-IZ+1).EQ.F(I,IX)) GO TO 2
      JFIX=IZ-1
      ID(I,IX)=IZ-1
      FLG=F(I,IX)
    2 CONTINUE
      IF(F(I,IX).GE.BIG) GO TO 20
      GO TO 3
   20 IF(G(I,IX).LE.BIG) GO TO 21
      GO TO 3
   21 F(I,IX)=G(I,IX)
      IF(F(I,IX).GE.BIG) GO TO 3
      ID(I,IX)=IX-1
    3 CONTINUE
    5 CONTINUE
C ..... SOLUTION SECTION ..............................................
    6 ISTAR(1)=ID(1,KP1)
      DO 8 I=2,N
      ISUM=0
      IM1=I-1
      DO 7 J=1,IM1
    7 ISUM=ISUM+ISTAR(J)
    8 ISTAR(I)=ID(I,KP1-ISUM)
      ISUM=ISTAR(N)+ISUM
      IF(ISUM.LT.K) WRITE(6,14) Q
      CALL SPILL(ISTAR,N,K,QINC,ID)
      PSUM=0.
      DO 9 I=1,N
      PEACH(I)=G(I,ISTAR(I)+1)
      PSUM=PEACH(I)+PSUM
    9 QEACH(I)=FLOAT(ISTAR(I))*QINC
      QFND=FLOAT(ISUM)*QINC
      PPT=0.
      QPT=0.
      DO 18 I=1,N
      DO 17 J=2,KP1
      IK=KP1+2-J
      IF(G(I,IK).LT.BIG) GO TO 19
      GO TO 17
   19 QP(I)=FLOAT(IK-1)*QINC
      PP(I)=G(I,IK)
      QPT=QP(I)+QPT
      PPT=PP(I)+PPT
      GO TO 18
   17 CONTINUE
   18 CONTINUE
C ..... UNITS CONVERSION SECTION .....................................
      DO 12 I=1,N
      IF(IHQP-7.GE.0) CALL INTRP (E(I),QEACH(I),H,QA,I)
      IF(IHQP-5.EQ.0) E(I)=H(I,2)+H(I,3)*QEACH(I)+H(I,4)*QEACH(I)**2
     *+H(I,5)*QEACH(I)**3
```

```
      IF(IHQP-7.GE.0) CALL INTRP(HP(I),QP(I),H,QA,I)
      IF(IHQP-5.EQ.0) HP(I)=H(I,2)+H(I,3)*QP(I)+H(I,4)*QP(I)**2+H(I,5)*
     *QP(I)**3
   12 CONTINUE
      SPLT=QFND-Q
      SAFT=(QINC/2.)*N
      I=1
      IF(ISYS-6)  26,27,27
   27 CALL INTRP(HSYP,QPT,SS,QS,I)
      GO TO 25
   26 HSYP=SS(I,2)+SS(I,3)*QPT+SS(I,4)*QPT*QPT+SS(I,5)*QPT*QPT*QPT
C ..... REFERENCE VALUES COMPUTATION ....................................
   25 AFLAG=0.
      BFLAG=0.
      CFLAG=0.
      HDD(N+1)=0.00
      EFF(N+1)=0.00
      QSPILL=QPT-QFND
      IWNDO=IFIX(WNDO*1000.)
      IF(QFND.GT.0.001) HDD(N+1)=HSYS-SS(1,2)+PML(N+1)
      PWR(N+1)=QFND*HDD(N+1)/FACP
      IF(QFND.GT.0.001) EFF(N+1)=(100.*QFND*HSYS)/(FACP*PSUM)
      UPWR(N+1)=PSUM*0.01*EFF(N+1)
      IF(PML(N+1).NE.0.) BFLAG=BFLAG+1.
      DO 34 I=1,N
      IF(PML(I).NE.0.) BFLAG=BFLAG+1.
      IF(IV(I).EQ.0.)  CFLAG=CFLAG+1.
      EFF(I)=0.00
      HDD(I)=0.00
      IF(PEACH(I).GT.0.01) EFF(I)=100.*QEACH(I)*E(I)/(FACP*PEACH(I))
      IF(QEACH(I).GT.0.001) HDD(I)=E(I)-HSYS+PML(I)+PML(N+1)
      PWR(I)=QEACH(I)*HDD(I)/FACP
      IF(QEACH(I).GT.0.001) UPWR(I)=PEACH(I)*.01*EFF(I)
      DO 34 J=1,3
      IF(LBND(I,J).NE.0.OR.UBND(I,J).NE.0.) AFLAG=AFLAG+1.
   34 CONTINUE
C ..... SOLUTION PRINT ..................................................
      IF(QFND.EQ.0.) GO TO 28
      GO TO 40
   28 WRITE(6,29)
      IF(Q.GT.QPT.AND.QPT.GT.0.) WRITE(6,30)
      IF(Q.LT.QPT.AND.QPT.GT.0.) GO TO 32
      GO TO 33
   32 IF(AFLAG.GT.0.)  WRITE(6,35)
      IF(HSYS.LT.HSYP) WRITE(6,31) QSPILL
      IF(BFLAG.GT.0.)  WRITE(6,36)
   33 IF(HSYS.LT.HSYP) WRITE(6,37)
      IF(HSYS.GE.HSYP) WRITE(6,38)
   40 IF(0.05.LT.QFND.AND.CFLAG.NE.0.) WRITE(6,42)
      WRITE(6,15) QFND,HSYS,PSUM,QPT,HSYP,PPT
      IF(QFND-SAFT.GT.Q) WRITE(6,23) QFND,SPLT,Q
      WRITE(6,16)
      DO 22 I=1,N
   22 WRITE(6,13) I,QEACH(I),E(I),PEACH(I),QP(I),HP(I),PP(I)
C ..... REFERENCE INFO. PRINT ...........................................
```

```
      WRITE(6,45) IWNDO
      DO 43 I=1,N
   43 WRITE(6,1) I,IV(I),PML(I),HDD(I),PWR(I),UPWR(I),EFF(I)
      I=N+1
      WRITE(6,44)          PML(I),HDD(I),PWR(I),UPWR(I),EFF(I)
      WRITE(6,24)
      RETURN
      END
      END$
```

APPENDIX B-I

PROGRAM LISTING

```
FTN4
      PROGRAM WATER(3),LAST EDIT DATE821118.1401>
C**********************************************************************C
C                                                                      C
C         CROP WATER REQUIREMENTS AND IRRIGATION SCHEDULES             C
C                          FOR MIXED CROPS                             C
C           WITH TOTAL SYSTEM IRRIGATION DEMAND ESTIMATES              C
C                                                                      C
C                                                                      C
C                        UNIVERSITY OF IDAHO                           C
C                                AND                                   C
C               UNITED STATES DEPARTMENT OF AGRICULTURE                C
C                                                                      C
C                                       R.G. ALLEN     01/XX/82        C
C                                       R.D. WELLS     03/XX/82        C
C                                                                      C
C  THIS IS A MULTIPLE USE PROGRAM. IT MAY BE USED TO FIND THE          C
C  NORMAL CONSUMPTIVE USE OF NINE CROPS BASED ON HISTORICAL OR         C
C  CURRENT REFERENCE EVAPOTRANSPIRATION VALUES. THE REFERENCE          C
C  USED HERE IS ALFALFA. THE REFERENCE COEFFICIENTS ARE CALIBRATED     C
C  TO KIMBERLY IDAHO AND ARE BASED ON 14 YEARS OF DATA. OUTPUT "A"     C
C  AND "B" RELATE TO SINGLE CROP CONSUMPTIVE USE WITH EXTRA EVAP-      C
C  ORATION ESTIMATES. PART "C" IS A COMPILATION OF CROP REQUIRE-       C
C  MENTS FOR ALL CROPS CONSIDERED RESULTING IN A SYSTEM DEMAND         C
C  ESTIMATE.                                                           C
C  ..................................................................  C
C  "WATER" READS FROM LU5 AND WRITES TO LU6. ALL OPTIONS ARE SPECI-    C
C  FIED IN THE INPUT DATA FILE.                                        C
C**********************************************************************C
      DIMENSION ETHM(7,2),ET80(7,2),ET20(7,2),STDEV(7,2)
      DIMENSION MCUT(6),NDCUT(6),JCUT(6)
      DIMENSION EFF(10),SUM(12),FRACW(12)
      DIMENSION NAME(35),DM(7),ED(7,2),ED20(7,2),ED80(7,2)
      DIMENSION IRDAT(30),AMNT(30)
      REAL INPFT
      DATA DM/15.,16.,15.,16.,16.,15.,16./
      DATA IEND/2HEN/
      NMB=6
      DO 1 I=1,7
      DO 1 J=1,2
      ED(I,J)=0.0
      ED20(I,J)=0.0
    1 ED80(I,J)=0.0
```

```
      DO 2 K=1,12
    2 SUM(K)=0.
      TA=0.
      T2=0.
      T8=0.
      PALF=0.0
      PBE =0.0
      PCO =0.0
      PPA =0.0
      PPE =0.0
      PPO =0.0
      PSB =0.0
      PSG =0.0
      PWW =0.0
C
C     READ IO DATA IF IO = 1 INDIVIDUAL CROP DATA IS OUTPUT
C                  IF IO = 0 ONLY THE CROP DISTRIBUTION DATA IS OUTPUT
C
      READ(5,*)IO
      READ(5,*) ACRE,FACK
C
C   READ IN (MM/DAY) THE 15 DAY MEANS AND STD DEV. FOR THE 15 DAY
C   PERIODS FROM APRIL 1-15 TO OCT 15-30
C
      READ(5,5)((ETHM (I,J),J=1,2),I=1,7)
      READ(5,5)((STDEV(I,J),J=1,2),I=1,7)
    5 FORMAT(8F5.2/8F5.2)
C
C  CONVERT TO INCHES/PERIOD AND COMPUTE 80% AND 20% PROB LEVELS
C
      DO 100 I=1,7
      DO 100 J=1,2
      DAYS=15
      IF(J.EQ.2) DAYS=DM(I)
      ETHM(I,J)=ETHM(I,J)/25.4*DAYS
      STDEV(I,J)=STDEV(I,J)/25.4*DAYS
      ET80(I,J)=ETHM(I,J)+0.85*STDEV(I,J)
      ET20(I,J)=ETHM(I,J)-0.85*STDEV(I,J)
  100 CONTINUE
C
C     READ NUMBER OF EFFICIENCY LEVELS AND CORRESPONDING EFFICIENCIES (%)
C     FOR FINAL OUTPUT, ONLY.
C
      READ(5,7) NEFF,(EFF(I),I=1,NEFF)
    7 FORMAT(I3,10F5.1)
C     READ UPPER LIMIT ON SURFACE EVAPORATION PER IRRIGATION (INCHES)
C     (SOIL DEPENDENT), AND DAYS FOR SURFACE EVAPORATION TO DECREASE
C     TO PRE-IRRIGATION/PRECIPITATION LEVEL (3 DAYS FOR SAND, 5 FOR
C     SILT LOAM, AND 7 FOR CLAY),  AND % OF SOIL SURFACE COVERED
C     BY IRRIGATION  (80-100 FOR SPRINK), (50-100  FOR SURF)
      READ(5,*) TSEVAP,TD,FW
C  LOOP THROUGH CROPS
C
      DO 1000 K=1,20
      IFLAG=0
```

```
      NIRR=0
      IZD=0
      WU=0.0
      EVAP=0.0
      READ(5,10) NAME
 10   FORMAT(35A2)
      IF(NAME(1).EQ.IEND) GO TO 1200
C     READ CROP INFORMATION AND PERCENTAGE (DP)
      IF(IO.EQ.1)WRITE(6,15) NAME
 15   FORMAT(1H1,7X,' HALF-MONTHLY CONSUMPTIVE USE ESTIMATES FOR',
     *' KIMBERLY IDAHO..14 YEARS OF RECORD (EJLW)',/,9X,35A2)
      READ(5,77)ICRP,MPL,NDPL,MEC,NDEC,MHV,NDHV,MRMIN,NRMIN,MRMAX,NRMAX,
     $         RTMIN,RTMAX,INPFT,PAVAL,DP
 77   FORMAT(11I3,5F5.0)
      ALLOW=INPFT*PAVAL/100.
      IF(IO.EQ.1)WRITE(6,25)ICRP,MPL,NDPL,MEC,NDEC,MHV,NDHV,
     $          MRMIN,NRMIN,MRMAX,NRMAX,RTMIN,RTMAX,INPFT,PAVAL,ALLOW
 25   FORMAT(/,5X,'CROP NUMBER ',I4/
     & 5X,'DATE OF PLANTING    ',I3,'/',I3/
     & 5X,'DATE OF EFF.COV.    ',I3,'/',I3/
     & 5X,'DATE OF HARVEST     ',I3,'/',I3/
     & 5X,'DATE OF MIN ROOT    ',I3,'/',I3/
     & 5X,'DATE OF MAX ROOT    ',I3,'/',I3,31X,'P A R T   A'/
     & 5X,'MIN. ROOT DEPTH,FT ',F5.2/
     & 5X,'MAX. ROOT DEPTH,FT ',F5.2/
     & 5X,'AVAIL.MOIST.,IN/FT ',F5.2/
     & 5X,'ALLOW. DEPLETION,% ',F5.2/
     & 5X,'ALLOW. DEPL.,IN/FT ',F5.2//
     *20X,'     C O N S U M P T I V E   U S E   A N D   E V A P O R A T
     *I O N   E S T I M A T E S   (INCHES)'/)
 650 FORMAT(5X'ALFALFA CUT DATES  ',I3,'/',I3/
     % 24X,I3,'/',I3 / 24X,I3,'/',I3/24X,I3,'/',I3//)
      JEM=JPL
      NCUT=0
      IF(ICRP.EQ.1) READ(5,77)NCUT
      IF(NCUT.GT.0)READ(5,77)(MCUT(L),NDCUT(L),L=1,NCUT)
      IF(ICRP.EQ.1.AND.IO.EQ.1) WRITE(6,650) (MCUT(L),NDCUT(L),L=1,
     % NCUT)
      IF(IO.EQ.1)WRITE(6,620)
      IF(ICRP.EQ.1)PALF=DP*100.+PALF
      IF(ICRP.EQ.2)PBE =DP*100.+PBE
      IF(ICRP.EQ.3)PCO =DP*100.+PCO
      IF(ICRP.EQ.4)PPA =DP*100.+PPA
      IF(ICRP.EQ.5)PPE =DP*100.+PPE
      IF(ICRP.EQ.6)PPO =DP*100.+PPO
      IF(ICRP.EQ.7)PSB =DP*100.+PSB
      IF(ICRP.EQ.8)PSG =DP*100.+PSG
      IF(ICRP.EQ.9)PWW =DP*100.+PWW
      IF(ICRP.NE.1)GOTO200
      DO 30 L=1,NCUT
 30   CALL DAY (MCUT(L),NDCUT(L),JCUT(L))
 200  CALL DAY(MPL,NDPL,JPL)
      CALL DAY(MEC,NDEC,JEC)
      CALL DAY(MHV,NDHV,JHV)
      CALL DAY(MRMIN,NRMIN,JRMIN)
```

```
      CALL DAY(MRMAX,NRMAX,JRMAX)
      JROOT = JRMAX-JRMIN
      ROOT  = JROOT
C
C   LOOP THROUGH PERIODS
C
      ETT=0.
      ETT20=0.
      ETT80=0.
      ETS=0.
      DO 210 IRR=1,30
      IRDAT(IRR)=0
      AMNT(IRR) =0.
      TAMNT=0.
  210 CONTINUE
C
      DO 800 I=1,7
      DO 780 J=1,2
      DAYS=15
      IF(J.EQ.2)DAYS=DM(I)
C
C   FIND AVERAGE COEFFICIENT OVER PERIOD AND AVAILABLE MOISTURE.
C
      CKT=0.
      DEPTH=0.
      NDAYS=DAYS
      DO 600 N=1,NDAYS
      NDAM=(J-1)*15+N
      NMON=I+3
      CALL DAY(NMON,NDAM,JD)
      CALL CROPB(CK,JPL,JEM,JEC,JHV,ICRP,JD,NCUT,JCUT,NMB)
C     CALL CROPM(CKM,JPL,JEM,JEC,JHV,ICRP,JD,NCUT,JCUT,NMB)
      IF(JD.LT.JPL.OR.JD.GT.JHV) CK=0.
      CALL DAY(NMON,NDAM,JD)
      CKT=CKT+CK
      RDAYS=JD-JRMIN
      RDEPTH=RTMIN+RDAYS/ROOT*(RTMAX-RTMIN)
      RDEPTH=AMAX1(RTMIN,RDEPTH)
      RDEPTH=AMIN1(RTMAX,RDEPTH)
      DEPTH=DEPTH+RDEPTH
  600 CONTINUE
      CK=CKT/DAYS
      ETA=CK*ETHM(I,J)
      ETA80=CK*ET80(I,J)
      ETA20=CK*ET20(I,J)
      RDEPTH=DEPTH/DAYS
      ASMD=RDEPTH*ALLOW
C
C     ASSUME THE FOLLOWING SOIL MOISTURE CONDITIONS AT PLANTING
C     OR SPRING GREEN-UP:
C     BEANS,CORN,PEAS,SUGAR BEETS,SPRING GRAIN AT 75% FIELD CAPACITY;
C     POTATOES AT 90% FIELD CAPACITY;
C     ALFALFA,PASTURE,WINTER WHEAT AT 100% FIELD CAPACITY.
C     FIELD CAPACITY HERE IS DEFINED TO BE A WELL DRAINED SOIL.
C
```

```
      IF(JD.GE.JPL.AND.IFLAG.EQ.0) GO TO 5001
      GO TO 5002
 5001 IFLAG=IFLAG+1
      IF(ICRP.EQ.2) ASMD=ASMD*0.75
      IF(ICRP.EQ.3) ASMD=ASMD*0.75
      IF(ICRP.EQ.5) ASMD=ASMD*0.75
      IF(ICRP.EQ.6) ASMD=ASMD*0.90
      IF(ICRP.EQ.7) ASMD=ASMD*0.75
      IF(ICRP.EQ.8) ASMD=ASMD*0.75
 5002 CONTINUE
C
C     CALCULATE WET SURFACE EVAPORATION (JENSEN,WRIGHT,PRATT)
C          (DECREASING FUNCTION OF CK OVER 3 DAYS)
C         UPDATED BY WRIGHT, DEC 1981 (IRRIG. SCHED. CONF.) FOR
C         MULTIPLE DAYS AND UPPER LIMIT OF 1.
C OLD EWS=(1.44-1.60*CK)*ETHM(I,J)/DAYS
      EWS=0.
      DO 605 NTE=1,TD+1
      T=NTE-1
 605  EWS=EWS+(1.-CK)*(1.-SQRT(T/TD))*FW/100.*ETHM(I,J)/DAYS
      IF(EWS.LT.0.) EWS=0.0
      IF(EWS.GT.TSEVAP) EWS=TSEVAP
C
C     CALCULATE NUMBER OF IRRIGATIONS
C
      ETPD=ETA/DAYS
      NIR=0
      PEVAP=0.
      DO 610 JE=1,NDAYS
      NDAM=(J-1)*15+JE
      NMON=I+3
      CALL DAY(NMON,NDAM,JD)
      WU=WU+ETPD
      IF(WU.LT.ASMD) GO TO 610
      IF(JD.GT.(JHV-8)) GO TO 610
      IF(JD.LT.JPL) GO TO 610
      NIRR=NIRR+1
      IRDAT(NIRR)=JD
      AMNT(NIRR)=ASMD
      TAMNT=TAMNT+ASMD
      WU=WU-ASMD+EWS
      IF(NIRR.EQ.1) WU=0.
      PEVAP=PEVAP+EWS
      EVAP=EVAP+EWS
      NIR=NIR+1
  610 CONTINUE
      ED(I,J)=(ETA+EWS*NIR)*DP+ED(I,J)
      ED20(I,J)=(ETA20+EWS*NIR)*DP+ED20(I,J)
      ED80(I,J)=(ETA80+EWS*NIR)*DP+ED80(I,J)
      ACT=ETA+PEVAP
      ACT80=ETA80+PEVAP
      ACT20=ETA20+PEVAP
      DDDDD=RDEPTH
      IF(IO.EQ.1)WRITE(6,630) NMON,J,CK,ETHM(I,J),ETA,ETA80,ETA20,
     % EWS,NIR,PEVAP,DDDDD,ACT,ACT80,ACT20
```

```
 630 FORMAT(10X,I3,5X,I3,5X,F5.3,5X,4F6.2,3X,F6.2,I10,F8.2,F8.2,F15.2,
    &   2F7.2)
 620 FORMAT(9X,"MONTH",2X,"PERIOD",2X,"AVE CROP",6X"EVAPOTRANS FOR"
    % " PERIOD",3X,"EXTRA EVAP"3X,"NO. OF",2X"TOTAL  ROOT",6X,
    %"TOTALS, PERIOD AND MONTH"/15X,"(15 DAY)   COEF   ",6X,"REF",1X,
    % "ACTUAL",2X,"80%",3X,"20%",3X," PER IRR",6X,"IRR",3X,"EVAP",
    % "   DEPTH",5X,"REF",2X,"ACTUAL"
    % 3X,"80%",
    % 4X,"20%"/ )
C
    NIR=0
     IF(J.EQ.1) GO TO 700
     ETL=ETL+ACT
     ETL20=ETL20+ACT20
     ETL80=ETL80+ACT80
     ETTT=ETHM(I,J)+ETHM(I,1)
     IF(IO.EQ.1)WRITE(6,640)      ETTT,ETL,ETL80,ETL20
 640 FORMAT(  T97,4F7.2)
C
     ETL=0.
     ETL80=0.
     ETL20=0.
     GO TO 750
 700 ETL=ETA
     ETL80=ETA80
     ETL20=ETA20
 750 ETT=ETT+ETA
     ETT80=ETT80+ETA80
     ETT20=ETT20+ETA20
     ETS=ETS+ETHM(I,J)
 780 CONTINUE
C
 800 CONTINUE
    TA=TA+(ETT+EVAP)*DP
    T2=T2+(ETT20+EVAP)*DP
    T8=T8+(ETT80+EVAP)*DP
     IF(IO.EQ.1)WRITE(6,850) NAME,ETS,ETT,ETT80,ETT20,NIRR,EVAP
 850 FORMAT(38X,'*****************************************************'/
    *     38X,'SEASONAL TOTAL FOR SINGLE CROP'/
    *     38X,35A2,/
    *     38X,' N O T E:  ET FOR DRY SOIL SURFACE THROUGHOUT SEASON'/
    *     38X,'           INCLUDES SOIL EVAPORATION PRIOR TO '/
    *     38X,'           PLANTING AND AFTER HARVEST. EXTRA EVAP IS'/
    *     38X,'           DUE TO IRRIGATED WET SOIL SURFACE.'/
    &       38X,'TOTAL REFERENCE ET',F7.2,' INCHES'/
    &       38X,'ACTUAL CROP ET    ',F7.2/
    &       38X,'80 %   CROP ET    ',F7.2/
    &       38X,'20 %   CROP ET    ',F7.2/
    &       38X,'NO. OF IRRIGATIONS',I4,/
    &       38X,'TOTAL EXTRA EVAP. ',F7.2/
    &   38X,'*****************************************************')
C
C
    IF(IO.EQ.1)WRITE(6,988)NAME
    ILAST=IRDAT(1)
```

```
      DO 990 IRR=1,NIRR
      DO 940 MDT=1,12
  940 IF(MDT.EQ.NMON) SUM(MDT)=SUM(MDT)+AMNT(IRR)*DP*ACRE/12.0
      TSUM=TSUM+AMNT(IRR)*DP*ACRE/12.0
      CALL DATE(IRDAT(IRR),NMON,NDAY)
      NDAYS=IRDAT(IRR)-ILAST
      ILAST=IRDAT(IRR)
      IF(IO.EQ.1)WRITE(6,989) NMON,NDAY,NDAYS,AMNT(IRR)
  988 FORMAT(1H1,
     *60X,'P A R T   B'//
     *40X,'I R R I G A T I O N   S C H E D U L E   F O R C A S T'//
     *38X,'IRRIGATION DATES FOR MEAN CONSUMPTIVE USE REQUIREMENTS'/
     *38X,35A2/
     *38X,'*******************************************************'/
     *38X,' IRR. DATE     DAYS SINCE LAST IRR.      AMOUNT (IN.) '/
     *38X,'*******************************************************'/
     *)
  989 FORMAT(
     *38X,I4,' / ',I2,12X,I4,' DAYS',10X,F10.2)
C
  990 CONTINUE
      IF(IO.EQ.1)WRITE(6,991) NIRR,TAMNT,TD
  991 FORMAT(
     *38X,'*******************************************************'/
     *38X,'TOTAL NO. IRRIGATIONS = ',I6,3X,'TOTAL REQ. = ',F5.2////
     *38X,'THIS DATA INCLUDES WET SOIL EVAPORATION FOR '/
     *38X,I1,' DAYS FOLLOWING IRRIGATION.'/
     *38X,'THE SEASONAL IRRIGATION REQUIREMENT IS REDUCED BY '/,
     *38X,'ALLOWABLE DEPLETION NEAR THE SEASON END.'/)
 1000 CONTINUE
C
C     CYCLE THROUGH EFFICIENCY LEVELS SPECIFIED FOR OUTPUT.
C
 1200 DO 1250 NE = 1,NEFF
      IF(EFF(NE).LT.1.) GO TO 1250
      WRITE(6,1315)PALF,PBE,PCO,PPA,PPE,ACRE,PPO,PSB,PSG,PWW,EFF(NE)
      EF=EFF(NE)*0.01
      DO 1210 I=1,7
      NMON=I+3
      DO 1210 J=1,2
      EDI=ED(I,J)/EF
      ED20I=ED20(I,J)/EF
      ED80I=ED80(I,J)/EF
      DMDI=EDI/EF*ACRE/12.0
 1210 WRITE(6,1313) (NMON,J,EDI,ED20I,ED80I,DMDI)
      EFTA=TA/EF
      EFT2=T2/EF
      EFT8=T8/EF
      EFDMD=EFTA*ACRE/12.0
      WRITE(6,1500) EFTA,EFT2,EFT8,EFDMD
 1500 FORMAT(/ 8X 'SEASONAL TOTALS'4F10.2)
 1315 FORMAT(1H1,
     & 60X,'P A R T   C'//
     & 20X,'W A T E R   R E Q U I R E M E N T   S U M M A R Y   F O R
     &C R O P   D I S T R I B U T I O N '//
```

```
     &             6X,'       CROP DISTRIBUTION                    '//
     % 10X,'ALFALFA       'F6.2,' %'/
     % 10X,'BEANS         'F6.2,' %'/
     % 10X,'CORN          'F6.2,' %'/
     % 10X,'PASTURE       'F6.2,' %'/
     % 10X,'PEAS          'F6.2,' %',' TOTAL PROJECT ACRES  =  ',F7.0/
     % 10X,'POTATOES      'F6.2,' %'/
     % 10X,'SUGAR BEETS   'F6.2,' %'/
     % 10X,'SPRING GRAIN  'F6.2,' %'/
     % 10X,'WINTER WHEAT  'F6.2,' %'/
     %           / 5X,'THE HALF-MONTHLY WATER REQUIREMENTS FOR THIS'
     %      ,1X,'CROP DISTRIBUTION'
     %           ,/5X'FOR ***',F4.0,'% *** APPLICATION EFFICIENCY',
     %' ARE:',//
     % 10X,'MONTH',5X,'PERIOD',4X,'AVE',8X,'20%',7X,'80%',5X,'AC.FT.')
 1313 FORMAT( 8X,I5,5X,I5,4F10.2 )
      WRITE(6,1212)  FACK
 1212 FORMAT(/,1X,' MONTHLY SUMMARY OF ESTIMATED IRRIGATION DEMAND',//,
     *2X,'MONTH',5X,'AVE.AC.FT.',
     *29X,'EACH I EQUALS ',F5.2,' ACRE FEET DELIVERED',28X,'% W TOTAL',/
     *2X,'-----',5X,'--- -- -- ',96X,'- - -----',//)
      DO 5000 MDT=1,12
      SSS=SUM(MDT)/EF
      SS=SSS
      S=SSS
      FRACW(MDT)=100.*SSS/(TSUM/EF)
      CALL DFILL(SS,FACK)
      WRITE(6,1213) MDT,S,FRACW(MDT)
 1213 FORMAT(1X,I5,F15.0,98X,F5.2)
 5000 CONTINUE
      ESUM=TSUM/EF
      WRITE(6,1215) ESUM
 1215 FORMAT(/1X,'SUMMARY',F13.0,97X,'100.  %')
 1250 CONTINUE
      WRITE(6,1255)
 1255 FORMAT(1H1,5X)
      STOP
      END
      SUBROUTINE CROPB(CK,JPL,JEM,JEC,JHV,ICRP,I2,NCUT,JCUT,NMB)
C     EMA JPL,JEM,JEC,JHV,ICRP,I2,NCUT,JCUT(NMB)
      DIMENSION G(20,9),JCUT(NMB)
C
      DATA G/
C.....ALFALFA  (1)
     %0.50,0.58,0.67,0.75,0.80,0.85,0.90,0.95,0.98,1.00,
     %0.50,0.25,0.25,0.40,0.55,0.79,0.80,0.90,0.98,1.00,
C.....BEANS    (2)
     %0.15,0.17,0.18,0.22,0.38,0.48,0.65,0.78,0.93,0.95,
     D0.95,0.94,0.65,0.36,0.18,0.15,0.10,0.10,0.10,0.10,
C.....CORN     (3)
     %0.15,0.15,0.16,0.17,0.18,0.25,0.40,0.62,0.80,0.93,
     D0.95,0.95,0.93,0.91,0.89,0.83,0.76,0.30,0.20,0.15,
C.....PASTURE  (4)
     %0.34,0.43,0.52,0.59,0.66,0.73,0.78,0.82,0.85,0.87,
     D0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,
```

```
C.....PEAS     (5)
     %0.20,0.17,0.16,0.18,0.20,0.28,0.48,0.67,0.86,0.95,
     D0.93,0.82,0.50,0.37,0.20,0.10,0.10,0.10,0.10,0.10,
C.....POTATOES (6)
     %0.15,0.15,0.15,0.21,0.35,0.45,0.60,0.72,0.78,0.80,
     D0.80,0.80,0.75,0.74,0.73,0.72,0.70,0.50,0.25,0.20,
C.....SUGAR BEETS (7)
     %0.20,0.17,0.15,0.15,0.16,0.20,0.30,0.50,0.80,1.00,
     D1.00,1.00,1.00,0.96,0.93,0.89,0.86,0.83,0.80,0.75,
C.....SPRING GRAIN(8)
     %0.15,0.16,0.20,0.28,0.55,0.75,0.90,0.98,1.00,1.02,
     D1.02,1.00,0.80,0.50,0.25,0.10,0.10,0.10,0.10,0.10,
C.....WINTER GRAIN(9)
     %0.65,0.70,0.75,0.80,0.85,0.90,0.95,0.98,1.00,1.02,
     D1.02,1.00,0.96,0.50,0.20,0.10,0.10,0.10,0.10,0.10/
C
C
C...CROP COEFFICIENTS
      J=ICRP
      I=I2
      REC=JEC-JPL
C
C...LINEARLY INTERPOLATE BETWEEN COEFFICIENTS
C
      IF(I.GE.JEC)GO TO 321
C...BEFORE EFFECTIVE COVER
  315 P1=(I-JPL)/REC*100
      IF(P1.LT.10.)P1=10.01
      IP1=INT(P1/10.)
      DIFF=AMOD(P1,10.)/10.
  318 CK=G(IP1,J)+(G(IP1+1,J)-G(IP1,J))*DIFF
      GOTO 327
C
C...AFTER EFFECTIVE COVER
  321 D1=I-JEC
      DIFF=AMOD(D1,10.)/10.
      ID1=INT(D1/10.)+10
      IF(ID1.LT.11)DIFF=0.
      IF(ID1.LT.11)ID1=11
      IF(ID1.GT.19) DIFF=1
      IF(ID1.GT.19) ID1=19
  320 CK=G(ID1,J)+(G(ID1+1,J)-G(ID1,J))*DIFF
      IF(I.GT.JHV) CK=G(20,5)
C
C...CHECK FOR ALFALFA
      IF(J.GT.1) GOTO 327
      IF(I.GT.JHV) GOTO 326
C...CUTTINGS
      D9=I
      DO 310 NQ1=1,NCUT
      D1=D9-JCUT(NQ1)
      IF(D1.LT.20..AND.D1.GT.0.) GOTO 324
  310 CONTINUE
      CK=1.00
      GOTO 327
```

```
C...USE SECOND SET OF COEFFICIENTS TO DESCRIBE ET DURING REGROWTH
C.....ASSUME 20 DAYS FOR REGROWTH PERIOD
  324 D1=D1/20.*100.
      DIFF=AMOD(D1,10.)/10.
      ID1=INT(D1/10.)+10
      IF(ID1.LT.11) DIFF=0.
      IF(ID1.LT.11)ID1=11
      CK=G(ID1,J)+(G(ID1+1,J)-G(ID1,J))*DIFF
      GOTO 327
C...DECREASE OF ALFALFA ET AFTER HARVEST (KILLING FROST)
  326 CK=0.80-(I-JHV)*0.01833
      IF(CK.LT.0.25) CK=0.25
  327 CONTINUE
  328 RETURN
      END
      SUBROUTINE DAY(M,ID,JD)
C..
C..THE SUBROUTINE DAY CHANGES MONTH AND DAY TO JULIAN DAY
C..
      DIMENSION MD(12)
      DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
      ISUM=0
      DO 5 J=1,12
      IF(M.EQ.J)GOTO10
      ISUM=ISUM+MD(J)
    5 CONTINUE
   10 JD=ID+ISUM
      RETURN
      END
      SUBROUTINE DATE(JD,M,ID)
C..
C..THE SUBROUTINE DATE CHANGES JULIAN DAY TO MONTH AND DAY
C..
      DIMENSION MD(12)
      DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
      ISUM=0
      DO 5 M=1,12
      ISUM=ISUM+MD(M)
      IF(JD.LE.ISUM)GOTO10
    5 CONTINUE
   10 ID=JD-ISUM+MD(M)
      RETURN
      END
      SUBROUTINE DFILL(SUM,FACK)
      REAL SUM
      DIMENSION JFMT(60)
      DATA JFMT/2H(",2H*",2H,T,2H26,2H,",2H  ,2H >,50*2HBB,
     *2H",,2H"2H")/
C
C     THIS ROUTINE GRAPHS THE TABULAR VALUES PASSED FROM MAIN
C
      Z=SUM/FACK
C     CREATE A BLANK ARRAY
    5 DO 12 I=8,57,1
   12 JFMT (I)=2H
```

```
C     FILL THE BLANK ARRAY
      NCP=INT(Z+0.51)
      IFP=8
      IF (NCP.LT.2) GO TO 20
      DO 16 L=2,NCP,2
      IF (IFP.GT.57) GO TO 30
   31 JFMT(IFP)=2HII
   36 IF(IFP.GE.57) GO TO 30
      IFP=IFP+1
   16 CONTINUE
C     FILL THE FRACTIONAL ARRAY SPACE
   20 IFRAC=MOD(NCP,2)
   33 IF (IFRAC.NE.0) JFMT(IFP)=2HI
   30 WRITE(6,JFMT)
      END
      END$
```

APPENDIX C-I

PROGRAM LISTING

```
FTN4
      PROGRAM HPOW
C**********************************************************************C
C                                                                      C
C              ENERGY USE AND COST DATA FORMATTING PROGRAM             C
C                                                                      C
C                          UNIVERSITY OF IDAHO                         C
C                                  AND                                 C
C               UNITED STATES DEPARTMENT OF AGRICULTURE                C
C                                                                      C
C                                          R.WELLS       02/XX/82      C
C                                                                      C
C THIS IS AS PGM TO READ COST AND POWER DATA FROM A RECORD CONTAINING  C
C MULTIPLE RECORDS FROM A SINGLE PROJECT, CALCULATE THE MEAN DAILY     C
C RECORDS FOR ALL BILLING PERIODS THAT DO NOT CORRESPOND AS TO DATE    C
C   SUM THEM TO OBTAIN A SINGLE DAILY FIGURE FOR COST AMD ENERGY FOR   C
C FOR THE PROJECT, AND THEN ..AGAIN, SUM TO FIND THE MONTYLY TOTALS    C
C WHICH CORRESPOND TO AVAILABLE MONTHLY WATER USE RECORDS..........    C
C A BAR CHART SUBROUTINE IS INCLUDED TO AID INTREPRETATION. ON THE     C
C DAILY NUMBERS, THE BARS FORM A HISTOGRAM WITH THE DAILY INCREMENTAL  C
C FIGURES APPEARING TO THE LEFT. IN THE MONTHLY ENERGY OUTPUT FIGURES, C
C THE MONTHLY TOTAL IS FOR KWH AND DOLLAR COST WITH THE PERCENT OF     C
C YEARLY TOTAL APPEARING ON THE SAME LINE AND TO THE RIGHT.            C
C OPTIONS ARE OFFERED TO SELECT OR LIMIT THE DAILY DATA SECTION.       C
C                                                                      C
C***********************************************************************
C                                                                      C
C     LU 56 IS SPOOLED TO SAVE RESULTS FROM MONTHLY TOTALS.            C
C     IT RECEIVES 14 LINES IF DATA INCLUDING A TITLE FOR EACH RUN.     C
C     LU 25 IS ASSIGNED TO THE INPUT DATA FILES.                       C
C     LU 06 RECEIVES THE OUTPUT HARD COPY AND BAR CHART DATA.          C
C     LU 01 IS CONVERSATIONAL AND PREVIEWS THE FORMATTED DATA.         C
C                                                                      C
C**********************************************************************C
      DIMENSION DD(200),ED(200),KD(200),CD(200)
      DIMENSION DJ(12),JD(200), KE(366),CE(366),LABEL(30)
      COMMON    JD,DD
      COMMON    KSUM,CSUM,FACK,FACC
      REAL KD,KE,KSUM,KKSUM
      DATA  DJ/31.,59.,90.,120.,151.,181.,212.,243.,273.,304.,
     *334.,365./
      WRITE(1,20)
   20 FORMAT(1X,' LABEL THE OUTPUT')
```

```
      READ(1,21)  LABEL
   21 FORMAT(30A2)
      WRITE(1,3)
    3 FORMAT(1X,'YOU ARE GIVEN FIVE OPTIONS.',
     */'  1  OUTPUT INCLUDES DAILY AVERAGES AND MONTHLY TOTALS ON LU 6',
     */'  2  OUTPUT INCLUDES ACCUMULATED DAILY AVERAGES AND MONTHLY TOTA
     *ALS ON LU 6',
     */'  3  OUTPUT INCLUDES ONLY MONTHLY AVERAGES ON LU 6',
     */'  4  OUTPUT INCLUDES MONTHLY AVERAGES AND WRITE TO LU 6 & 56',
     */'  5  MONTHLY AVERAGES ARE WRITTEN TO LU 56 ONLY',
     */' ENTER YOUR SELECTION...........')
      FLG=-9999999.99
      READ (1,*) FLAG
      WRITE (1,4)
    4 FORMAT(1X,'YOU ARE GIVEN FOUR ADITIONAL OPTIONS',
     */' "-4" IF ALL INPUT DATA IS DESIRED',
     */' "-3" IF INPUT FROM SEGMENT THREE IS DESIRED',
     */' "-2" IF INPUT FROM SEGEMENT TWO IS DESIRED',
     */' "-1" IF INPUT FROM SEGMENT ONE IS DESIRED')
      READ(1,*) IFLG
C
C     READ IN THE UNFORMATTED DATA
C
      IF(FLAG.LT.3) WRITE(6,5030)
 5030 FORMAT(1X," THIS IS ENERGY AND POWER COST DATA THAT HAS BEEN MODIF
     *IED TO SYNC WITH MONTHLY WATER RECORDS")
      CSUM=0.
      KSUM=0
      DO 1000 I=1,1000
  999 READ(25,*)  DD(I), ED(I), KD(I), CD(I)
 6008 IF(DD(I).LT.0.) GO TO 6007
      IF(DD(I).GT.13.0)  GO TO 1003
 6005 IF(DD(I).LT.0.) GO TO 999
      CALL DAY (DD(I),JD(I))
      CSUM=CSUM+CD(I)
      KSUM=KSUM+KD(I)
 1000 CONTINUE
 6007 TSR=AINT(DD(I)/100.)
      IF(IFLG.EQ.-4) GO TO 6005
      IF(IFLG.EQ.TSR) GO TO 6005
      IF(IFLG.GT.13)  GO TO 1003
 6006 READ(25,*) DD(I),ED(I),KD(I),CD(I)
      IF(DD(I).GT.13.0) GO TO 1003
      IF(DD(I).GT.0)    GO TO 6006
      GO TO 6008
 1003 IF(FLAG.LE.2) WRITE (6,998)  KSUM, CSUM
      SAVK=KSUM
      CSAV=CSUM
  998 FORMAT(1X,"KSUM=  ",I10,5X,"CSUM=  ",F10.2)
      JD(I+1)=9999
      IBILLS=I-1
C
C     CALCULATE AND ASSIGN MEAN DAILY ENERGY BY PUMP PER PERIOD
C
      DO 1007 I=1,366,1
```

```
      KE(I)=0.0
 1007 CE(I)=0.0
 1002 DO 1004 I=2,IBILLS,1
      IF (JD(I).GT.400.0) GO TO 1005
      IF (CD(I).EQ.0.) I=I+1
      DO 2000 KINTER=JD(I-1)+1,JD(I),1
      IF(KINTER.GT.366) GO TO 1004
      KE(KINTER)= KD(I)/(JD(I)-JD(I-1))+KE(KINTER)
      CE(KINTER)= CD(I)/(JD(I)-JD(I-1))+CE(KINTER)
 2000 CONTINUE
 1004 CONTINUE
 1005 DD(366)=366.
C
C     WRITE OUT THE MEAN DAILY PROJECT ENERGY AND POWER
C
      IF(FLAG.LE.2) WRITE(6,4999)
      IF(FLAG.LE.2) WRITE(6,5000)
 4999 FORMAT(1X,/," THIS IS DAILY ENERGY AND POWER COSTS PROJECT WIDE WI
     *TH GRAPHICAL REPRESENTATION OF THE DATA")
 5000 FORMAT(1X,´J-DAY        KWH         $CST´,33X,´KWH CODES TO "" AND
     * $CST CODES TO "===" ´//)
      IF(FLAG.EQ.1) FACK=600.
      IF(FLAG.EQ.2) FACK=35000.
      IF(FLAG.EQ.1) FACC=30.
      IF(FLAG.EQ.2) FACC=1750
      KSUM=0
      CSUM=0
      IF(FLAG.LE.2) WRITE(6,1001) FACK,FACC
 1001 FORMAT(/1X,40X,´ "" EQUALS ´,F5.0,´  KWH AND "=" EQUALS ´,
     *F5.0,´  ENERGY DOLLARS´//)
      DO 1009 I=1,366
      KSUM=KE(I)+KSUM
      CSUM=CE(I)+CSUM
      IF(I.GT.366) GO TO 1011
      IF(FLAG.EQ.1) CALL DFILL (KE(I),CE(I),FACK,FACC)
      IF(FLAG.EQ.2) CALL DFILL (KSUM,CSUM,FACK,FACC)
      IF(FLAG.LE.2) WRITE(6,1010) I,KE(I),CE(I)
 1010 FORMAT(1X,F5.0,2F10.0)
 1009 CONTINUE
C
C     CALCULATE THE MEAN MO. ENERGY AND COSTS AND WRITE IT
C
 1011 I=0
      KSUM=0
      CSUM=0.
      IF(FLAG.LE.4) WRITE(6,5010) LABEL
      IF(FLAG.GE.4) WRITE(56,21)  LABEL
 5010 FORMAT(1H1,//////////////,
     *1X," MONTHLY SUMMARY ENERGY AND POWER COSTS",10X,30A2)
      IF(FLAG.LE.4) WRITE(6,5005)
 5005 FORMAT(//2X," MONTH           KWH          $CST",
     *70X,"% K TOTAL    % $ TOTAL"/,2X,"------",10X,"---",
     *10X,"---",70X,"- - -----",4X,"- - -----")
      KKSUM=0
      CCSUM=0.
```

```
      FACK=10000.
      FACC=500.
      IF(FLAG.LE.4) WRITE(6,1006) FACK,FACC
 1006 FORMAT(/1X,40X,´ "" EQUALS ´,F5.0,´  KWH AND "=" EQUALS ´,
     *F5.0,´  ENERGY DOLLARS´//)
      DO 1105  M=1, 12
 1110 I=I+1
      KSUM=KSUM+KE(I)
      CSUM=CSUM+CE(I)
      IF (I.LE.DJ(M))   GO TO 1110
      SUMK=KSUM
      FRACK=100.*SUMK/SAVK
      CFRAC=100.*CSUM/CSAV
C
C     WRITE OUT THE MEAN MONTHLY PROJECT ENERGY AND POWER
C
      IF(FLAG.LE.4) WRITE(6,1115) M,KSUM,CSUM,FRACK,CFRAC
      IF(FLAG.GE.4) WRITE(56,1116) M,KSUM,CSUM,FRACK,CFRAC
 1115 FORMAT(/,1X,I5,I15,F15.2,70X,F5.2,10X,F5.2)
 1116 FORMAT(1X,I5,2F15.2,2F10.2)
      IF(FLAG.LE.4) CALL DFILL(KSUM,CSUM,FACK,FACC)
      KKSUM=KSUM+KKSUM
      KSUM=0
      CCSUM=CSUM+CCSUM
      CSUM=0.
 1105 CONTINUE
      IF(FLAG.LE.4) WRITE(6,6000) KKSUM, CCSUM
      IF(FLAG.GE.4) WRITE(56,6001) KKSUM, CCSUM
      IF(FLAG.GE.4) WRITE(56,6002) FLG
 6000 FORMAT(1X,//" KSUM=  ",I10,"   CSUM=  ",F10.0,69X,´100.00 %´,
     *7X,´100.00 %´)
 6001 FORMAT(1X,2F15.2)
 6002 FORMAT(1X,F15.2)
      END
      SUBROUTINE DAY (DD,JD)
      DIMENSION MD(12)
      DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
      ISUM=0
      A=(DD-AINT(DD))*100.
      ID= IFIX (A)
      B=AINT(DD)
      M= IFIX(B)
      DO 5 J=1, 12
      IF(M.EQ.J) GO TO 10
      ISUM=ISUM+MD(J)
    5 CONTINUE
   10 JD=ID+ISUM
      RETURN
      END
      SUBROUTINE DFILL(KSUM,CSUM,FACK,FACC)
      REAL KSUM
      DIMENSION JFMT(60)
      DATA JFMT/2H(",2H*",2H,T,2H26,2H,",2H  ,2H >,50*2HBB,
     *2H",,2H"2H")/
      J=-1
```

```
C
C     THIS ROUTINE GRAPHS THE TABULAR VALUES PASSED FROM MAIN
C
      Z=KSUM/FACK
C     CREATE A BLANK ARRAY
    5 DO 10 I=8,57,1
   10 JFMT (I)=2H
C     FILL THE BLANK ARRAY
      NCP=INT(Z+0.51)
      IFP=8
      IF (NCP.LT.2) GO TO 20
      DO 15 L=2,NCP,2
      IF (IFP.GT.57) GO TO 30
      IF (J) 31,32,32
   31 JFMT(IFP)=2H
      GO TO 36
   32 JFMT(IFP)=2H==
   36 IF(IFP.GE.57) GO TO 30
      IFP=IFP+1
   15 CONTINUE
C     FILL THE FRACTIONAL ARRAY SPACE
   20 IFRAC=MOD(NCP,2)
      IF (J) 33,34,34
   33 IF (IFRAC.NE.0) JFMT(IFP)=2H
      GO TO 30
   34 IF (IFRAC.NE.0) JFMT(IFP)=2H=
   30 WRITE(6,JFMT)
      IF (J) 35,40,40
   35 Z= CSUM/FACC
      J=0
      GO TO 5
   40 RETURN
      END
      END$
```

APPENDIX C-II

PROGRAM LISTING

```
FTN4
      PROGRAM HWTR
C**********************************************************************C
C                                                                      C
C                  WATER USE DATA FORMATTING PROGRAM                   C
C                                                                      C
C                        UNIVERSITY OF IDAHO                           C
C                               AND                                    C
C               UNITED STATES DEPARTMENT OF AGRICULTURE                C
C                                                                      C
C                                      R.WELLS      02/XX/82           C
C                                                                      C
C  THIS IS A DATA FORMATTER USED TO PREVIEW AND PRESENT MONTHLY        C
C  PROJECT WATER USE DATA FROM A FILE LISTING WATER USE BY USER        C
C  AND MONTH. IT READS FROM LU 1 AND 25, AND DEPENDING ON THE          C
C  OPTIONS SELECTED, WRITES TO LU 1, OR LU 1 AND 56, OR TO LU 1        C
C  AND 56 AND 6. LU 56 IS USED TO CREATE A FILE RECORD OF THE          C
C  NUMERICAL RESULTS, WHILE LU 6 DOES THE SAME AND ALSO IS ENHANCED    C
C  WITH A BAR GRAPH OF MONTHLY WATER USE DATA. OPTIONS AND LABELS      C
C  ARE SPECIFIED FROM LU 1.                                            C
C                                                                      C
C**********************************************************************C
      DIMENSION REACW(13),FRACW(13),SUM(13),IU(150),W(150,7),IACR(150),
     *LBL(30),FH(150),FA(150),FW(150)
   49 FORMAT(1X,'SELECT FROM THE FOLLOWING,THEN ENTER A LABEL FOR THE SU
     *MMARY DATA'/,'"1" FOR CRT PREVIEW'/,'"2" FOR FILE STORAGE'/,'"3"
     *FOR FILE STORAGE AND PRINT',/,'"4" FOR STORAGE AND PRINT WITH SORT
     *')
   50 FORMAT(I1,30A2)
   48 FORMAT(1X,'MONTHLY SUMMARY PROJECT WATER DELIVERY RECORDS',/,1X,30
     *A2,/,1X,'IRRIGATED ACRES =  ',I5)
   20 FORMAT(1X,30A2,/,1X,'IRRIGATED ACRES = ',I5)
   21 FORMAT(1H1,//////////////,
     *1X,' MONTHLY SUMMARY PROJECT WATER DELIVERY RECORDS',/,1X,30A2,
     *1X,'ACRES:  IRRIGATED = ',I5,', DRY = ',I5,', TOTAL = ',I5,
     *//,2X,'MONTH',9X,'AC.FT',96X,'% W TOTAL',
     */,2X,'-----',9X,'-- --',96X,'- - -----',
     *//,49X,'EACH D EQUALS ',F5.2,' ACRE FEET DELIVERED'//)
   22 FORMAT(1X,I5,2F15.2)
   23 FORMAT('*',I5,F15.0,96X,F5.2)
   25 FORMAT(//,2X,'TOTAL=',F14.0,94X,F5.2,' %')
   26 FORMAT(1X,'HAPPY?',/'IF SO, YOU MAY RESELECT OUT PUT OPTIONS AND
     *RE-LABEL, OR YOU MAY END'/,'END=0')
   60 FORMAT(1X,'ENTER THE HIGH AND LOW WATER USE PER ACRE VALUES FOR TH
```

```
     *E ABSTRACTING OPTION')
  100 FORMAT(1X,'THE FOLLOWING IS A LISTING OF SINGLE USER STATISTICS FO
     *R THE YEAR OF RECORD;',/,
     *1X,'THEY INCLUDE ONLY THOSE USERS THAT ARE CREDITED WITH AT LEAST
     *ONE UNIT OF DEMAND:')
  101 FORMAT(1X,/,11X,'USER',12X,'USER',6X,'ACRE FEET',6X,'ACRE FEET',8X
     *,'% TOTAL',7X,'% WATER',/,10X,'NUMBER',10X,'ACRES',6X,
     *'DELIVERED',7X,'PER ACRE',10X,'ACRES',6X,'DELIVERED')
  103 FORMAT(1X,/,' THE HIGH WATER USERS. IRRIGATORS APPLYING ',F3.2,
     *' FEET OR MORE:'/)
  104 FORMAT(,1X,'THE LOW WATER USERS. IRRIGATORS APPLYING ',F3.2,
     *' FEET OR LESS:'/)
  105 FORMAT(1X,/,' THE PROJECT AVERAGE:'/)
  106 FORMAT(1X,/,9X,'SUMMARY',2F15.0,3F15.3)
  108 FORMAT(1X,/,'-----------------------------------------------------
     *-------------------------------------',/)
  107 FORMAT(1X,/,' OF THE USERS LISTED THIS YEAR, THE ONES USING NO WAT
     *ER COMPILED THE FOLLOWING STATISTICS:')
  109 FORMAT(1X,I15,2F15.0,3F15.3)
      WRITE(1,49)
      READ(1,50) IFLG,LBL
      IF(IFLG.GE.4) WRITE(1,60)
      IF(IFLG.GE.4) READ(1,*)  UHW,ULW
      ISUM=0
      DO 9 J=1,13
      FRACW(J)=0.0
      SUM(J)=0.0
      ITSUM=0
    9 CONTINUE
C
C     READ THE RAW DATA
C
      DO 10 I=1,150
      READ(25,*) IU(I),IACR(I),FX,(W(I,J),J=1,7)
C     CONVERT CFS DAYS TO ACRE FEET
      DO 7 J=1,7
    7 W(I,J)=W(I,J)*1.98
      IF (IU(I).GT.300) GO TO 2019
      DO 8 J=1,7
    8 SUM(J+4)=SUM(J+4)+W(I,J)
      ITSUM=ITSUM+IACR(I)
      IF(W(I,7).GT.0) ISUM=ISUM+IACR(I)
      IF(IACR(I).NE.0) FH(I)=W(I,7)/IACR(I)
      IF(IACR(I).EQ.0) FH(I)=0.
   10 CONTINUE
 2019 SUM(13)=SUM(11)
      SSS=0.
      DO 5000 J=1,6
      SSS=SSS+SUM(J+4)
 5000 CONTINUE
      SUM(11)=0.
      FACW=100.00
      IDSUM=ITSUM-ISUM
C
C     CALCULATE THE MONTHLY FRACTION OF SEASONAL WATER USE
```

```
C
      DO 11 J=1,13
   11 FRACW(J)=100.*SUM(J)/SSS
C
C     PREVIEW LABEL AND PRINT THE DATA
C
   55 WRITE(1,48) LBL,ISUM
      IF(IFLG.GE.2) WRITE(56,20) LBL,ISUM
      IF(IFLG.GE.3) WRITE(6,21)  LBL,ISUM,IDSUM,ITSUM,FACW
      DO 15 J=1,12
      WRITE(1,22) J,SUM(J),FRACW(J)
      IF(IFLG.GE.2) WRITE(56,22) J,SUM(J),FRACW(J)
      IF(IFLG.GE.3) WRITE(6,23)  J,SUM(J),FRACW(J)
   15 IF(IFLG.GE.3) CALL DFILL(SUM(J),FACW)
      J=13
      WRITE(1,22) J,SSS,FRACW(J)
      IF(IFLG.GE.2) WRITE(56,22) J,SSS,FRACW(J)
      IF(IFLG.GE.3) WRITE(6,25) SSS,FRACW(J)
      IF(IFLG.GE.4) GO TO 116
      GO TO 115
  116 WRITE(6,1000)
 1000 FORMAT('1','  ')
      WRITE(6,108)
      WRITE(6,100)
      WRITE(6,101)
      WRITE(6,108)
      WRITE(6,103)  UHW
      IASM=0
      WSM=0.
      DO 110 I=1,150
      IF(IU(I).GT.300) GO TO 111
      FA(I)=100.*IACR(I)/ITSUM
      FW(I)=100.*W(I,7)/SSS
      IF(FH(I).GE.UHW)WRITE(6,109)IU(I),IACR(I),W(I,7),FH(I),FA(I),FW(I)
      IF(FH(I).LT.UHW) GO TO 110
      IASM=IASM+IACR(I)
      WSM=WSM+W(I,7)
  110 CONTINUE
  111 FRACA=100.*IASM/ITSUM
      FRACD=100*WSM/SSS
      FRACU=WSM/IASM
      WRITE(6,106) IASM, WSM,FRACU,FRACA,FRACD
      WRITE(6,108)
      WRITE(6,104)  ULW
      IASM=0
      WSM=0.
      DO 121 I=1,150
      IF(IU(I).GT.300) GO TO 113
      IF(IACR(I).GT.0) GO TO 120
      GO TO 121
  120 IF(FH(I).LE.ULW.AND.W(I,7).GT.0.) WRITE(6,109)IU(I),
     *IACR(I),W(I,7),FH(I),FA(I),FW(I)
      IF(FH(I).GT.ULW) GO TO 121
      IASM=IASM+IACR(I)
  112 WSM=WSM+W(I,7)
```

```
  121 CONTINUE
  113 FRACA=100.*IASM/ITSUM
      FRACD=100.*WSM/SSS
      FRACU=WSM/IASM
      IASM=IASM-IDSUM
      WRITE(6,106) IASM,WSM,FRACU,FRACA,FRACD
      WRITE(6,108)
      WRITE(6,105)
      FRACA=100.0
      FRACD=100.
      FRACU=SUM(13)/ISUM
      WRITE(6,106) ISUM,SSS,FRACU,FRACA,FRACD
      WRITE(6,108)
      WRITE(6,107)
      DO 123 I=1,150
      IF(IU(I).GT.300) GO TO 115
      IF(IACR(I).GT.0) GO TO 122
      GO TO 123
  122 CONTINUE
  114 IF(W(I,7).LT.1.)WRITE(6,109)IU(I),IACR(I),W(I,7),FH(I),FA(I),FW(I)
  123 CONTINUE
      FRACA=100.*IDSUM/ITSUM
      WSM=0.
      WRITE(6,106) IDSUM,WSM,WSM,FRACA,WSM
      WRITE(6,108)
  115 WRITE(1,26)
      READ(1,50) IFLG,LBL
      IF(IFLG.GT.0) GO TO 55
      END
      SUBROUTINE DFILL(SUM,FACK)
      REAL SUM
      DIMENSION JFMT(60)
      DATA JFMT/2H(",2H*",2H,T,2H26,2H,",2H  ,2H >,50*2HBB,
     *2H",,2H"2H")/
  100 FORMAT(1X,/,´ ´)
C
C     THIS ROUTINE GRAPHS THE TABULAR VALUES PASSED FROM MAIN
C
      Z=SUM/FACK
C     CREATE A BLANK ARRAY
    5 DO 12 I=8,57,1
   12 JFMT (I)=2H
C     FILL THE BLANK ARRAY
      NCP=INT(Z+0.51)
      IFP=8
      IF (NCP.LT.2) GO TO 20
      DO 16 L=2,NCP,2
      IF (IFP.GT.57) GO TO 30
   31 JFMT(IFP)=2HDD
   36 IF(IFP.GE.57) GO TO 30
      IFP=IFP+1
   16 CONTINUE
C     FILL THE FRACTIONAL ARRAY SPACE
   20 IFRAC=MOD(NCP,2)
   33 IF (IFRAC.NE.0) JFMT(IFP)=2HD
```

```
30 WRITE(6,JFMT)
   WRITE(6,100)
   END
   END$
```

MANAGEMENT MAINTENANCE AND OPERATION

OF

PUMP SUPPLIED IRRIGATION PROJECTS

FINAL REPORT: PART TWO

METHODS AND PROCEDURES

OF

INVESTIGATION, ANALYSIS, AND DATA PRESENTATION

by

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OVERVIEW

The FINAL REPORT for this project has been written in three sections with an appendix. Part I, is a set of user´s guides for computer programs useful as water management tools. Part II, this part, is a description of methods and procedures of measuring (pump) irrigation project performance, analyzing the data, and presenting the results. Part III is a set of five case studies where the tools of Part I and the procedures of Part II were applied to real situations. The Appendix to the final report contains a set of data from pump tests which were conducted during this study.

Part II of the final report emphasizes method first and application second. The first section of Part II discusses the physical characteristics of pump supplied irrigation projects and methods of measuring performance. It also discusses management characteristics in addition to methods aimed at understanding management attitudes. Results are presented. The first section should be of intrest to managers and project policy making groups.

The second section of Part II discusses the uses of project performance data and some methods of analysis and presentation. This latter section should be of interest to consultants or managers interested in critically examining a project and its operation.

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METHODS AND PROCEDURES

OF

INVESTIGATION, ANALYSIS, AND DATA PRESENTATION

I. INTRODUCTION

The objective of this study was to determine methods for using water and energy efficiently in irrigation districts in which water is supplied by pumps. The specific objectives were:

1. To acquire a data base of current practices and operational procedures of pump-supplied irrigation projects.

2. To determine the effects of management practices, maintenance schedules, and system modification on energy conservation in system operation and water delivery schedules.

3. To determine how irrigation district management, operation and system design can be modified to minimize the adverse impacts of escalating energy costs and/or limited availability of energy and water.

4. To develop a general planning methodology to specify system plans and procedures of operation and management that will provide practically attainable levels of energy conservation.

Ten pump supplied projects in Oregon, Washington, and Idaho participated in this study. The projects are:

1.	Owsley Canal Company	Terreton, Idaho
2.	Osgood Canal Company	Idaho Falls, Idaho
3.	Burley Irrigation District	Burley, Idaho
4.	Northside Pump Company	Hazelton, Idaho
5.	Bell Rapids Mutual Irrigation Company	Hagerman, Idaho
6.	King Hill Irrigation	King Hill, Idaho
7.	South Board of Control	Homedale, Idaho
8.	Roza Irrigation District	Sunnyside, Washington
9.	South Columbia Basin Irrigation District	Pasco, Washington
10.	The Dalles Irrigation District	The Dalles, Oregon

These projects were similar due to their reliance on pumps in at least a portion of their water supply or delivery systems. The cost of maintaining and operating the pumps made the assessments higher than corresponding gravity supplied systems. There was a great deal of variation among the ten projects in their management organization and authority, project size, layout, age, and operation procedures. The variation provided an excellent resource from which this study drew.

The first phase of this study involved travel to the projects, project familiarization, and testing at least a portion of the pumping units. Data from the pump test are in the appendix. Second, and in some cases, third visits were made to interview managers, project personnel, and to collect data. Methods and procedures of the investigation are the subject of the following sections.

II. PHYSICAL CHARACTERISTICS OF IRRIGATION SYSTEMS

The fundamental purpose of an irrigation system is to deliver adequate water economically, equitably, and reliably. The degree of success of a water delivery organization can be evaluated using a combination of data and judgement. An estimate of system potential performance, can be made by observing the physical characteristics of the system. Physical Measurements can supply the facts on system performance, suggested Systematic Observations may supply estimates where facts do not, and Interviews with system personnel can supply some seasoned judgement based on experience.

The first phase of this study documented how well each of the selected projects was in accomplishing its fundamental purpose. The objective of this effort was not just to gather data but to develop data collection and analysis methods which could be used in similar situations.

A program of pump testing and system evaluation was initiated. Together with energy and water data obtained from project records and supplemented with personal notes taken during tours of the project with the ditch rider, many of the strong and weak features of the individual systems became apparent. The following is a description of the methods that were used during this study and some general observations about existing conditions on ten pump supplied irrigation projects. Pertinent data collected from these projects will be presented in later sections.

II A. Physical Measurements

The management of each of the cooperating irrigation projects was quite interested in seeing the results of a systematic critique of their system. The reason for their cooperation may have been that water delivery costs were emphasized by the researcher at the initial contact. Because of this interest, routine project records were available to the investigator.

As a business, water projects and, in this case, projects that pump a large quantity of water, must operate within a balanced budget. A financial audit of business records shows where the money goes and provides answers to a multitude of questions about the total operation. Obtaining physical measurements was important because each of the projects were viewed by the investigator as a three part system of balances: a balance of finances, water, and energy.

Usually, project finances were well documented and up to date. Each project operated on a budget and there was a rigid tradition of making the budget balance. Yearly operation records were itemized and summarized. With this detail and order, the "financial health" of the business end of the operation was apparent, and could be independently determined through and examination of the annual financial report and ledgers.

Ordinarily, water records on diversion and delivery were adequately documented and usually up to date. In most cases, there was more water at the source than required on the project. The interest in quantifying the amount was tied to the requirement of moving water through the system and delivering an adequate water supply to individual turn-outs. None of the ten projects had developed a detailed water balance although three of the study projects measured and recorded surface water runoff accurately enough to estimate a total project water balance. In general, a record of the water use of the project was not supplemented with enough information to make a measured assessment of the efficiency that water was moved and used.

The quality of water records in the office, at best, was as good as the available field records. The water measurement record which received most office attention was the amount ordered by the water user in advance of the actual delivery. Whether the irrigator received the water he ordered was not obvious in the records. The operational efficiency of the project would have been more readily apparent if the use of water was documented as well as project finances.

The energy records on all of the projects were the most precisely measured and the least utilized. In the manned pumping plants, log books were kept that included hour or kilowatt hour meter readings on at least daily intervals. Only one of seven unmanned but daily visited pump plants recorded daily energy use on a routine basis. Most of the project personnel's interest in pumps was focused on the ability to deliver water during peak demand, and the pumping unit reliability; not energy efficiency.

The most common form of energy record was lumped so that single unit or pump duty group usage was masked in the total energy sum. The operators of one project (Case Study II in Part III) estimated the volume and timing of groundwater pumping to storage by direct water measurement. They chose not to use energy records to estimate volumes of pumped water. This is not to imply that the project did not have a functioning record system; however, more information was available at little cost which could provide a more complete picture of the operation. In general on all projects, the volume of water pumped was estimated using water records and not energy records.

Proper interpretation of energy use data needs to be encouraged. In the short run, this could result in better managment and operation and, in the long run, could result in a timely update of present water policy reflecting current operating costs, water supply and demand.

Measurements and Methods. All of the cooperating projects had adopted their own combination of water measurement methods. Most of them were standard techniques using weirs, submerged orifices, and mechanical meters. Rated canal sections were used for double checking but only one project used them as the primary recording point. The projects did not routinely use portable water measurement equipment (ie., current meters) and only one owned it's own portable gear. Evaluaton of existing fixed water measurement devices would have shown a need to adjust the estimate of flow on devices in five of ten of the projects. In general, a better understanding of the limitations of measurment devices could (potentially) improve accuracy. Case Study No. III in the FINAL REPORT: Part III describes a seminar conducted to educate users on the operation of various devices and methods of water measurement.

In a few cases where a water balance could productively be estimated, university investigators supplemented routine data with additional measurements. Control points were selected and project personnel were asked to make additional notes during routine operation. Two water stage recorders were installed on one project where fluctuating water level in canals was a problem. Stream current velocity meters were used where control points did not exist. A dye dilution technique was used where turbulence and access was a problem, especially in conduit flow. A seepage meter was used in one situation to estimate seepage losses where other methods had failed. Pitot type (Collins and Hall) meters were used in measuring some conduit flow. With perhaps the exception of the dye dilution technique, the water measurement methods used by the investigators were and are practical alternatives available to all operating water projects.

At the smaller unmanned pump stations, most operators relied on reduced water flow, vibration, heat, and the traditional "smoke test" to identify deteriorating motor and pump conditions and tended to ignore the power meter at the pumping site. One cooperating project, had a problem adjusting valves in a bank of pumps so that station discharge met the irrigation demand. On the same project, air entrapment in centrifugal pumps was a recurring problem. The pumps were calibrated by university personnel to three indicators: pump discharge water pressure, valve settings and ammeter readings. Each method was capable of estimating unit discharge. On another project, small trash collected in the eye of centrifugal pumps in a bank of pumps and identifying the fouled unit was a problem. (A letter dated 1926 indicated that the same difficulty existed on the same pumps during that season.) An inexpensive clamp-on ammeter could have been used to find the fouled unit in the pump bank. Pump tests conducted by the investigators required measuring the water pressure, discharge, and power demand of individual pumping units. The pressure was measured with calibrated gages. Electrical demand was measured using watt-hour meters, control pannel meters, and a clamp-on ammeter. Most pump discharge was measured using the dye dilution technique (Wells, et al. 1978).

Pump testing frequently involved measuring the discharge of a single pump which immediately flowed into a manifold. Most often pipe lengths were too short or flow was too turbulent to measure with pitot type equipment. The dye dilution technique could be used without drilling holes or making other modifications. Usually the test could be done with dye without stopping the tested pump.

A pump test form, shown in Figure 1, was used to record field measurements. It was developed for three phase electrically driven pumps. Use of this standard form was very helpful as a check list and field record.

During 1979, 87 project pumps, mostly centrifugal and a few mixed flow pumps were successfully field tested for energy efficiency. The oldest units were installed in 1909 and the newest in 1979. Pump discharges ranged from 32 l/s (500 gpm) to 5800 l/s (92,590 gpm), and the total pumping head varied from 3 m (9.8 ft) to 118 m (387 ft). Over half the pumps had water power outputs of less than 150 kw (200 hp) and 16 produced greater than 450 kw (600 hp). Pump test data for all projects are in the Appendix.

PUMP TEST FORM

Name:________________ Pump No.:____ Date:____ Pump Tester:________________
Location:____
____

Lift: ________FT | Pressure: _______PSI | Flow: _______CFS | Speed: _______RPM

Measurment Devices:
__________ __________ __________ __________

Power Usage:

Meter Constant (Kh):___________ Multiplier (Mult):__________
Meter Disc Rev.(MDR):_______REV Time (T):_______SEC

Voltage (E):__________________ Amperage (I):__________

Power Input: (3.6)(MDR)(Kh)(Mult)/(T) = ____________________________KW
Horsepower Input: KW/(0.746) = ____________________________EHP
Power Factor: (1000)(KW)/(1.73)(E)(I) = ____________________________

Efficiency Calculations:

Total Dynamic Head (TDH): TDH = Lift + 2.31(PSI) = ____________FT
Water Horsepower (WHP): WHP = (Q)(TDH)/(8.814) = ____________HP

Efficiency: (100)(WHP)/(EHP) = ____________ %

Pump:
Type:__________________________ Make:__________________________

Motor:
Type:__________________________ Make:__________________________

Ratings..Horsepower:________ Amperage:__________ Voltage:________

************************** SUMMARY **************************

Flow:_______CFS Power Input:_______EHP Power Output:______WHP
Pressure:______PSI Total Head:_________FT Efficiency:_________%

(Sketch System on Reverse)

FIGURE 1: PUMP TEST FORM FOR FIELD MEASURMENTS.

Statistically, pumps larger than 450 kw were found to be significantly (.05 level) more efficient than pumps of less than 450 kw with mean group efficiencies of 61.7 and 71.4 percent. No other other differences were found between old pumps (before 1960) and new pumps, or between the federally financed and non-federally financed group (Busch,et. al, 1980). The distribution of energy efficiencies for all tested units is shown in Figure 2.

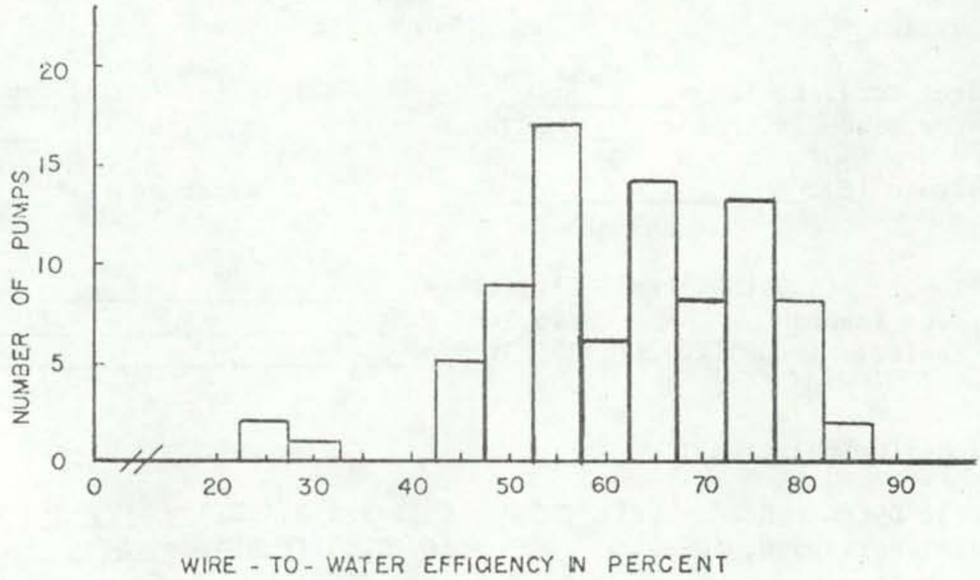

FIGURE 2: DISTRIBUTION OF PUMPING EFFICIENCIES

IIB. Systematic Observations

A set of observation forms were developed and used during the pump testing phase of this study. Use of these forms made the project visits more productive. The forms were used as records for a systematic critique. These Visual Inspection Forms (VIF's) could be used effectively by project personnel in a periodic review of the status of

I ________

VISUAL INSPECTION OF PUMPING PLANT ELECTRICAL SYSTEM

OWNER-OPERATOR ______________________ INSPECTED BY ____

SITE and LOCATION ______________________ DATE ________

Yes No*

A. Visible Wire Integrity (Includes main and remote components)

___ 1. Are conductors properly fixed to prevent flexing and shorting hazards

___ 2. Is the system clear of physical dangers to shielded and unshielded such as tree limbs, other unsecured conductors or pipes

___ 3. Is the system free of frayed or broken wires and worn insulation

___ 4. Does the system have a mother earth ground at the panel exclusive of the pumping plant

B. External Seals, Grommets, and Conductor Shields

Are the following items in good repair and functioning?

___ 5. Service head grommet

___ 6. Meter, service box, and motor conduit entrance connection

___ 7. Conduit and shielded cables

C. Service Panel

Service box integrity

___ 8. Is the box free of post installation ventilation holes

___ 9. Are there functioning door latches

___10. Does the door have adequate door seals or drip traps

Internal Service Box

___11. Is the service box free of moisture and contaminant intrusion including insects and rodents

___12. Are electrical connections secure and free of visible signs of arcing or resistance heating

___13. Are there lightning arrestors on the meter and motor sides of the buss and breaker

D. Motors and Peripheral Drives

___14. Are there wire screens over ventilation openings

___15. Are motor and drive units free of abnormal arcing or resistance heating

___16. Are drive units free of abnormal moisture and contaminant intrusion into housing

E. General

___17. Is the pumping plant shaded or housed

___18. Are pump units protected from sun, precipitation, sprinklers and flooding

*If checked, identify by number and comment on back.

FIGURE 3: INSPECTION FORM FOR PLANT ELECTRICAL SYSTEM.

II ________

VISUAL INSPECTION OF PUMPING PLANT MECHANICAL SYSTEM

OWNER-OPERATOR ______________________ INSPECTED BY ________

PUMP ID and LOCATION ______________________ DATE ________

INSTALLATION TYPE: SURFACE, GROUNDWATER; CENTRIFUGAL, TURBINE, MIXED FLOW

Yes No*

A. House, Foundation and Pumping Unit Support

___ 1. If there is a house, does it function as an effective "Plant shelter"

___ 2. Have potential combustibles been kept safely away from facility

___ 3. Are herbicides and pesticides stored away from the pumping facility

___ 4. Is there lightning protection separate from pumps and pipes

___ 5. Is there adequate fire protection on site

___ 6. Is the plant free of extraordinary mechanical or physical hazards

___ 7. If the facility is manned, is there reasonable protection from sound, heat, and vibration

___ 8. Does the facility have a stable foundation and deck

___ 9. Is each unit adequately supported and secured

___10. Is pumping bay or well accessible for routine inspection

___11. Can heavy equipment repair and maintenance aids (jacks and hoists) be easily applied

B. Pump and Motor Housing and Mounts

___12. Is there evidence of reasonable corrosion protection on exposed pump unit parts

___13. Are pump unit accessories and shields attached and functioning

___14. Are motor mounts and housing free of cracks and breaks

___15. Are hydraulic gaskets and seals functioning

C. Resistance, Friction, and Cooling

___16. Is the motor free from evidence of excess heat due to electrial load

___17. Are coils and rotating parts adequately ventilated

___18. Are all bearings adequately lubricated and cooled

D. Balance and Symmetry

___19. Are impellers running quietly, smoothly, and at a steady speed

___20. Is there an absence of ground vibration

___21. Is the motor running quietly and free of excess vibration

E. Plant Hydraulics

___22. Are there adequate trash racks around wells, bays, and sumps

___23. Is turbulence and water velocity minimized around pump intakes

___24. Is plant yield controlled by valve rather than spill

___25. Is the system secure from water hammer

___26. Does the system have an air relief for pumping unit drain down

___27. Is there a functioning pressure gage at the pump

___28. Is there provision for measuring pump lift

___29. Are there taps at the pump to measure pressure head

___30. Does the system have provision for measuring total pump discharge

___31. Is water free of abrasives

* Number and comment on back

FIGURE 4: INSPECTION FORM FOR PLANT MECHANICAL SYSTEM.

III ______

VISUAL INSPECTION OF IRRIGATION WATER CONVEYANCE SYSTEM

OWNER-OPERATOR ______

CONVEYANCE TYPE: OPEN, CLOSED ______

SECTION ______

OBSERVER ______ DATE ______

	*a DIV. TO PUMP	b PUMP TO HEAD	c HEAD TO TAIL	d MAIN THU LAT
A. System Design				
___ 1. The system is adequately sized (pipe dia. ch w/ freeboard)	___	___	___	___
___ 2. Hydraulic friction not caused by seasonal variation is at a minimum	___	___	___	___
___ 3. Where necessary, water measurement devices are functioning	___	___	___	___
___ 4. Trashing equipment is installed where it is required	___	___	___	___
___ 5. The system is designed to minimize erosion	___	___	___	___
___ 6. The system does not function ordinarily as a silt trap	___	___	___	___
___ 7. All open channels and critical areas are easily accessible	___	___	___	___
___ 8. Drainage problems caused directly by conveyance system are resolved	___	___	___	___
___ 9. Water level and head are easily stabilized	___	___	___	___
___ 10. Under normal conditions conveyance gradient is adequate	___	___	___	___
___ 11. Structures and control devices are water sealed and stable	___	___	___	___
B. Operational Considerations (unique local problems and treatments)				
___ 12. Hydraulic friction caused by aquatic plants is managed effectively	___	___	___	___
___ 13. Land weeds are managed early and effectively	___	___	___	___
___ 14. Unavoidable channel silt deposits are routinely managed	___	___	___	___
___ 15. Routine bank erosion and field sediment loading is discouraged	___	___	___	___
___ 16. Signs of burrowing pests are absent from vulnerable areas	___	___	___	___
___ 17. Trash rack refuse have not accumulated	___	___	___	___
___ 18. Water measurement devices are accurate throughout the season	___	___	___	___
___ 19. Excessive waste is not necessary to deliver lower system demand	___	___	___	___
___ 20. There are no "long term" leaks in the system	___	___	___	___
___ 21. Intermittent high demand deliveries do not affect adjacent demands	___	___	___	___
___ 22. Cultural practices do not routinely block access	___	___	___	___

* Describe the nature of negative responses on back

\+ = positive x = negative

8c. "Nature of negative response pertaining to main conveyance."

FIGURE 5: INSPECTION FORM FOR CONVEYANCE SYSTEM.

IV ______

VISUAL INSPECTION OF PRESSURIZED HYDRAULIC DELIVERY SYSTEM

OWNER-OPERATOR ______ INSPECTED BY ______

TYPE OF DISTRIBUTION SYSTEM ______ DATE ______

SYSTEM LOCATION ______

PUMP I.D. ______ MAINLINE TYPE: BURIED, SURFACE, STEEL, PLASTIC

	Yes	No*
A. Mainline		
___ 1. If buried, is the mainline covered adequately	___	___
___ 2. Is the mainline kept free of leaks (worn gaskets, holes, etc.)	___	___
___ 3. Is the system free of unnecessary hydraulic turbulence or friction	___	___
___ 4. If needed, does the mainline have an air release valve	___	___
___ 5. Can the mainline be readily drained and flushed	___	___
___ 6. If needed, are there screens or strainers in the system	___	___
B. Risers		
___ 7. Are risers numbered or individually identifiable	___	___
___ 8. Are risers located or flagged so they are not easily run into by machinery	___	___
___ 9. Is the ground around the risers free of weeds	___	___
___ 10. Are valve bushings and gaskets in good condition	___	___
___ 11. Is there a tight seal around valve opener	___	___
C. Laterals		
___ 12. Is system layout compatible with topography	___	___
___ 13. Are there enough laterals for adequate watering	___	___
___ 14. Is there an adequate water supply (pressure and flow)	___	___
___ 15. Are the laterals free of significant leaks (breaks, joints, drain valves, etc.	___	___
___ 16. Is the system free of excessive corrosion or wear	___	___
___ 17. Are chains, bearings, etc. working properly and lubricated adequately	___	___
D. Emitter or Sprinkler Heads		
___ 18. Is there a uniform application pattern from each sprinkler or emitter (consider local pressure variation)	___	___
___ 19. Are all sprinklers or emitters operating within the recommended pressure range	___	___
___ 20. If desirable, have flow controls been installed	___	___
___ 21. Are nozzles or emitters properly sized	___	___
___ 22. Do all sprinklers or emitters function properly	___	___
E. General		
___ 23. Is runoff minimal	___	___
___ 24. Does lateral orientation minimize wind drift	___	___
___ 25. Does the system perform adequately	___	___

*If checked, identify by number and comment on back

FIGURE 6: INSPECTION FORM FOR DELIVERY SYSTEM.

their own system. Use of the forms does require familiarity with pump and irrigation equipment and a critical attitude.

Since all of the cooperators in this study operated pumps, two VIFs were developed to critique pumping unit facilities. These were for the electrical and hydraulic portions of the pumping systems. The form for the electrical portion is shown in Figure 3. It follows the energy path from transformer to motor shaft. Similarly, Figure 4 continues the energy flow from the pump shaft to the main valve. Both forms group categories of inspected points so that summarizing the results is more convenient. The manager of one project was given pump critiques that specified 14 items of varying severity for him to consider. Total time for the survey was three hours covering 9 pumping locations and 14 units along a canal.

Figure 5 is a VIF for the total conveyance system. It is probably the least specific form because it is concerned with the largest portion of the system involving the most variations. This VIF form is concerned with the system between the diversion and delivery point or turn-out, excluding the pumping facilities. It could also be used to evaluate a gravity supplied system. The VIF in Figure 6 is concerned with a pressurized delivery system beyond the turn-out. It has been included because pressurized farm systems often have a high enough capacity that it can affect the ability of the delivery system to meet all of its demands. The repair, reliability, and efficiency of farm pumping systems are important to the delivery system operators.

The four forms were worded so that a negative response on any form generally indicated a situation that needed further attention. With a little ingenuity, location codes could be used to abstract the results of a detailed critique covering a wide area on one form.

II C. Interviews

The individual who lives with the operating characteristic of a irrigation system is most keenly aware of its assets and liabilities. The irrigator or consumer is aware that something good or bad occurred but the system operator-manager probably knows why it happened.

University personnel rode at least one route with the ditch-rider or manager on each of the ten cooperating projects. The host talked about his system and provided considerable information. The interviews and rides helped the interviewer form an appreciation for the boundaries and limitations of the system, and identify physical constraints against which the system operated.

Usually, on the routes, the rider had routine water deliveries on his mind. Note taking and later questioning was helpful. There was usually a discussion of the total system assets and shortcomings including overlapping areas of management and operations, and their effect on the physical system.

In selecting the projects for the study, the investigator first approached the project manager asking permission to study his project. Consequently, the manager was interviewed before any data were collected, or other employees approached. His impression of the state of the project was the first presented. Cost and efficiency of operation were usually discussed first, although it became apparent later that other matters were also important to him. A set of questionaires discussed in the following section helped to open up the discussion.

III. CHARACTERISTICS OF MANAGEMENT ORGANIZATIONS

III A. Organizational Structure

The organization that provides irrigation services has structure and has a "chain of command". To survive as a business and provide intended primary services, the organization must be cohesive, stable and goal oriented. In any case, there has to be a balance between responsive change and continuity. The policy making group (board of directors) and their first employee (the manager) are able to function based on their perception of their current position in relation to their goal.

The management structure usually consists of a board of directors who are elected water users and who in turn hire a manager. On larger projects the manager may hire an assistant manager and other managerial staff.

Ideally, the board should be composed of individuals whose first concern is the organization. Their philosophy on how the system should be operated is put in some form of policy statement and the rules that the full time manager uses to conduct organization business are based on the adopted board policy.

III B. Evaluating Management Attitudes

In order to assess policies and management procedures, a management audit questionaire (MQ) was developed around the same principles as other business management audit procedures (Barker et. al., 1979). The purpose of the questionaire was to determine what policies and procedures management had developed and how well they were carried out. The format was designed to gain insight into the strength and weaknesses of management as viewed by management (Busch et al, 1980).

The questionaire (MQ) shown in Figure 7 pertains to maintenance of mechanical equipment and in Figure 8 focuses on maintenance of fixed distribution system components. The two MQ s included suggested items of concern to most water projects and brought to mind additional items specific to individual irrigation projects. Operating procedures are reviewed by another MQ shown in Figure 9 which emphasizes communication in the management structure. Order and procedure on emergency-quick response, and routine operations are also reviewed. The questionaire in Figure 10 deals with personnel employment. These questions deal with working conditions, fairness, training and duties. The MQ in Figure 11 asks practical questions on project finances. Budgeting, The MQ in Figure 11 asks practical questions on project finances. Budgeting, investments, cost accounting, credit, and salaries are emphasized.

Figure 12 is a questionnaire dealing with general management duties and responsiblities. The manager must have a clear understanding of the board policy whether or not it is written. The implication of this form is that a clear, unmistakable policy should be written, clearly worded, and accessable to everyone in addition to the manager so that the reasons for management action are understood.

III C. Management Opinion

I. THE PHYSICAL SYSTEM

The components of an irrigation system have been divided into two categories. One part has to do with pumps and motors, vehicles, and maintenance equipment including machinery and shop equipment. The other part deals with the irrigation water delivery system itself.

This is a survey of your opinion, as much as an inventory of project maintenance practices. Your answers to these questions about maintenance and repair practices will be "yes, it is adequate (or not adequate)", "don't have an opinion", or "no, and should not (or would rather do more)". The first part is directed at project machinery. Respond by numbers 0 - 8ª.

A. Mechanical Equipment (Rotating, Electrical, Rolling)

____1. Do you have an organized maintenance program for project hardware?
____2. Do project employees perform some vehicle and equipment maintenance?
____3. Is pump and motor maintenance performed by project personnel?
____4. Do you have an adequate preventative maintenance program?
____5. Before the irrigation season, do you perform or contract for pump and motor maintenance?
____6. Have you developed a check-out and start-up procedure for major equipment?
____7. Are pumps and other major pieces of equipment prepared for winter?
____8. Do you measure the efficiency or capacity of project pumping units?
____9. Is pump capacity or pump curve information on file?
____10. Have you developed maintenance standards or designated an individual responsible for maintenance standards?
____11. For vehicles and major pieces of equipment, have you determined a schedule of replacement due to wear and obsolescence?
____12. Have you developed a pump and motor reconditioning schedule?
13. Which of the following receive routine attention by project employees whether they actually perform the maintenance or not?

Motors	Pumps	Vehicles
___a. lube	___e. stuffing, seals	___k. lube
___b. bushing, bearings	___f. impellers, bowls	___l. motors, engines
___c. brush, windings	___g. shaft, coupling, bearings	___m. tires
___d. heat, vibration	___h. panels	___n. alignment, brakes
	___i. service wiring	___o. gen. vehicle condition
	___j. electrical resistance (meg)	___p. machinery parts

FIGURE 7: MACHINERY MAINTENANCE AND OPERATION PROCEDURES.

THE PHYSICAL SYSTEM (continued)

The second part of this section has to do with the water delivery system itself.

B. Conveyance and Distribution System (Canals, Ditches, Pipelines)

____1. Does the system have the capacity to deliver design peak demands?
____2. Have water losses in the storage and distribution system been estimated?
____3. Is waste at the tail of the system at a minimum?
____4. Would energy cost of $15 per acre-foot of water delivered force major changes in maintenance practices or encourage rehabilitation projects?
____5. Have you studied the effects of pumping efficiency and system water loss on operating costs?
____6. Are project employees the only authorized operators of gates and turnouts?
____7. Are turnouts routinely locked?
____8. Is all water measured, and charged to the delivering turnout?
____9. Do you routinely inspect water measurement equipment?
____10. Is sediment in canals and pipes at a desirable level on this project?
____11. Are point sources of sediment identified and routinely eliminated?
____12. Is there a policy on waste water return flow?
____13. Is there a policy on bank erosion caused by return flow?
____14. Have trash removal devices been installed in the system?
____15. Does the project have sufficient equipment and manpower to deal with land and water weeds during a normal irrigation season?
____16. Can full time, year around employees handle system maintenance?
____17. Is there a positive effort at eliminating burrowing pests?
____18. Do you scrape or sandblast, and paint head gates and control structures?
____19. Does the system have the capacity to deliver water any projected expansion?
20. Does the project own or have assured access to the following maintenance equipment?

___a. drag line	___k. adequate shop
___b. back hoe, loader	___l. emergency equipment
___c. crawler tractor	___m. portable hoist
___d. grader, dozer	___n. portable welder
___e. pump-motor spares	___o. cathodic protection
___f. truck	___p. sand blaster
___g. machine trailer	___q. paint rig
___h. tractor	___r. cement mixer
___i. ditcher	___s. compressor - jack hammer
___j. mower	___t. spray rig

FIGURE 8: FACILITIES MAINTENANCE AND OPERATION PROCEDURES.

II. OPERATING PROCEDURES

The following section involves both facts and your opinion as manager about the operating procedures of your project. Respond by number 0 - 8*.

____1. Over the years, have the project directors worded precisely the policy they have established, and compiled the statements in a single document?
____2 Are you able to anticipate and act on project needs and troublesome situations soon enough to take advantage of pre-planning (for example, rising energy or construction costs)?
____3. Do you, as manager, give monthly status reports to the board including items on water use and physical project operation?
____4. Have the manager and executive board toured the project annually?
____5. Does the project own and use a camera?
____6. Have annual water user meetings and tour been sponsored by management?
____7. As manager, do you delegate accountability and responsibility?
____8. Do employees take the initiative on unscheduled small work details?
____9. From the management point of view, does "field initiative" lead to early resolution of "field problems" without delaying other important work related items?
____10. Are work lists routinely made and used?
____11. Does the manager maintain and operate from a daily prioritized work schedule?
____12. Have the manager (or assistant manager) and ditch riders made annual inspections of the distribution system?
____13. Are work lists compiled, and priorities set on maintenance items identified routinely by ditch riders and less frequent maintenance inspections?
____14. Are project employees allowed to drive project vehicles home from work routinely?
____15. Have there been sufficient unscheduled response calls to justify personal use of project vehicles?
____16. Do employees use project facilities (gas, lube, shop) for private purposes?
____17. Have you established a safety or loss prevention (CPR-First Aid, job safety, maintenance inspections) program?
____18. For emergencies and major accidents, have alert procedures (for example, telephone priority lists) been established?
____19. Have emergency plans been developed to handle major mishaps?
____20. Do you use consulting services other than the routine business audit?

FIGURE 9: ROUTINE OPERATION PROJECT PROCEDURES.

III. PERSONNEL

These questions deal with how operational employees fit into the project organization. Respond by number 0 - 8*.

____1. Have up-to-date descriptions of required duties been written for each position?
____2. Has the manager identified qualifications for project personnel?
____3. Do you have applications for hiring personnel?
____4. Is employee performance regularly reviewed and reflected in wage and salary adjustments?
____5. Are employees unionized?
____6. Do field employees participate in workshops and training programs?
____7. Are ditch riders aware of the limitations of project water measurement devices?
____8. Do ditch riders take and deliver water orders directly from the water users?
____9. Are weekends normal work days for ditch riders during the summer?
____10. Are water deliveries made on less than a 24 hour notice?
____11. Is the year around work force able to accomplish normal project maintenance, not including jobs requiring special skills?
____12. Do field employees drive their own vehicles?
____13. Are you satisfied with the rate of project personnel turnover?
____14. When grievances occur, are the procedures effective and orderly?
____15. Have all employees been hired on the basis of ability or skill (including the ability to work with fellow employees)?
____16. Is there a clear delegation of authority (for example, is an organizational chart available) within the project?
____17. Are there regular frequent group meetings between the watermaster or manager and the ditch riders?
____18. Are there two way radios in the ditch rider vehicles?

* 0 = Does not apply.

1 = YES, but needs improvement; would rather do/have more.
2 = YES, adequate; present level/amount is acceptable.
3 = YES, but should not; would rather do/have less.

4 = Do not know.

5 = NO, needs improvement; would rather do/have more.
6 = NO, but adequate; present level/amount is acceptable.
7 = NO, and should not; no need, not justified.

8 = Do not have an opinion.

FIGURE 10: PROCEDURES RELATING TO EMPLOYEES.

IV. FINANCES

This section asks some factual and subjective questions about project management of finances. Respond by numbers 0 - 8*.

____1. Does the project operate from an operating budget?
____2. Do wages account for the bulk of Operation and Maintenance funds?
____3. Have unbudgeted emergencies been accounted for in the budget?
____4. Is there a fund for equipment replacement?
____5. Are reserve or replacement funds invested?
____6. Do you carry liability insurance?
____7. Have you estimated the "own-rent" break even point on equipment?
____8. Are the costs of repairs frequently reviewed by the manager?
____9. As manager, are you satisfied with your present method of estimating future O and M costs?
____10. Is this project's O and M accessment compatible with the O and M of similar projects?
____11. If you have an excess water use charge, does it reflect the full cost of water delivery?
____12. Does the manager or especially qualified individual routinely examine the expenses and budget to see if it is realistic?
____13. Has an estimate been made concerning short and long term effects of rising energy costs?
____14. Have you calculated the total operating costs per hour or mile for project equipment?
____15. In 1979, did the project budget enough to cover O and M expenses without borrowing from a special fund?
____16. Have costs related to re-occurring situations been identified and accounted for in the budget?
____17. Are operational personnel salaries close (say ± 7%) to salaries in the area requiring similar qualifications and effort?

FIGURE 11: PRACTICES IN MANAGING PROJECT FINANCES.

V. POLICY

The following is a list of topics about which the Executive Management or Board may have adopted a policy or rule. The "understanding" between the Board and Management may have been established in the By-Laws, by Policy, by Statement, by Special Directive or contractually. The question in this section is not what the policy is, but whether the stand on the particular issue is clear and unmistakable as understood by management. Respond by numbers 0 - 8*.

A. Management Duties and Responsibilities

1. General Delegated Responsibilities and Authority

____a. planning responsibility
____b. organization review and authority
____c. personnel management
____d. operations responsibility
____e. fiscal responsibility
____f. state-of-project reports

2. Manager-Water Master Specific Duties, Responsibilities

____a. inspections
____b. maintenance program
____c. spending limitations
____d. record keeping standards
____e. water service standards
____f. billing procedure
____g. restricted equipment use
____h. minor contracts & agreements
____i. management contract

B. Specified Policies

1. Personnel Policy including vacation (V), sick-leave (SL), over time (OT), and comp. time (CT).

____a. normal working hours
____b. pay period, advances
____c. wages, salaries, benefits
____d. working OT and CT
____e. specified holidays
____f. V, S, OT, CT accrual
____g. V, S, OT, CT policy
____h. dismissal, layoff-justification
____i. grievance procedures
____j. nepotism, favoritism
____k. conflicting interest
____l. employee opinion of policy

2. Water User Policy

____a. water season
____b. peak period demand
____c. annual allotment
____d. excess charges
____e. downstream to upstream water transfers
____f. off project water use
____g. pump and high demand deliveries
____h. silt load, return water quality
____i. drainage water
____j. credit for power outages
____k. additional Turn Outs
____l. water charges to Turn Outs
____m. weed control responsibilities
____n. rights-of-way, use and maintenance
____o. Turn Out & meas. struct. O & M

FIGURE 12: AREAS OF UNDERSTOOD PROJECT POLICY.

The form of the questionnaires did not lend itself to producing a "hard" score to compare one manager or project to another. They proved to be an effective "ice breaker" and the self-audit form caused most managers to consider potential improvements in management and operations of their organizations. A comparison of the responses of board members and the manager might have produced a clear understanding between the two concerning the letter and the spirit of the existing policy, and perhaps identify gaps in that policy. A summary of the results from interviews using management questionaires is presented.

1 -- Physical system, A--Mechanical Equipment. (Figure 7.) Nearly all managers indicated that maintenance procedures were adequate including pump and motor maintenance. Two responses indicated a need to improve winter preparation procedures as well as check-out and start-up procedures for pumping plants. In contrast, only two of the cooperating project managers indicated that they had adequate knowledge of the measured efficiencies of pumping plants and information about pump capacities and operating characteristics. Even though the responses pointed out that most managers lacked information about actual pump performance, all except one did not feel a need to improve pump and motor reconditioning schedules. This contradiction gives an indication of why some of the pumps tested were operating at low efficiencies.

1 -- Physical System, B--Conveyance and Distribution System. (Figure 8.) At least half of the responses showed that the managers felt that their systems lacked the capacity to deliver peak design water demands and three indicated that there was a possibility of reducing operational waste at the end of the delivery system. Nearly all responses indicated

a need for improved water control within the system including the control of farm drainage water re-entering the delivery system that might cause sediment and bank erosion problems. Only three of the responding managers said that they had studied the effects of water loss in conjunction with pumping plant efficiency on project operating costs.

II -- Operating Procedures. (Figure 9.) The majority of managers felt that project operating policy was defined quite well by project directors, but several indicated that it could be compiled and worded more precisely. Nearly all said they did an adequate job of reporting to their boards of directors and in delegating authority and/or duties to other project employees. Over half of the managers used outside consulting services for various functions. There were differences in opinion about the value of project tours and water user meetings to keep the water users informed about current operations and the state of repair of the system.

III -- Personnel. (Figure 10.) There was little difference in the responses concerning personnel. Nearly all managers felt that their personnel policy and procedures were adequate; two indicated that job descriptions and grievance procedures could be better defined. There were also some differences of opinion regarding the weekend work duties of ditch riders and the amount of notice time required for water delivery. Employees of two of the projects studied were unionized and required more concise personnel policy.

IV -- Finances. (Figure 11.) All projects operated from an approved operating budget, and in the majority of projects, wages accounted for the bulk of operation and maintenance funds. This fact may partially explain why the effects of water losses and pumping plant efficiencies had not been studied more fully by management. Over half of the projects had an excess water use charge which they felt was adequate in each case. However, only half of the managers said they had calculated the total operating costs for project equipment and estimated the short and long term effects of rising energy costs. All 1979 project budgets were adequate, and nearly all felt that the wages for nonmanagement personnel were competitive.

V -- Policy. (Figure 12.) The majority of managers said that their project policy was adequate on all of the questions covered on the policy section. Two responses indicated a lack of personnel policy; however, only one manager felt it should be improved. Three managers did say that the policy governing their record keeping and water service standards should be improved (Busch et al., 1980).

The effective manager has a grasp of the total operation under his control. He also has the obligation to be involved with the routine operations. Managers capable of stepping back and constructively looking at the overall operation after detailed involvement are real assets. Time, experience, training, and talent are factors that shape the manager's judgement. The manager has options of using management tools, delegating responsibility, or hiring expertise to meet the requirements of a given situation. The techniques or tools used to deal with the overall operation are important.

IV. DATA COLLECTION ON PUMP SUPPLIED IRRIGATION PROJECTS

The projects selected for this study were functioning water projects so that documenting their boundaries and capacities were first steps in understanding project scope. The main emphasis of the study was operation efficiency and costs. Variable costs were associated with the volume of water delivered so that forming a model of the system configuration was convenient as a reference for the investigators.

IVA. Physical System Layout and Component Dimensioning

Most of the information for documenting system layout and dimensions was obtained during a preliminary interview. All projects had some literature on their origin and claimed access to maps; however, only six of ten possessed recent maps. If good maps were available, the location of water and power supply, pumping systems, boundaries, points of delivery, drains, wasteways, and intra-project recovery were apparent.

For most situations, a simple sketch in schematic form helped to supplement a map and note information that was of particular interest to the interviewer. With "skeletal" information available pertinent data was easier to recognize.

IVB. Physical System Operation Data Requirements

Early in the investigation it became obvious that a limit to the scope of study was necessary for each of the ten cooperating projects. For example, in the case of the King Hill System, only that portion of the system under the Glenns Ferry Pumping Plant could be studied in detail. The Glenns Ferry sub-system was selected because it showed the greatest potential for improvement. (That sub-system used large amounts of power and water, and was the source of many user complaints.)

On all projects, pumping efficiency of at least a portion of the project pumps was measured by university personnel because it provided the manager with both the peak capacity and efficiency of the units under his direct control.

Other types of collected data were costs, power consumption, irrigation water demand, and flow rate. Depending on the project, data were collected to document at least the project diversion and at most the individual water user demand. The appropriate detail of water records in one case was limited by the sensitivity of the water user to "outside interference". In this case water demand by general area was the appropriate detail. On another project (Case Study II) water demand by user and location was proper.

Additional information was collected as required. For example, on two projects, crop consumptive water requirements appeared to be important, and information on total acres of specific crops under the system, the irrigation type, planting and harvesting dates and weather data were gathered. On the same projects, irrigation schedules were of interest so data on soil type and depth were estimated.

IV C. Sources and Methods of Data Collection

Sources. Ideally, the best source of information was the irrigation project itself. The projects that kept precise, complete and up to date records had the fewest field problems. The second best sources of information were organizations and people, and the last resort was direct field measurement. Sources consulted during this study were:

1. USDA Agricultural Research Service
2. U. S. Soil Conservation Service
3. U. S. Bureau of Reclamation
4. National Weather Service
5. Army Corps of Engineers
6. U. S. Forest Service
7. Bureau of Land Management
8. Environmental Protection Agency
9. Land grant universities
10. State departments of water resources
11. State water districts
12. Natural gas utilities
13. Electric power utilities
14. Representatives of motor and pump companies
15. Representatives of pipe and valve companies
16. Private engineering consultants

Methods. Contact with data collectors usually gave some indication of the accuracy of records. In the case of water projects and water records, the condition of water measuring devices was indicative of data accuracy. Generally, one of the following methods of data aquisition was used.

1. Routine project methods (project personnel)
2. Special project records (project personnel)
3. Direct measurement (consultant or investigator)
4. Extrapolation and comparisons from similar data
5. Approximation

IV D. Raw Data Compilation

For this study raw data was coded to computer files as soon as possible. Whether automated processing was used or not, the standard formats provided quick access to specific information. For example, the following data formats were used for Owsley Canal Company records:

Acres. User number 8 in 1977 through 1980 farmed 320, 160, 160, and 160 acres in Range 34, Section 29.

FORMAT: 8 320 160 160 160 4.29

Water. User number 8 in the months of May through October used 0, 143, 116, 54, 31, and 37 cfs-days for a total of 381.

FORMAT: 8 0 143 116 54 31 37 381

Power. All of the delivery pumps (-1) metered by meter number 2 and totaling 525 horsepower drew a maximum of 262 kw and consumed 149,760 kwh valued at $3449.78 between the 20th and 30th of May (5) of 1980.

-102,525

5.20, 0,0,0

5.30, 262, 149720, 3449.78

Pump test data. The appendix contains tables of data collected during pump tests on units operating at open discharge.

V. DATA COLLECTION, ORGANIZATION, AND ANALYSIS

V A. Introduction

Collecting and compiling data on the configuration, operation, and and management of an irrigation system requires time and ultimately money. One manager commented during the 1979 season that compiling energy records into a more convenient format was something for which he did not have time. Power restriction and rate hikes during the 1980 and 81 seasons may have encouraged him to re-evaluate his position. The average farm irrigation efficiency of this manager's project was 74% in 1979. The users of this project are generally efficient water users but the data in Case Study II indicate that there is room for improvement. The project management discussed in Case Study No. I operated a pumping plant which supplied a main canal. The plant contained five pumps, each with different operating characteristics. The investigator used the pump characteristics to find the the most efficient combination of single units to meet varying irrigation demands. The evaluation required the use of pump characteristic curves from project files, and the results from three pump tests.

The value of good documentation and well kept, accurate records goes beyond an appreciative engineer's fascination for numbers and maintenance standards. Good documentation enables a project to quickly recover when one or a group of key individuals in a team is replaced. In-house records on design, maintenance, and operation of project facilities can help during planning or when new employees arrive or operational crises develop. One of the first tasks of a consultant is to assess the completeness and quality of existing records. Routine measured data collection encourges a discipline of meeting performance standards. Usually the effort and cost of compiling data after the fact or doing without is greater than the cost of collection during routine operation.

VB. Operation Data Compilation and Organization

A detailed analysis can provide an accurate accounting of water throughout a distribution and application system if accurate field measurments are made and records collected. As the data are obtained, point of water entry or exit may be noted on a system schematic. Gains and losses within a system can include:

Gains	Losses
1. diversions	3. deliveries
2. recoveries	4. operational wastes
	5. seepage losses
	6. consumptive losses
	7. evaporative losses
	8. unaccounted losses

Meriam and Keller (1978) produced a comprehensive manual on methods, procedures, and equipment to measure field irrigation efficiency. The manual discusses eleven different types of irrigation and includes suggested formats of field data sheets. It does not discuss conveyance or "out of field" delivery system performance; however, the techniques are similar and transferrable.

Once points of use and loss along the water path have been defined, the "energy path" may be established. When water is gained or lost, the energy required to deliver it to that point may be charged to the system at that point. If water and energy costs are known, that portion of variable costs may be calculated. Analysis of these types of data can have an affect on the water delivery, and pricing policy.

V C. Project System Demand Potentials

A method of calculating irrigation schedules and total water demand is presented in the FINAL REPORT: Part IB. It is essentially a water balance scheme which relies on proscribed estimate of evapotranspiration and water losses. The method has been put in the form of a computer routine. The procedure for obtaining values for that method and similar strategies is discussed here.

Consumptive water use. Crop evapotranspiration (ET) requirements are usually obtained by using the calculated or measured ET requirements of a reference crop, then applying a coefficient to that value to obtain the ET values for specific crops. For example, the consumptive use of Egyptian cotton may be referenced to that of grass for similar conditions. A popular reference crop in the United States is alfalfa.

There is little doubt that measured ET is the most accurate consumptive use data. The data were available at Kimberly, Idaho and hence were selected as input to the example discussed in Case Study No. II. Measured ET data are site (growing condition) specific and expensive. The United States Bureau of Reclamation has sponsored irrigation scheduling pilot programs utilizing indirect field (neutron probe) measurements and calculated estimates of ET. Allen and Brockway

(1982) have used the "FAO-Blaney Criddle" method as described by Doorenbos and Pruitt (1977) to update crop consumptive use estimates for Idaho.

Soil and channel lining characteristics. Aside from its fertility characteristics soil provides a "reservoir" for moisture and it also serves as the construction material for water conveyance. Soil moisture holding characteristics, infiltration rates, and permeability values are factors affecting potential irrigation or project water use efficiency.

The potential infiltration rate of field soils may be measured by matching the measured intake rate with the water application rate using an infiltrometer. There are several types of infiltrometers. The infiltration rates of soils under furrow irrigation was measured during the King Hill Study described in Case Study No. III using an inflow-outflow method. An aveage moisture holding capacity value was taken from soil survey information and the irrigation efficiency calculated along with deep percolation losses. (Measured irrigation efficiencies on loamy sand and sandy soils ranged from 50 to 10 percent.)

Soil Conservation Service soil survey reports were excellent sources of information as an aid in estimating the fractional proportion of soil groups of the total study area exhibiting similar characteristics.

At King Hill the seepage losses in a canal were successfully measured using a constant head seepage meter in a flowing channel below the water surface. This method was selected after a previous attempt failed using an inflow-outflow method. (In the first attempt the magnitude of seepage losses was less than the accuracy of the current metered measurement.) On another project, channel losses were estimated by recording the rate of water loss from an initially full reach of canal that was dammed at both ends.

Estimates of potential seepage rates in channels may be made if the channel material or liner can be identified, the mean hydraulic wetted perimeter estimated, and the effective saturated thickness of material determined. On the King Hill Project, expected seepage rates based on bank material composition were verified by seepage meter measurements.

Precipitation and soil moisture. The amount of moisture in the soil at the beginning of the season may be assumed or measured. The previous year's crop, winter precipitation, and amount of tillage, affect the amount of total pre-season soil moisture. For calculation of water use, the amount of moisture in the zone of root growth is important. As the root grows, the volume of soil in the effective zone increases and the potential for retention of moisture increases.

Soil moisture may be estimated by feel after extraction from the ground with a shovel, or auger; usually this valuation is sufficient, especially with shallow seed beds. More exact (drying) methods can be used. The same methods can be used on deep rooted crops but tensiometers and neutron probes have become popular as they do not disturb the profile.

Irrigation supplies the portion of moisture not available from the soil moisture reservoir or from precipitation. Estimates of the effective soil moisture recharge may be made from measurements of in-season precipitation. Soil surface moisture, especially in arid climates and with no cover (shading by a crop canopy) is likely to partially evaporate before it infiltrates into the soil. Light, frequent rain on bare fields is likely to contribute little to the total available moisture.

The amount of available moisture in the soil is only a portion of the total. Most plants (crops) can extract about half of the total available moisture before exhibiting significant moisture stress. However, the economic value of the crop, the definition of significant stress, and the likelihood of not being able to irrigate when required may cause the irrigator to adjust his estimate to the lowest level of soil moisture he will allow (allowable depletion) before ordering water.

Irrigation schedules and water requirements. If natural soil moisture depletion and recharge are known, depletion limits and planting dates specified, and average initial moisture level estimated, a schedule of irrigation dates for the entire season can be determined. In addition, if losses due to evaporation, run off, deep percolation and irrigation application uniformity (ie, irrigation efficiency) can be estimated or measured, the amount of irrigation water required for single or even mixed crops can be estimated. The method described in FINAL REPORT: Part IB does the arithmetic portion of the procedure described above after all necessary data has been compiled.

V-D. Project Historic Performance Levels

Water Records. Good water records are the result of good field and office practices. Their utility is dependent on completeness and on the form of record for specific situations. An example of good record keeping can be seen at the Dalles Irrigation District where pumping capacity is of particular concern due to high value crops. The measurement of water delivery is complete and every turn-out on the system has a mechanical meter with totalizer. Water delivery data are plotted on a large wall graph when they reach the office. This plot helps the manager anticipate expected demand in relation to other years and extrapolate from current season use. A computer program (HWTR) described in FINAL REPORT: Part IC can be used to summarize historical water records, and sort the record for high and low values. The result is a histogram that may be used to analyze current season data as they become available (Case Study II).

With data on potential system demand generated by farm demand and estimated by the procedure in previous sections (V-C and FINAL REPORT: Part IB) an irrigation efficiency may be calculated by comparing the monthly or seasonal values to the historical record. A conveyence efficiency may also be calculated using water diversion records.

Many irrigation projects may have suspiciously low overall conveyance efficiencies. Routine water records may not contain sufficient detail to define the limits of canal reaches that have acceptable conveyance efficiencies. Special seepage measurements may be necessary (Case Study III).

Energy Records. Records of energy use on irrigation projects were generally not well documented. Energy records may be recorded by project personnel at specific and regular times (perhaps to coincide with water records) or they may be obtained from utility billing records. Comparison with energy billings which are only available at unscheduled times with water use records is difficult except on a seasonal basis.

Another computer program (HPOW) described in FINAL REPORT: Part IC can be used to generate a timely monthly energy record either for pumping plants or for separate pumps of different duty groups. With a regular monthly energy record, the energy data can be compared to water records in order to estimate unit delivery costs or monthly power requirements per unit of water delivered.

Pump tests can be used to measure the energy efficiency and capacity of pumps and may be used to define the potential of the system in meeting its system demand. If the pumping system is complex, the pump test data may be used in the computer routine described in FINAL REPORT: Part IA to estimate peak pump station energy efficiency potentials (Case Study I).

When special water measurements are not convenient, detailed energy records may be used to estimate the missing portion. Estimated water records are especially helpful in estimating lake, reservoir, and canal losses after the fact when a system is being reviewed for "historic" performance levels.

Record Processing and Utility. A well written computer routine for data processing is similar to a well defined office procedure. The utility of any routine is dependent on the form of the results and whether the user can readily draw conclusions. Graphic enhancements of summarized, tabulated data are also useful. The user will probably work backwards looking first at graphical then at tabulated summaries, and finally at detail leading to the summary.

A suggested order of records processing, most of which was incorporated into the computer routines in FINAL REPORT: Part IC, is:

1. compilation of records
2. eliminate inconsequential records
3. create master file
4. sort master file by selected values
5. print master file
6. scan file for significant values
7. graph and tabulate significant figures

Consistant form of the final output is important. The user should be able to compare results with little explanation. One goal of effective record processing is to aid the reviewer in his objectivity and to assist in drawing conclusions based on facts. Again, the assumption is that good information will result in effective planning and good decisions.

VI. RECOMMENDATIONS

The major portion of this report deals with data acquisition and preparation. The next logical step is to use the information to aid management in routine duties and to assist in formulating recommendations to improve systems or system management.

A suggested order of investigation and analysis, most of which was incorporated into the King Hill Study (Case Study III) is as follows:

1. Project assessment
2. Identification of data requirements
3. Constraints of investigation
4. Statement of assumptions
5. Analysis
6. Presentation of results

The final pages of Case Study No III are a set of recommendations given to the board of directors of the King Hill Irrigation District. The district was dealing with several problem areas at that time so the recommendations were organized into appropriate groups. The study area and detail of investigation was limited by time so that for the most part, recommendations tended to be general. The report and recommendations did <u>identify</u> important problems such as water use efficiency, their relative importance, and some suggested solutions. Some of the recommendations urged the board to pursue additional investigations.

During the King Hill District investigation, two basic interrelated problems were identified. The first problem was the project's philosophy of water use and the second was a need for water user education. At two separate meetings sets of recommendations were presented, the first being more general than the second. Those meetings were separated by a workshop on water measurement. Whether the recommendations were the direct cause or not, the board of directors, in an effort to deal with uncomfortably operation costs instituted some sweeping changes before the second set of recommendations were presented (the manager, office, and field manpower were replaced).

Some additional suggestions on presentation of results are:

1. Define the study area. Discuss problems as the project governing board, management and/or water user views them.
2. Evaluate project performance. Present the recommendation as identified by the analysis.
3. Allow "audience" to digest the recommendations and consider alternative courses of action.
4. Present courses of action by priority.

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MANAGEMENT, MAINTENANCE, AND OPERATION

OF

PUMP SUPPLIED IRRIGATION PROJECTS

FINAL REPORT: PART THREE

PUMP SUPPLIED IRRIGATION PROJECTS,

FIVE CASE STUDIES

by

R.D. Wells, C.E. Brockway, and J.R. Busch

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OVERVIEW

This FINAL REPORT has been written in three sections and an appendix. Part I, is a set of user's guides for computer programs useful as water management tools. Part II is a description of methods and procedures of measuring (pump) irrigation project performance, analyzing the data, and presenting the results. Part III, this part, is a set of five case studies where the tools of Part I and the procedures of Part II were applied to real situations. The Appendix, the forth part, is a set of data from pump tests which were conducted during this study.

The case studies of Part III have been written to emphasize application. Case Study No. I examines the operating characteristics of a pumping station with a variable irrigation demand and high energy costs. Case Study No. II describes a project that had storage requirements, high utility power costs, and a wide range of single user irrigation demand; potential and historical water use and energy cost data were developed for consideration of the the company directors. Case Study No. III deals with an old gravity supplied irrigation project that was forced to switch to a pumped water supply with increased operating costs and limited water availability; sets of recommendations were made to assist the district meet its challenges. Case Study No. IV describes a project that had developed a progressive pump maintenance program; pump tests were conducted and the study describes testing methods and specific recommendations. Case Study No. V deals with routine operation of an old pump supplied district that recently completed an extensive rehabilitation project; the study reports on system operation from a ditch rider's point of view.

The purpose of writing these five case studies is three fold: (1) Each study describes at least a portion of the management, maintenance, and/or operation of five of the ten projects included in this study; there was a great deal of project to project variation. (2) The case studies describe a successful application of the methods and procedures described in the FINAL REPORT: PARTS I and II and are used as examples. (3) The case studies may be used as a source for ideas and parallel application in similar situations.

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FIGURE 4-F: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-15-6 171

CASE STUDY NO.I

DEVELOPING OPERATION GUIDELINES FOR MULTIPLE PUMPS IN PARALLEL

Background. In 1979 the University of Idaho tested the efficiency of pumping units in the Osgood Project main lift station. During this contact, the solution to the problem of finding the most energy efficient combination of pumps was discussed and judged to be important enough to pursue.

The Osgood Project, located eight miles from Idaho Falls, was originally a gravity irrigated, pump supplied development. Four of the five pumps are original units dating from 1916. A fifth replacement unit brought the pump bank to a delivery capacity of 140 c.f.s. before 1961. By 1965, all of the land under the Osgood Canal had been converted to sprinkler irrigation and peak water demand fell to 65 c.f.s.

Recent energy rate increases have made the project manager aware of the cost of all pumping requirements and the main lift costs in particular. The University's interest in the delivery system energy efficiency was welcomed.

The Situation. Four of the Osgood lift pumps were horizontal centrifugal double suction (CDS) pumps and the fifth was a vertical turbine (VT). The plant total dynamic head (TDH) is approximately 60 feet.

The operators were asked about their procedure for selecting individual units to match irrigation water supply with demand. There was no definite procedure but general practice relied on spilling, pump combination, and limited valving. When questioned about the practice of spilling and valving, there were several responses. They are:

1. One combination of pumps and valve settings was generally unchanged for a long period. Spilling was used for fine adjustments several times daily.

2. Three of the horizontal pumps were worn and vibrated less longitudinally (end play) with open valves.

3. Routine spills were minimized.

Selections of appropriate pumps from the group of four CDS units was a matter of convenience and habit as well as need. The vertical unit was known to have a higher delivery capacity and it was used when irrigation Pemand became less variable typically, during June through August. The VT unit was used as little as possible because it ran with a particularly irritating howling sound in contrast to the quieter CDS units. The pump characteristic curve and data on motor energy consumption indicated that at open discharge, it was the most efficient unit in the station. The Owsley Lift pump test results are shown in Table I-A.

TABLE I-A

OSGOOD CANAL COMPANY PUMP TEST RESULTS[1]
Main Lift Pumps on the New Sweden Canal

Pump Name	HP Rating	Type[2]	Valve ?	EHP[3] Elect	TDH feet	Q cfs	WHP[4] Mech	EFF[5] %
U1	250	VT	yes	--	--	(26)	(189)	(77)E
U2	250	CDS	no	284	62	22.45	158	56 F
U3	125	CDS	yes	131	62	10.68	75	57 F
U4	250	CDS	yes	--	--	(24)	(169)	(67)G
U5	250	CDS	no	251	62	24.08	169	67 G
TOTAL	11250			--	62	(102)	(760)	(66)

Blanks indicate the unit was not tested.
Parenthesis indictate an estimated value.

1. Results from June 4, 1979 tests.
2. VT = Vertical Turbine, CDS = Centrifugal Double Suction Pump
3. Electrical Horse Power, Measured
4. Water Horse, Measured
5. "Wire to water" energy efficiency. Rating of performance range were developed by Pacific Gas and Electric (ie, E= excellent, G-Good, F-Fair, L=Low)

Method of Investigation. The University tested three of the five units for open discharge capacity and energy efficiency. A dye dilution technique was used to measure pump discharge because it did not require system interruption or modification in order to measure individual pump discharge (Wells, et al. 1978). Electrical power to the motors was measured using station metering equipment and checked with portable test equipment.

Results from the pump test were compared with pump characteristic curves which the company manager kept on file. Using these data, a set of nomographs were constructed to find "acceptable" combinations of pumps and methods of controlling net station discharge. The guidelines that resulted from this procedure included a set of recommended "good practices" for that station along with combinations of pumps for ranges of irrigation demand. The procedure was tedious. A much more refined procedure was developed and reduced to a computer routine which is the subject of PART IA of this final report.

Recommendations and Results. Maintenance costs to improve units U2 and U3 would probably be justified by savings in energy alone; however, other factors were controlling the maintenance budget at the time of the test.

Some general recommendations were made when the manually developed set of plant operation guidelines were presented to the Osgood Project manager. They are site specific and intended to help the operator when he was required to make a choice in routine station operation.

1. Don't valve more than 30% of open capacity from any pump or combination of pumps. This keeps pump efficiency near or above 60%.

2. When increasing flow, open up the largest pump and most efficient pump first, then the smaller (and less efficient) pumps.

3. Valve the centrifugals first then spill. Valving the CDS pumps saves between 2 and 4% on energy as opposed to spilling.

4. Avoid valving the vertical turbine, U1 unit.

Pump and station characteristics were processed by computer to determine the optimum pump configuration at a variety of discharges within the range of the Osgood lift. The recommended alternatives (based on minimum energy requirement) are listed in Table IB. A change from one setting to another may require a judgement that only the operator could supply on a day to day basis but the potential for kilowatt-hour savings is significant.

TABLE I-B

OSGOOD CANAL COMPANY PUMP STATION FLOW RECOMMENDATION

Recommendations based on operational constraints and total station minimum energy requirements.

Station Discharge (GPM)	Station Eff (%)	Power Required (SFT-HP)	Unit Discharge Resulting in Total Station Minimum Energy (GPM) #U1	#U2	#U3	#U4	#U5
5000	61	122	0	0	5000	0	0
7500	60	186	0	7500	0	0	0
10000	69	217	0	0	0	10000	0
12500	63	299	0	5917	6583	0	0
15000	71	318	0	9800	5200	0	0
17500	78	340	11958	0	5542	0	0
20000	74	409	11933	8067	0	0	0
22500	78	439	11925	0	0	10575	0
25000	73	525	11917	6500	6583	0	0
27500	79	540	11917	9808	5775	0	0
30000	75	623	11900	7100	0	11000	0
32500	80	635	11917	9533	0	11050	0
35000	74	736	11900	5600	6533	10967	0
37500	78	758	11875	9500	6125	10000	0
40000	80	789	11867	0	6533	10667	10933
42500	81	854	11900	9492	0	10200	10908
45000	75	953	11850	5400	6450	10500	10800
47500	78	976	11875	7758	6333	10767	10767

Final Comment. Minimizing the total energy consumption for irrigation is "good practice" for both the producer and consumer of electric power. Another "good practice" is minimizing the peak power demand (kilowatts) in addition to the total energy used (kilowatt-hours). Power utility's rate structures vary from one supplier to the next. In the case of the

Osgood project the rate is based both on the number of kilowatt-hours and the highest level of power consumption during a single billing cycle. Avoiding an excessively high peak power demand requires good operation and management. Using Table 1B as a guide, the relative consequences of selecting other than optimum pumping conditions can be weighed. Pump breakdowns, rotating pump duty, and daily variations in irrigation demand are constraints which may be more critical.

Additional information giving any irrigation project manager data on anticipated irrigation demand would be helpful several ways. For the Osgood project operators information of this type would make the optimum recommendations in Table 1B more useful. CASE STUDY II shows how anticipated irrigation demand information was generated on another similar irrigation project.

CASE STUDY NO. II

DEVELOPING UNIT COSTS FOR DELIVERED IRRIGATION WATER AND CROP WATER DEMAND WITH SPECIFIED IRRIGATION EFFICIENCY LEVELS

Background As in Case Study No. I, the University of Idaho tested the efficiency of pumping units operated by the Owsley Canal Company, located at Terreton, Idaho. The company put its first pump into operation in 1909 and has added more units to the system since. The expanded water delivery system required development of a water supply system from ground water. This expansion involved more pumps and reservoir storage.

During one interview the operators of Owsley discussed their pumping costs and were particularly concerned with availability of power and water due to limitations in the power supply during periods of peak demand.

A simple method was developed to give Owsley and similar groups a clear understanding of their water requirements in relation to their present water demand, and the energy costs of meeting that present demand. The results of one application of that method are presented here.

The Situation. At Terreton Idaho, the elevation is 4800 feet, and the growing season is short. There are sprinkler irrigation systems in the area but under the Owsley Canal Company system, border irrigation is used almost exclusively. The irrigated land area under the Owsley Canal is about 17,500 acres. Mud Lake serves as a reservoir for Owsley and four other groups of irrigators. The surface water supply feeding the lake is Camas Creek, an intermittant stream. Years ago, when irrigation demand exceeded supply, several user groups drilled ground water wells and began storing pumped water in the lake. Presently, ground water pumping into the lake begins typically in early May and extends into late October depending on the surface water supply. Irrigation pumping from the lake for Owsley begins in late April and ends in mid-October. Managing the Mud Lake System involves cooperation of several water users, and active state participation in crediting water users with contributions and withdrawals from the lake.

The Owsley system is faced with several problems. Being a pump supplied project, the cost of power is significant. It accounts for half of the operating budget. The power supplier is a fossil fuel based utility and increased electrical demand from all sources has forced the price of electricity up and pushed the total peak electrical load to capacity. In order to contain the growing portion of the irrigation pumping demand, the utility initiated a load management program in which the customer was given three options. Option A allowed unrestricted power use but at a high price. Option B required the customer to accept up to a total of 12 hours shut down on three of five days (Monday through Friday) of his choosing. Option C was the same as Option B except the customer was not given a choice of days. The cheapest rate was Option C. The Owsley Canal Co. has canal water levels to maintain but have chosen to manage around the restrictions of Option C.

Another problem had to do with water supply. Because the natural surface water supply flowing into Mud Lake is variable, a decision of the amount and quantity of early season ground water pumping must be made before the irrigation season begins and the natural supply arrives. Ground water pumping capacity cannot meet irrigation season demand. Because storage is limited a bad guess means a shortage of water or a high power bill and wasted water.

Still another problem, with which the company has not dealt, has to do with the nature of the Owsley irrigation demand. The Terreton area is suitable for production of alfalfa and spring grain. The soil within the system has an intake rate varying from slow to very slow. Standing water in fields on hot days often results in scalding and reduced yields. More permeable soils do not require the close attention to the amount of applied water that the less permeable soils do. The Owsley water assessment is a uniform charge on a per acre basis and was in the $11 to $15 per acre range during the period of study. The incentive to use water conservatively within the company service area is not uniform.

In an effort to provide the Owlsey board of directors with information they could use to evaluate the state of company facilities and company water delivery policy, the university tested pumps, and collected information on operation and costs. In the case of the Owsley system, the objective of the effort was to provide the company with information and allow management to draw its own conclusions.

Method of Investigation. The information developed for the Owsley System was intended to show when, where, and how much pumping energy and irrigation water was used over a period of four years. In addition it was to show the irrigation requirement, an idealized irrigation schedule for the local crops, and the required total project irrigation demand. The methods of preparing these from the raw data are described in Parts 1B and 1C of the FINAL REPORT. Selected data from Owsley is presented here.

Results. Two of the five pumps on the Owsley "main lift" were tested on June 5, 1979. Units M2 and M3 were ooperating at 56 and 44 percent efficiency. The main lift pumps are high volume - low head (mixed flow) pumps and on the date of the tests, the total pump discharge was used in supplying irrigation demand. Because all of the main lift pumps are large and unvalved, any unused fraction of the plant discharge had to be spilled to control net station discharge. On August 2, 1979 total plant energy efficiency was 39 percent with 40 cfs of a total station discharge of 133 cfs being spilled.

Figure 2-A shows the total pumping energy used by the Owsley Canal Company during the years 1977 through 1980. Figure 2-B is the monthly total irrigation demand for the same period. A break down of the total energy demand for all years was calculated but 1978 was selected as a typical year. Figure 2-C shows where within the system when the

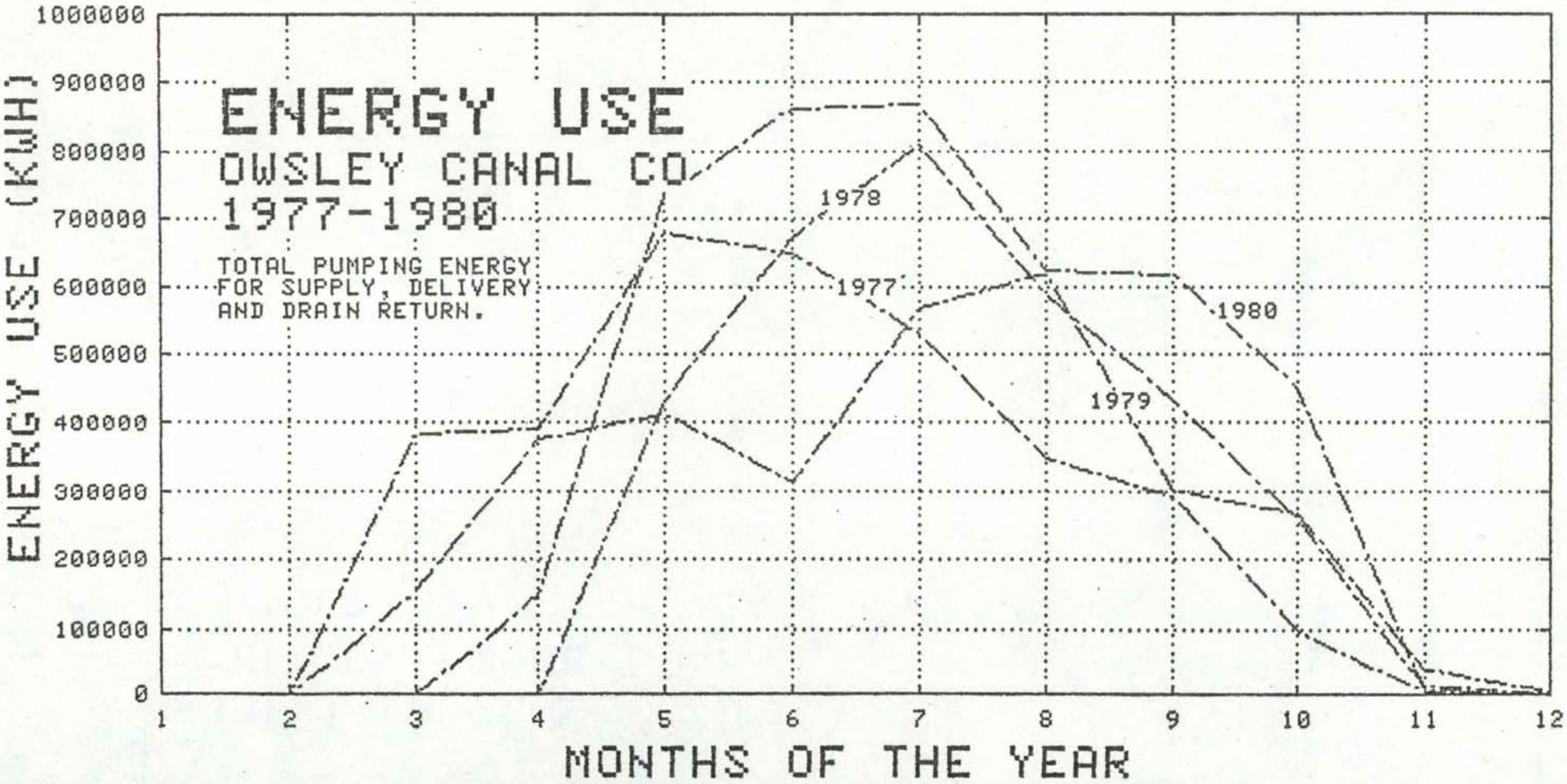

FIGURE 2-A. Total Pumping Energy Use of Owsley Canal Co. for Four Years.

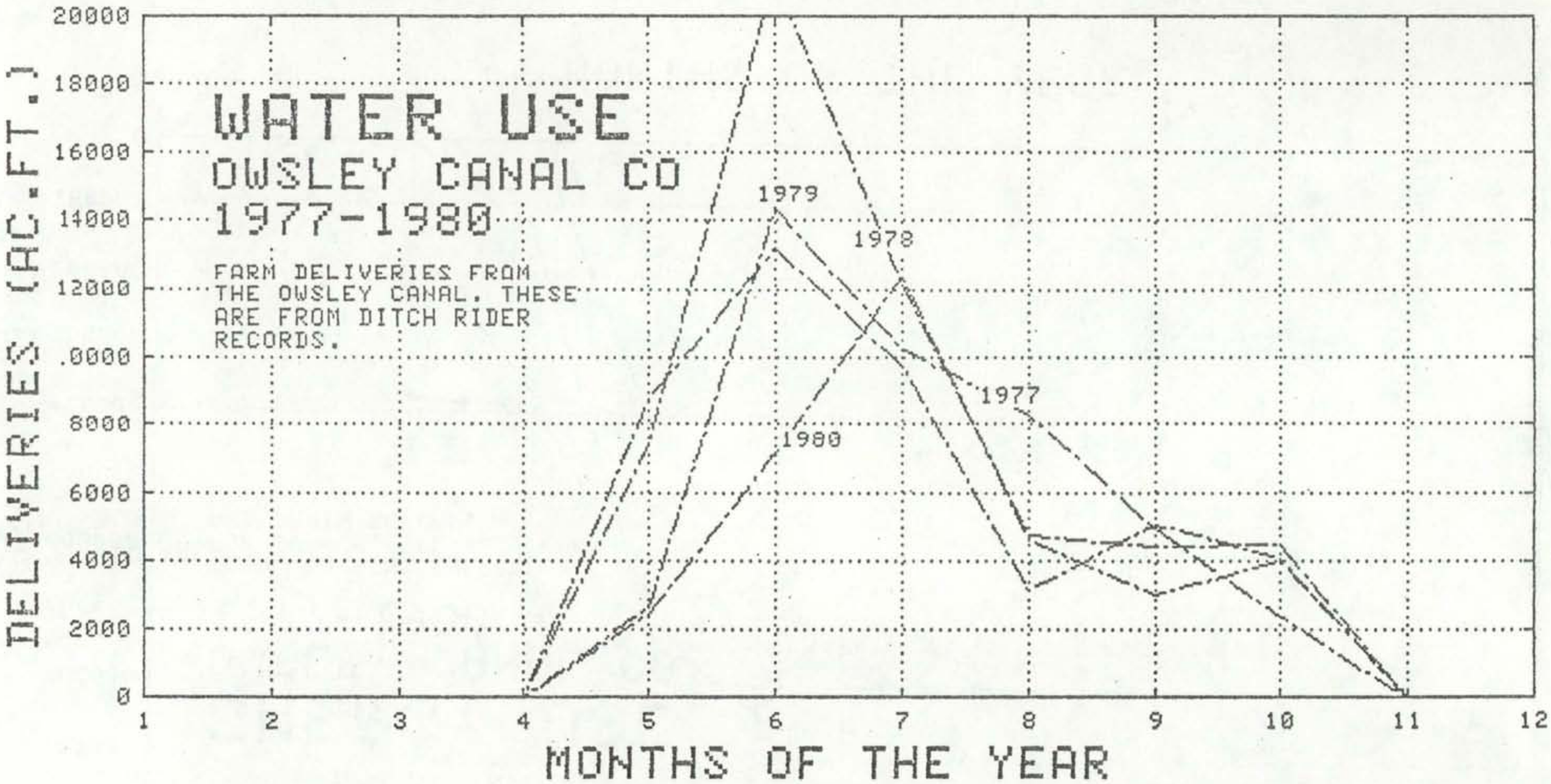

FIGURE 2-B. Total Water Delivered by Owsley Canal Co. for Four Years.

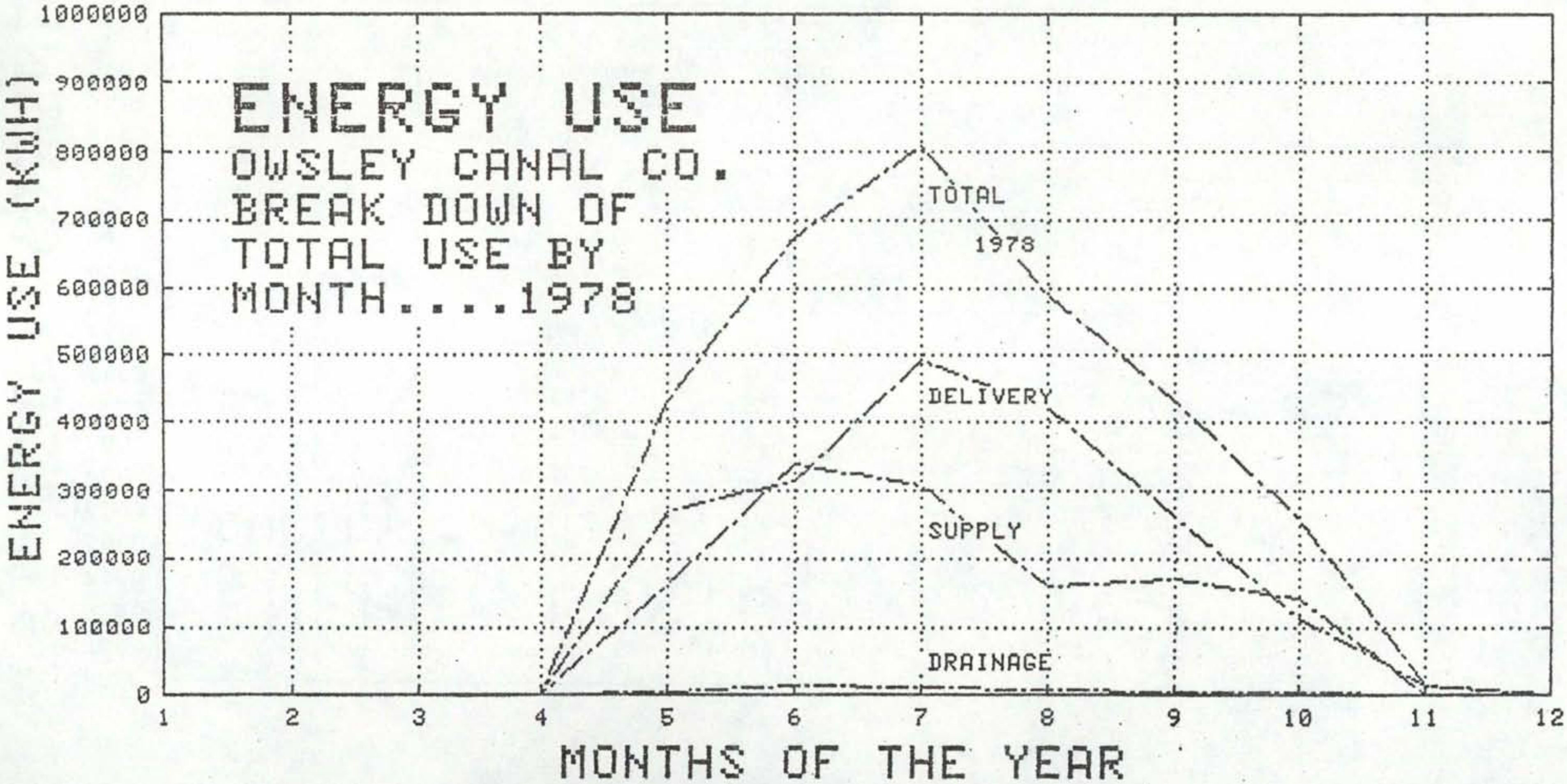

FIGURE 2-C. Break Down of Total Energy for 1978.

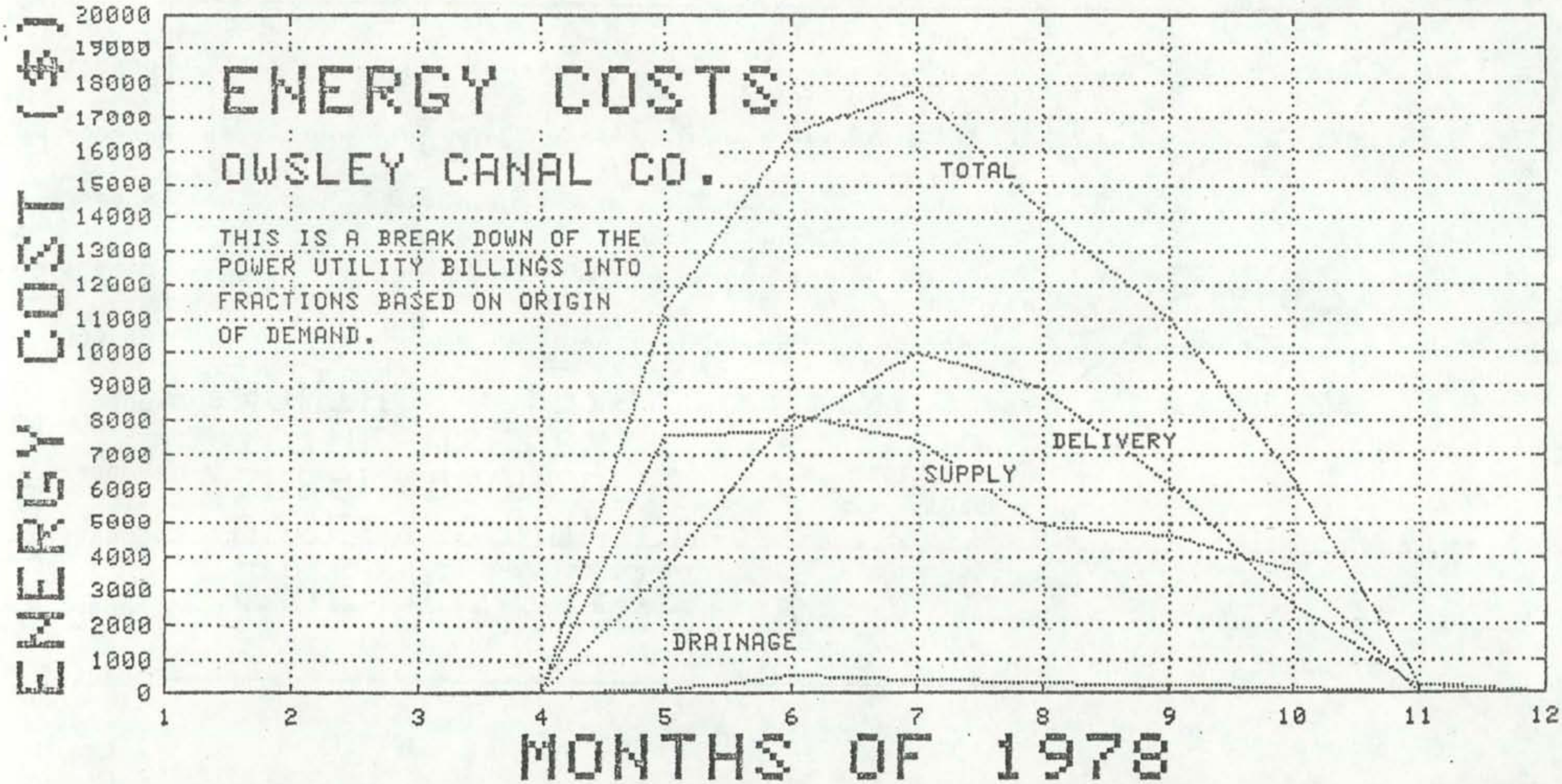

FIGURE 2-D. Break Down of Pumping Energy Costs for 1978.

FIGURE 2-E1: CONSUMPTIVE USE OF WATER FOR ALFALFA AT TERRETON, IDAHO.

HALF-MONTHLY CONSUMPTIVE USE ESTIMATES FOR KIMBERLY IDAHO..14 YEARS OF RECORD (EJLW)
ALFALFA - SANDS AND LOAMS UNDER BORDER, GREEN UP MAY 01

CROP NUMBER 1
DATE OF PLANTING 5/ 01
DATE OF EFF.COV. 5/ 15
DATE OF HARVEST 9/ 10
DATE OF MIN ROOT 4/ 15
DATE OF MAX ROOT 8/ 20 (block 1) PART A
MIN. ROOT DEPTH,FT 4.00
MAX. ROOT DEPTH,FT 4.00
AVAIL.MOIST.,IN/FT 1.80
ALLOW. DEPLETION,% 55.00
ALLOW. DEPL.,IN/FT .99
ALFALFA CUT DATES 7/ 01 8/20

C O N S U M P T I V E U S E A N D E V A P O R A T I O N E S T I M A T E S (INCHES)

MONTH	PERIOD (15 DAY)	AVE CROP COEF	EVAPOTRANS FOR PERIOD REF	ACTUAL	80%	20%	EXTRA EVAP PER IRR	NO. OF IRR	TOTAL EVAP	ROOT DEPTH	TOTALS, PERIOD AND MONTH REF	ACTUAL	80%	20%
4	1	0.000	2.42	0.00	0.00	0.00	.26	0	0.00	4.00		0.00	0.00	0.00
4	2	0.000	2.80	0.00	0.00	0.00	.30	0	0.00	4.00		0.00	0.00	0.00
											5.22	T0.00	T0.00	T0.00
5	1	.772	3.42	2.64	2.90	2.38	.08	0	0.00	4.00		2.64	2.90	2.38
5	2	1.000	4.06	4.06	4.46	3.67	.00	1	0.00	4.00		4.06	4.46	3.67
											7.48	T6.70	T7.36	T6.04
6	1	1.000	4.01	4.01	4.46	3.56	.00	1	0.00	4.00		4.01	4.46	3.56
6	2	1.000	4.58	4.58	5.10	4.04	.00	1	0.00	4.00		4.58	5.11	4.04
											8.59	T8.59	T9.57	T7.60
7	1	.529	4.69	2.48	2.62	2.34	.24	1	0.24	4.00		2.72	2.85	2.58
7	2	.979	4.86	4.75	5.10	4.41	.01	1	0.01	4.00		4.76	5.11	4.42
											9.55	T7.24	T7.73	T6.67
8	1	1.000	4.36	4.36	4.66	4.05	.00	1	0.00	4.00		4.36	4.66	4.05
8	2	.597	4.00	2.39	2.67	2.10	.16	1	0.16	4.00		2.55	2.84	2.26
											8.36	T6.91	T7.50	T6.31
9	1	.603	3.25	1.96	2.15	1.77	.14	0	0.00	4.00		1.96	2.15	1.77
9	2	0.000	2.68	0.00	0.00	0.00	.29	0	0.00	4.00		0.00	0.00	0.00
											5.93	T1.96	T2.15	T1.77
10	1	0.000	2.11	0.00	0.00	0.00	.23	0	0.00	4.00		0.00	0.00	0.00
10	2	0.000	1.68	0.00	0.00	0.00	.17	0	0.00	4.00		0.00	0.00	0.00
											3.80	T0.00	T0.00	T0.00

(^^^ block 2)

(block 3 >>>)

****
SEASONAL TOTAL FOR SINGLE CROP
ALFALFA - SANDA AND LOAMS UNDER BORDER, GREEN UP MAY 01
N O T E: ET FOR DRY SOIL SURFACE THROUGHOUT SEASON
INCLUDES SOIL EVAPORATION PRIOR TO PLANTING AFTER
HARVEST. EXTRA EVAP IS DUE TO IRRIGATED WET SURFACE.
TOTAL REFERENCE ET 48.92 INCHES
ACTUAL CROP ET 31.23
80 % CROP ET 34.14
20 % CROP ET 28.32
NO. OF IRRIGATIONS 07
TOTAL EXTRA EVAP. 0.41
****

FIGURE. 2-E2: CONSUMPTIVE USE OF WATER FOR SPRING GRAIN AT TERRETON, IDAHO.

HALF-MONTHLY CONSUMPTIVE USE ESTIMATES FOR KIMBERLY IDAHO..14 YEARS OF RECORD (EJLW)
SPRING GRAIN - SANDS AND LOAMS UNDER BORDER, PLANT APRIL 25

CROP NUMBER 8
DATE OF PLANTING 4/ 25
DATE OF EFF.COV. 6/ 24
DATE OF HARVEST 8/ 20
DATE OF MIN ROOT 5/ 05
DATE OF MAX ROOT 7/ 20 (block 1) PART A
MIN. ROOT DEPTH,FT .50
MAX. ROOT DEPTH,FT 4.00
AVAIL.MOIST.,IN/FT 1.80
ALLOW. DEPLETION,% 50.00
ALLOW. DEPL.,IN/FT .90

CONSUMPTIVE USE AND EVAPORATION ESTIMATES (INCHES)

MONTH	PERIOD (15 DAY)	AVE CROP COEF	EVAPOTRANS FOR PERIOD REF	ACTUAL	80%	20%	EXTRA EVAP PER IRR	NO. OF IRR	TOTAL EVAP	ROOT DEPTH	TOTALS, PERIOD AND MONTH REF	ACTUAL	80%	20%
4	1	0.000	2.42	0.00	0.00	0.00	.26	0	0.00	.50		0.00	0.00	0.00
4	2	0.000	2.80	.17	.20	.14	.28	0	0.00	.50		.17	.20	.14
											5.22	T0.17	T0.20	T0.14
5	1	.175	3.42	.60	.66	.54	.30	1	0.30	.67		.90	.96	1.97
5	2	.479	4.06	1.95	2.14	1.76	.21	1	.21	1.35		2.16	2.35	1.97
											7.48	T2.76	T3.01	T2.51
6	1	.911	4.01	3.65	4.06	3.25	.04	2	0.08	2.07		3.73	4.14	3.32
6	2	1.012	4.58	4.63	5.18	4.09	.00	2	0.00	2.76		4.63	5.18	4.09
											8.59	T8.28	T9.24	T7.33
7	1	1.010	4.69	4.74	5.00	4.47	.00	1	0.00	3.45		4.74	5.00	4.47
7	2	.783	4.86	3.85	4.13	3.57	.10	1	0.10	3.97		3.95	4.23	3.67
											9.55	T8.69	T9.23	T8.14
8	1	.378	4.36	1.65	1.76	1.53	.29	1	0.29	4.00		1.94	2.05	1.82
8	2	.055	4.00	.22	.25	.19	.38	0	0.00	4.00		0.22	0.25	0.19
											8.36	T1.87	T2.01	T1.72
9	1	0.000	3.25	0.00	0.00	0.00	.35	0	0.00	4.00		0.00	0.00	0.00
9	2	0.000	2.68	0.00	0.00	0.00	.29	0	0.00	4.00		0.00	0.00	0.00
											5.93	T0.00	T0.00	T0.00
10	1	0.000	2.11	0.00	0.00	0.00	.23	0	0.00	4.00		0.00	0.00	0.00
10	2	0.000	1.68	0.00	0.00	0.00	.17	0	0.00	4.00		0.00	0.00	0.00
											3.80	T0.00	T0.00	T0.00

(^^^ block 2)

(block 3 >>>)

****
SEASONAL TOTAL FOR SINGLE CROP
SPRING GRAIN - SANDS AND LOAMS UNDER BORDER, PLANT APR 15
N O T E: ET FOR DRY SOIL SURFACE THROUGHOUT SEASON
INCLUDES SOIL EVAPORATION PRIOR TO PLANTING AFTER
HARVEST. EXTRA EVAP IS DUE TO IRRIGATED WET SURFACE.
TOTAL REFERENCE ET 48.92 INCHES
ACTUAL CROP ET 21.45
80 % CROP ET 23.37
20 % CROP ET 19.53
NO. OF IRRIGATIONS 09
TOTAL EXTRA EVAP. 0.98
****

P A R T B

I R R I G A T I O N S C H E D U L E F O R C A S T

IRRIGATION DATES FOR MEAN CONSUMPTIVE USE REQUIREMENTS
ALFALFA - SANDS AND LOAMS UNDER BORDER, GREEN UP MAY 01

IRR. DATE	DAYS SINCE LAST IRR.	AMOUNT (IN.)
5 / 21	0 DAYS	3.96
6 / 06	16 DAYS	3.96
6 / 20	14 DAYS	3.96
7 / 05	15 DAYS	3.96
7 / 22	17 DAYS	3.96
8 / 05	14 DAYS	3.96
8 / 21	16 DAYS	3.96

TOTAL NO. IRRIGATIONS = 7 TOTAL REQ. = 27.72

IRRIGATION DATES FOR MEAN CONSUMPTIVE USE REQUIREMENTS
SPRING GRAIN - SANDS AND LOAMS UNDER BORDER, PLANT APR 25

IRR. DATE	DAYS SINCE LAST IRR.	AMOUNT (IN.)
5 / 11	0 DAYS	0.60
5 / 24	13 DAYS	1.22
6 / 04	11 DAYS	1.86
6 / 11	07 DAYS	1.86
6 / 20	9 DAYS	2.48
6 / 28	8 DAYS	2.48
7 / 08	10 DAYS	3.10
7 / 20	12 DAYS	3.57
8 / 08	19 DAYS	3.60

TOTAL NO. IRRIGATIONS = 9 TOTAL REQ. = 20.78

THIS DATA INCLUDES WET SOIL EVAPORATION FOR
3 DAYS FOLLOWING IRRIGATION.

THE SEASONAL IRRIGATION REQUIREMENT IS REDUCED BY
ALLOWABLE DEPLETION NEAR THE SEASON END.

FIGURE 2-F. IRRIGATION SCHEDULE FOR ALFALFA AND
SPRING GRAIN AT TERRETON, IDAHO.

FIGURE 2-G: CROP WATER AND IRRIGATION REQUIREMENTS FOR THE OWSLEY CANAL COMPANY.

PART C
WATER REQUIREMENT SUMMARY FOR CROP DISTRIBUTION

CROP DISTRIBUTION (block 1)

ALFALFA	66.00 %
BEANS	0.00 %
CORN	0.00 %
PASTURE	0.00 %
PEAS	0.00 %
POTATOES	0.00 %
SUGAR BEETS	0.00 %
SPRING GRAIN	34.00 %
WINTER WHEAT	0.00 %

TOTAL PROJECT ACRES = 17527.

THE HALF-MONTHLY WATER REQUIREMENTS FOR THIS CROP DISTRIBUTION FOR *** 74.% *** APPLICATION EFFICIENCY ARE: (block 2)

MONTH	PERIOD	AVE	20%	80%	AC.FT.
4	1	0.00	0.00	0.00	0.00
4	2	0.08	0.06	0.09	152.32
5	1	2.77	2.50	3.03	5461.21
5	2	4.62	4.18	5.06	9110.24
6	1	5.29	4.70	5.88	10440.90
6	2	6.21	5.48	6.94	12257.18
7	1	4.60	4.35	4.84	9075.19
7	2	6.06	5.63	6.50	11968.38
8	1	4.78	4.45	5.10	9429.44
8	2	2.37	2.10	2.64	4684.26
9	1	1.75	1.58	1.92	3454.09
9	2	0.00	0.00	0.00	0.00
10	1	0.00	0.00	0.00	0.00
10	2	0.00	0.00	0.00	0.00
SEASONAL TOTALS		38.52	35.05	42.00	56264.59

MONTHLY SUMMARY OF ESTIMATED IRRIGATION DEMAND (block 3)

MONTH	AVE.AC.FT.	EACH I EQUALS 200.0 ACRE FEET DELIVERED	% W TOTAL
1	0.	>	0.00
2	0.	>	0.00
3	0.	>	0.00
4	0.	>	0.00
5	7223.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	14.43
6	16977.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	
7	15132.	>IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	30.23
8	5159.	>IIIIIIIIIIIIIIIIIIIIIIIIII	10.31
9	0.	>	0.00
10	5563.	>IIIIIIIIIIIIIIIIIIIIIIIIIIII	11.11
11	0.	>	0.00
12	0.	>	0.00
SUMMARY	50053.		100. %

FIGURE 2-H: MEASURED WATER DELIVERIES FOR 1978.

MONTHLY SUMMARY PROJECT WATER DELIVERY RECORDS

OWSLEY IRRIGATION DELIVERIES, 1978 ACRES: IRRIGATED = 17778, DRY = 63, TOTAL 17841

EACH D EQUALS 200.0 ACRE FEET DELIVERED

MONTH	AVE.AC.FT.		% W TOTAL
1	0.	>	0.00
2	0.	>	0.00
3	0.	>	0.00
4	0.	>	
5	7417.	>DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD	13.62
6	21228.	>DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD	
7	12161.	>DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD	22.03
8	4740.	>DDDDDDDDDDDDDDDDDDDDDDDD	8.70
9	4431.	>DDDDDDDDDDDDDDDDDDDDDDD	8.31
10	4497.	>DDDDDDDDDDDDDDDDDDDDDDD	8.25
11	0.	>	0.00
12	0.	>	0.00
SUMMARY	54474.		88.81%

THE FOLLOWING IS A LISTING OF SINGLE USER STATISTICS FOR THE YEAR OF RECORD; THEY INCLUDE USERS THAT ARE CREDITED WITH AT LEAST ONE UNIT OF DEMAND:

USER NUMBER	USER ACRES	ACRE FEET DELIVERED	ACRE FEET PER ACRE	% TOTAL ACRES	% WATER DELIVERED
THE HIGH WATER USERS. IRRIGATORS APPLYING 4.5 FEET OR MORE:					
3	78.	457.	5.864	.437	.840
8	160.	776.	4.851	.897	1.425
12	40.	337.	8.451	.224	.618
21	80.	356.	4.455	.448	.654
51	80.	362.	4.529	.448	.665
55	660.	3166.	4.797	3.699	5.812
69	320.	1495.	4.672	1.794	2.744
70	80.	453.	5.668	.448	.832
72	80.	566.	7.079	.448	1.040
75	100.	539.	5.386	.561	.989
92	40.	283.	7.079	.224	.520
93	4.	28.	6.930	.022	.051
99	160.	834.	5.272	.897	1.548
104	160.	816.	5.099	.897	1.498
113	6.	28.	4.620	.034	.051
118	668.	3041.	4.553	3.744	5.583
SUMMARY	2716.	13546.	4.997	15.279	24.867
THE LOW WATER USERS. IRRIGATORS APPLYING .80 FEET OR LESS:					
28	640.	261.	.408	3.587	.480
68	80.	59.	.743	.448	.109
91	398.	156.	.393	2.231	.287
SUMMARY	1118.	477.	.404	6.620	.876
THE PROJECT AVERAGE:					
SUMMARY	17776.	54474.	2.721	100.00	100.00
THE USERS CONSUMMING NO WATER COMPILED THE FOLLOWING STATISTICS:					
4	3.	0.	0.000	0.017	0.000
5	2.	0.	0.000	0.011	0.000
9	1.	0.	0.000	0.006	0.000
22	3.	0.	0.000	0.017	0.000
26	4.	0.	0.000	0.022	0.000
30	2.	0.	0.000	0.011	0.000
40	2.	0.	0.000	0.011	0.000
47	8.	0.	0.000	0.045	0.000
48	1.	0.	0.000	0.006	0.000
52	5.	0.	0.000	0.028	0.000
76	4.	0.	0.000	0.022	0.000
81	3.	0.	0.000	0.017	0.000
84	1.	0.	0.000	0.006	0.000
94	1.	0.	0.000	0.006	0.000
100	3.	0.	0.000	0.017	0.000
108	1.	0.	0.000	0.006	0.000
114	6.	0.	0.000	0.034	0.000
115	6.	0.	0.000	0.034	0.000
116	6.	0.	0.000	0.034	0.000
117	1.	0.	0.000	0.006	0.000
SUMMARY	63.	0.	0.000	0.345	0.000

FIGURE 2-I: SINGLE USER STATISTICS FOR THE OWSLEY CANAL COMPANY

electrical demand for 1978 was developed and Figure 2-D shows how much the company was charged for that energy, by system component. Table 2-A1, and 2-A2 are estimates of the consumptive 15-day water requirements for alfalfa and spring grain in the Terreton area in a typical year. (See FINAL REPORT: PART 1B for interpretation of these figures). Table 2-B is an estimated irrigation schedule for these two crops and the required effective application. Table 2-C is an estimate of the total consumptive crop water requirement and the resulting irrigation requirement, both adjusted to 74% irrigation efficiency. The 74% level is the average irrigation efficiency of Owsley during 1977 through 1980. The potential efficiency is higher than 74%. Table 2-D is a break down of the actual total system irrigation demand by month for 1978. Table 2-E is a listing of single irrigator statistics for the same year. This information shows who the high and low water users were, the acres farmed, the total water demanded, the seasonal application, and the fraction of the total acres and water accounted for by each user. Also shown are the share holders who did not use water in 1978.

The detail of the results that follow are available for all years of this study. A single year`s data have been selected in Figures 2-C and 2-D in order to demonstrate the application.

CASE STUDY NO. III

DEVELOPING RECOMMENDATIONS FOR REVIEW OF PROJECT WATER POLICY, MANAGEMENT, AND OPERATION

Background. The King Hill Irrigation District began delivering water in 1908 using water diverted from the Malad River. The headworks to the system included an inverted siphon across the Snake River. In 1978 the system delivered water until July when the last in a series of major structural failures occurred. Before the failure occurred, the district was paying on two loans on major rehabilitation projects. Thirty miles of canals, siphons, and flumes from the diversion point to the first delivery were not economically repairable. The 52 year old gravity system had no water supply.

In a flurry of activity, four sites along the Snake River were selected as pump diversion points to supply the remaining 50 miles of the system. The plants were designed, built, and functioning by May 4, 1979. The first season of operation as a pump supplied project was expected to be a operational challenge but it also developed into a budgetary challenge as well. The budgeted costs of system operation jumped from

$12.88 per acre in 1977 to $35 in 1979. To the alarm of the irrigators, it jumped to $45 in 1980 and $59 in 1981.

The University of Idaho became involved in 1979. That same year, the Soil Conservation Service and University of Idaho agreed to cooperate to eliminate duplication. Results of the study were presented to representatives of the King Hill Irrigation District at three seperate meetings.

The Situation. The board of directors believed that the district was paying too much for the energy component of water delivery costs. System operators blamed rehabilitation design (new pump stations), canal seepage losses, and excessive irrigation demand. Irrigators blamed the system operators and their neighbors for mismanagement. Farm operating costs were suddenly uncomfortably high. Morale was low.

Method of Investigation. System operation was observed during 1979 and 1980. The new pumps were tested for overall energy efficiency. The district system below Glenns Ferry was selected for closer study as it appeared to have the most potential for improvement. At one thousand-foot intervals, canal cross sections were surveyed and canal flow was measured at selected points. Seepage meter measurements were conducted at selected points. Irrigation efficiency was measured. Crop acreages were inventoried and classified by irrigation method and soil type. Consumptive requirements of irrigated crops were calculated.

Results and Recommendations. (First Meeting) After analyzing the data and considering mutual observations, the following points were presented at a meeting of the board of directors, by the Soil Conservation Service and the University of Idaho on February 6, 1981.

1. Conversion from a single point diversion system to multiple point diversion system resulted in channels with an unnecessarily high wetted perimeter leading to excess seepage. Recommendation: Shrink the channels by 50% from the Black Mesa Pumps to the Glenns Ferry Siphon and abandon all unnecessary canal reaches.

2. Seepage losses below Glenns Ferry amounted to 10.6 cfs in a channel (conveyance efficiency was 84%) supplied with 67 cfs. Two reaches totaling 18,300 ft. out of the 52,000 ft. of unlined portion of the Glenns Ferry-Hammett canal accounted for 9.1 cfs. Recommendations: Line these two reaches.

3. A reasonable expected irrigation efficiency given the soils, crops and irrigation and methods is 50%. The average irrigation efficiency was 32%. The overall project efficiency was 27%. By independent calculation, the Soil Conservation Service and University of Idaho arrived at the following figures. The average amount of water entering the Glenns Ferry area was 9 1/4 ft. per acre where 4 2/3 was a reasonable irrigation requirement and 2 1/2 ft. was the crop consumptive requirement. Recommendation: Reduce excessive water application on the farm in the Glenns Ferry area.

4. Over the years, water measurement and record keeping practices have become poor to non existent. Recommendation: Install weirs and flow meters, lock head gates, limit use to water rights and record each user's total use.

5. Present water policies penalize the efficient water user and reward the inefficient one by charging the same per acre water accessment. Recommendation: Set a seasonal total water application and charge for water by the unit over this amount. Reward good irrigation water management with cost incentives.

(Second Meeting)

On February 16, 1981, after discussion with members of the board of directors, the University of Idaho conducted a water measurement workshop for the district staff and interested water users, including members of the board. Worksheets were provided illustrating standard flow measuring devices, how they operate, how to calculate flows, and common problems with each. Several portable and semi-portable meters and devices were displayed. United States Bureau of Reclamation "Water Measurement Manuals" were provided for the workshop and subsequently ordered for the district's use. One hundred "Water Measurement Bulletins", enough for every water user in the district, were delivered for general distribution. The bureau manuals were promoted as the best reference for the majority of water measurement problems and that most questions could resolved by them. Additional literature on water regulations were supplied. Reaction to the workshop was positive.

(Third Meeting)

On February 24, 1981, the University presented a another report to the board of directors to provide current cost figures and the effect on those costs of improved operating efficiencies and improved system user performance. The report is included here:

REPORT TO THE

KING HILL IRRIGATION DISTRICT

Pumping Operation Costs and

District Condition in 1980

INTRODUCTION

The King Hill Irrigation District is faced with a rather serious cost of operation problem. This paper is an attempt to examine the nature of the problem and suggest some solutions. The results of calculations presented here are based on data collected by the University of Idaho, Soil Conservation Service, and the district, mostly during the 1980 season.

PROJECT DESCRIPTION

The data presented in Table 3-A describes the project and its performance in 1980. In this table, tested pump efficiencies were used to determine the volume of water diverted. The value of power may differ from the district records because the average Idaho Power revenue per kilowatt-hour for agriculture pumps has been used (based on 65% pump duty). The energy used is from district records and acres are the number of acres for which the pump stations were designed. No correction has been made in Table 3-A for flow from Black Mesa to the Glenns Ferry area or for storage and surface water used in the King Hill system.

Table 3-B is a schedule of power requirements versus average depth diverted over the entire project and the cost of the power based on average power costs in 1980.

Table 3-C is a summary of calculations estimating irrigation demands on the 3394 acres of farm land under the Glenns Ferry plant given readily achievable irrigation efficiencies and taking into account the soil type, depth, irrigation system type and crops of 1980. The actual irrigation efficiencies were less than the ones listed in this table.

Tables 3-D1, 3-D2 and 3-D3 present the range of estimates of pumping costs resulting from varying the efficiency of both the ditch (conveyance) system and the on-farm irrigation system. The crop requirements were calculated taking into account the soils and crop varieties. The tables should be used to target the acceptable pumping diversions and associated costs. Note that the lifts and pump efficiencies are all different and the efficiency estimates bracket the existing levels.

Table 3-E is a breakdown of where water was used during 1980 and the amounts. Because the delivery totals were not available, estimates for conveyance and irrigation efficiencies were made. The system efficiency, or the ratio of required water to diverted water should be rather close so that only the amount delivered to the turn out is in question. In the Glenns Ferry area, total system losses were in an approximate ratio of one part conveyance losses and two parts farm losses.

DISCUSSION

The information in this paper is intended to help the King Hill Irrigation District, Board of Directors attach some numerical values to the cost of operating their district. It is also intended to show some options as to where they may wish to put their effort in reducing their operating costs.

At this point there is insufficient informaton to fix definite ditch (conveyance) and irrigation efficiencies. This requires detailed water records. There are good estimates of the volume of water diverted, and the volume of water required to grow healthy crop plants. The irrigator controls the irrigation efficiency, and the state and operation of the irrigation water delivery system determines the conveyance efficiency.

Water Conservation Incentive Programs

GENERAL

It is clear, at this time, that the cost of diverting and distributing water on the King Hill Irrigaiton District is high. The question of whether it is too high or rather, whether it is acceptable is up to the Board of Directors and their constituency. The range of variable operating costs are shown in Table 3-D of this report. This section deals with the energy cost of delivering water to the farm.

The District as a processor and handler of material needs to (1) meet its operating expenses and (2) maintain the system at the lowest cost. The following are two suggested plans the Board may wish to consider in order to plan for short and long term funding while upgrading the system and, at the same time, partially reimburse the efficient water user and charge the inefficient water user for his excesses.

THE CONSERVATION PROGRAMS

Plan No. One:

1. Budget for 6.7 ac-Ft/Ac in the first year.

2. Charge conveyance system losses against the general energy fund.

3. Measure water and calculate the average water demanded per acre project wide.

4. Rebate year end energy excesses to users in proportion to the per acre difference from the project average. Rebate at the cost of pumping the delivered water. (Example: Low water users receive a check and high water users receive a bill invoice).

5. Apply the remaining funds due to reduced total demand to the following year's energy budget or toward system update.

Effect of Plan One. The cost of building and operating efficient on-farm irrigation systems is partially offset by revenue from the high water users. District wide, the net cost of delivering water is the same to the District. The total volume demanded will decrease. The following year's budget for energy will decrease. A portion of the savings could finance new facilities. There is a direct, strong, current season incentive to use water prudently and water users are charged for exactly what they use.

Plan No. Two:

Step 1,2,3,and 5... same as Plan No. One.

4. Same as Plan No. One except, do not rebate to low water users. Do charge the high water user at the current season pumping cost.

Effect of Plan Two. Efficient water users are not reimbursed by inefficient water users, but there is an overall incentive to decrease water consumption. Carryover revenue is greater than Plan No. 1.

COST INCENTIVE PLANS

Table 3-F is a schedule of per acre rebates to irrigators and Table 3-G is the resulting charge per acre on the specified soil type and at the irrigation efficiencies indicated. It was assumed that the average delivery was 4.31 ft. per acre project wide, that the pre-season assessment was $44.86 per acre, and the year end Idaho power credit was $25.94 per acre. 1980 power rates were used and average system lifts and pumping efficiencies were considered.

There may be a danger to Plan No. One. Suppose that a large portion of the irrigators chose to develop their own sources of water and their individual demand went to zero. this would result in the system losses being distributed among fewer users and smaller acreages. Of course, as the conveyance system becomes more efficient, the problem would become less important.

There is a pressing need to reduce water pumpage. Suddenly imposed, or phased-in economic incentives are two extremes. Imposed water regulations may be another alternative. A water policy could be implemented such that at, say 4.8 ac ft per acre, the water is turned off. There may be some legal problems on this alternative. Another alternative might be to disallow runoff not used in the immediate area of delivery to eliminate waste and deep percolation losses. In the short run, cost incentives seem to be a positive approach that could be immediately implemented.

RECOMMENDATIONS

The following are some possible areas you may already have considered. Together, they suggest a comprehensive knowledge of the "State of the District" as seen by unbiased observers . We recommend that you formulate a plan of action based on these suggestions.

A. Financial Standing of the District
   1. Document the standing of the District to date.
   2. Develop cost values from input resulting from studies on "Water and Power Conservation", "District Rehabilitation" and "District Operation".
   3. Set priorities and establish estimated dates for necessary action.
   4. Develop cash flow diagrams of the district for 1981, 1986, and 1991, taking into account any increasing fixed and variable costs.
   5. As closely as possible, develop acceptable ranges of operating costs the district can support from the producers standpoint.
   6. Consider the cost effectiveness of the District purchasing, making, or performing goods and services at cost to encourage water and power conservation <u>on the farm</u> (Example: fabricating slip forms for ditch lining. Use of district equipment <u>at cost</u> to improve farm systems. Contract for or construct farm water measurement and control structures and provide to users at cost.)

B. Water and Power Conservation
   1. Develop an understanding of the sources of the Districts operating costs, as it relates to water and power. Make this information available to irrigators. (See some suggestions in this report.)
   2. Find out for certain what is and isn´t legal under the updated Idaho Code. (Obtain a copy of the Idaho Code, Volume 8. See titles 42 and 43 and current updates).
   3. Develop a water user education program. Ask for assistance from SCS, University of Idaho, public organizations or utilize district resources to promote water conservation and promote prudent power use.

C. System Rehabilitation
   1. Develop a district wide water measurement device assessment in two parts (Example: state of the present system, and overall water measurement requirements.)
   2. Continue studies by section on total district needs as time allows.

3. After an assessment of required canal capacity requirements, redesign, shrink, and line canals in the order of a priority assigned to them. Design new control devices to allow for the smallest safe wetted perimeter.
4. When equipment and manpower is available, charge the district resources out at cost to promote on farm water conservation.
5. Design and build efficient flotation gear for pump station moss problems.

D. District Operation

1. Do not spill water from Black Mesa to Glenns Ferry. This water has been lifted 87 feet higher from the Glenns Ferry water and must go through a rather long leaky canal.
2. Record hours, amps, and volts in as much detail as possible on each pump and pump station.
3. Independently compare pumpage to direct measurement of total plant flow.
4. Utilize temporary measurement techniques until permanent devices are installed.
5. As water measurement capability increases, identify sources of loss and the actual users.
6. Set up an efficient water accounting procedure.
7. Build office accounting procedures around the Board of Director´s "need to know".
8. Develop a comprehensive water policy for the district.

Table 3-A. Station and Project Performance, Design and Cost Values. KHID for 1980.

Pump Site TDH = ft	Design Ac % Total	Div. Water % Total	Energy Use % Total	Cost Cost/Ac	Avg Div (ft) Pump Sta. Eff.
Wiley	1,395 A	8,622 AF	2,448,720	$52,647	6.18 ft
TDH = 208	12%	11.2%	10.2%	$37.14/A	75%
Black Mesa	5,076 A	32,803 AF	12,075,900	$259,631	6.46 ft
TDH = 266	43.7%	42.5%	50.2%	$51.15/A	74%
King Hill	1,052 A	4,700 AF	1,282,400	$27,550	4.47 ft
TDH = 197	9.1%	6.1%	5.3%	$26.18/A	74%
Glenns Fry	4,082 A	31,111 AF	8,,265,600	$177,710	7.62 ft
TDH = 179	35.2%	40.3%	34.3%	$43.54/A	69%
KHID-Avg	11,605 A	77,236 AF	24,071,620	$517,540	6.67 ft
TDH = 222	100%	100%	100%	$44.60/A	73%

Table 3-B. Schedule of Expected Diversions and Costs for various levels of Energy Use on the KHID System.

Energy Used (Million-KWH)	Volume Diverted (Ac-Ft)	Depth Diverted (ft)	Energy Costs ($)	Average Cost ($/Ac)
10.0	32,111	2.77	$215,000	$18,53/A
12.5	40,139	3.46	268,750	23,16/A
14.0	44,955	3.87	301,000	25.94/A
15.0	48,166	4.15	322,500	27.79/A
17.5	56,194	4.84	376,250	32.42/A
20.0	64,222	5.53	430,000	37.05/A
22.5	72,249	6.23	483,750	41.68/A
24.0	77,066	6.64	516,000	44.46/A
25.0	80,277	6.92	537,500	46.32/A

Table 3-C. Summary of Expected Irrigation Demands on the Glenns Ferry System given Conditions below the System, Crops of 1980 and Standard (not high) Irrigation Efficiencies. Note that these Irrigation Efficiencies are Probably Higher than 1980 Average Values.

Irrigation Method	Soil Type	Irrigation Efficiency	Turn Out Demands	Acres	Average Applied
Sprinkler	Loamy Sand	65%	1640 AF	389 A	4.2 ft
Sprinkler	Sand	65%	5279 AF	1359 A	3.9 ft
Gravity	Loamy Sand	40%	3456 AF	477 A	7.2 ft
Gravity	Sand	40%	7832 AF	1167 A	6.7 ft
Overall		49.5%	18,207 AF	3394	5.4 ft

Table 3-D1. Effect of Conveyance and Irrigation Efficiency on Pumping Costs by Station. Wiley and Black Mesa.

Area A=Acre	Irrigation Requirement (Ac-ft)	Conveyance Efficiency (high-low)	Irrigation Efficiency (high-low)	Pump Diver (Ac-ft)	Pumping Cost ($)	Cost per Acre ($-Ac)	Diverted Depth (Ac-ft/Ac)
Wiley A=1395	3,566 AF	95%	70%	5,362	$32,744	$23.47	3.84
			50%	7,507	$45,842	$32.86	5.38
		90%	70%	5,660	$34,563	$24.78	4.06
			50%	7,924	$48,389	$34.69	5.68
Black Mesa A=5076	13,034 AF	80%	70%	23,275	$184,218	$36.29	4.59
			60%	27,154	$214,920	$42.34	5.35
		60%	70%	31,033	$245,623	$48.39	6.11
			60%	36,205	$286,560	$56.45	7.13

Table 3-D2. Effect of Conveyance and Irrigation Efficiency on Pumping Costs by Station. King Hill and Glenns Ferry.

Area A=acre	Irrigation Requirement (Ac-ft)	Conveyance Efficiency (high-low)	Irrigation Efficiency (high-low)	Pump Diver (Ac-ft)	Pumping Cost ($)	Cost per Acre ($/Ac)	Diverted Depth (Ac-ft/Ac)
King Hill A=1052	2,656 AF	90%	70%	4,216	$24,716	$23.49	4.01
			60%	4,918	$28,836	$27.41	4.68
		80%	70%	4,742	$27,806	$26.43	4.51
			60%	5,533	$32,440	$30.84	5.26
Glenns Ferry A=3394	9,012 AF	80%	65%	17,331	$119,060	$35.08	5.11
			30%	37,550	$257,964	$76.01	11.07
		60%	65%	23,108	$158,747	$46.77	6.81
			30%	50,067	$343,951	$101.35	14.75

Table 3-D3. Effect of Average Conveyance and Irrigation Efficiency on Pumping Cost of the Total System. King Hill System.

Area A=Acre	Irrigation Requirement (Ac-ft)	Conveyance Efficiency (high-low)	Irrigation Efficiency (high-low)	Pump Diver (Ac-ft)	Pumping Cost ($)	Cost per Acre ($/Ac)	Diverted Depth (Ac-ft/Ac)
KHID-Ave A=10,917	28,269 AF	80%	60%	58,893	$419,175	$38.40	5.39
			50%	70,672	$503,009	$46.08	6.47
		60%	60%	78,525	$558,899	$51.20	7.19
			50%	94,230	$670,679	$61.43	8.63

Table 3-E. Station and Project Performance. Water Diverted and Utilization Estimates on the KHID System for 1980.

Acres A=Acres	Diverted Conv. Eff.	Delivered Irr. Eff.	Required Sys. Eff.	Avg. Req'd Avg. Appl'd Avg. Div'd
Wiley A=1,395	8,622 95%	8,191 AF 44%	3,566 AF 41%	2.56 F 5.87 F 6.18 F
Black Mesa A=5,076	30,413 AF 60%	18,248 AF 71%	13,034 AF 43%	2.57 F 3.59 F 5.99 F
King Hill A=1,052	4,700 AF 85%	3,995 AF 66%	2,656 AF 57%	2.52 F 3.23 F 4.47 F
Glenns Ferry A=3,394	33,501 AF 60%	20,100 AF 45%	9,012 AF 27%	2.66 F 5.33 F 9.87 F
KHID-Avg. A=10,917	77,236 Af 65%	50,531 AF 56%	28,268 AF 36%	2.59 F 4.31 F 7.07 F

Table 3-F. Ranges of Per Acre Rebates to Irrigators under Irrigation Efficiencies and Soil Conditions.

Irrigation Efficiency on Soil Types	Plan No. One[1] \$ Rebate Changes + = Credit to Irrigation	Plan No. Two \$ Rebate Ranges − = Added Charge
65% on Sand	2.85 R 28.79	0.00 R 0.00
65% on Loam	0.63 R 26.57	0.00 R 0.00
40% on Sand	-10.08 R 9.86	-16.08 R 0.00
40% on Loam	-19.50 R 6.81	-19.50 R 0.00
System Average 56%, all soils	-19.50 R_{Av} 22.79	-19.50 R_{Av} 0.00

(1) Note that the range is \$25.94/Acre, or the amount of the Idaho Power year end credit on Plan One and system averages are extremes of the above.

Table 3-G. Ranges of Per Acre Energy Charges to Irrigators Under Plan No. One and Two.

Irrigation Efficiency on Soil Types	Plan No. One $ Yearly Charges to Irrigators	Plan No. Two $ Yearly Charges to Irrigators
65% on Sand	16.07 YC 42.01	18.92 YC 44.86
65% on Loam	18.29 YC 44.23	18.92 YC 44.86
40% on Sand	35.00 YC 60.94	35.00 YC 60.94
40% on Loam	38.05 YC 64.36	38.00 YC 64.36
System Average 56%, all soils	16.07 YC 64.36	18.92 YC 64.36

CASE STUDY NO. IV

DEVELOPING PUMP TEST DATA AND RECOMMENDATIONS FOR PUMP FACILITIES

The Roza Irrigation District was one of ten pumping projects selected to participate in this University study. The district was selected because it depended on pumps to deliver a substantial portion of its total irrigation demand. It`s operators dealt with many routine problems common to irrigation projects.

The Roza Irrigation District manager is Henry Vancik who was interviewed and agreed to cooperate in the study. He referred the university investigator to his pump foreman in order to arrange for the pump tests. The pump foreman interview, observations, pump tests and results are presented here.

The district had a very progressive maintenance and upkeep program on district pumps, canals, and structures. The operation appeared to be well organized and the management allowed itself only a few operational luxuries. The district tested its pumps for capacity but not energy efficiency at the end of each season. Two men worked full time on pump maintenance and operation.

THE ROZA PROJECT VISIT

The university pump test team arrived at Sunnyside, Washington in a van filled with pump test equipment on 7-9-79 and tested pumps on 7-10-79.

District Field Operation

Water delivery adjustments are made Monday through Friday and must be ordered 24 hours in advance. The delivery set on Friday is assumed to be the water order through the weekend. Some district personnel are on week-end call but not necessarily on duty during the weekend. Water orders were phoned to the district office and the Ditch Riders (DRs) picked up their orders at the office and delivered them.

There are 12 DR routes. Each "beat" included portions above and/or below the main canal. The Water Master and DRs are responsible for canals and laterals and daily operation of the pumps including ordinary valve adjustments and trashing problems. They rode the system Monday through Friday. Approximate pump flows were set by the DR using motor amps as a guide.

System maintenance and operation was supported by the mechanical shop and some 30 pieces of major equipment and a small fleet of light pickups and cars. In addition to the mechanical shop foreman the district has a Pump Foreman (Don Harker) and separate pump shop facilities.

INTERVIEW

Don Harker, Pump Foreman, Roza Irrigation District 7-10-79

SUBJECT; PUMP DUTY

Harker estimates that pumps on Roza are valved to pump discharges less than 75 percent of the peak capacity a total of 40 percent of the time. He mentioned that the pump duty is rotated in a bank of pumps to avoid excessive wear on a single unit but did not elaborate.

SUBJECT: CAVITATION

Because he has seen so much impeller and ring wear in pumps, Harker would like to see bypass (recycling of pump flow) spill (wasting water to the pump bay) flow control options on pumps that have been valved to the point of cavitation. The inefficiency in power and additional modification cost would have to offset the inconvenience, expense, and downtime of pump repair.

SUBJECT: LENGTH OF ROZA SEASON

Pumping began on Roza about 1 April this year. Full capacity pumping usually occurs from mid-June and ends about the end of August. The end the season is usually September 10 to October 20.

SUBJECT: PUMP UNIT MAINTENANCE RECORD

The records on installation, repair, and maintenance of all units that Harker would like tested cover 28 years and include a parts cross reference index. Every unit on Roza has a "record".

SUBJECT: WATER ABRASION

Westinghouse in Spokane reported to Harker that Roza has at least some magnetite in its canal water. They have suggested that this may be part of the reason for accelerated pump bearing wear. The water is relatively clean except for moss and trash problems. The district annually works on pump plant inlets when channel silt problems are being corrected.

SUBJECT: IN HOUSE PUMP MAINTENANCE

The district has been relying on commercial services for most of major repairs on impellers and bowls. The original pumps are now old enough that major repairs are necessary. At least one mold was made for Roza on one impeller. (Harker claims that one stainless steel impeller will pump more water than the corresponding impeller of bronze from which it was copied.)

One 17 5/8 in. impeller cost the district $5000. In the shop, there is at least one spare impeller for all pumps. With such high hardware and contractual maintenance costs, the district has decided to to maintain pumps as much as possible between major repairs.

SUBJECT: OTHER PUMP RELATED RECORDS

The Roza District was a USBR constructed project; consequently, early emphasis was placed on record keeping and order. For example, the district has a sketch detailing dimensions of every pump impeller on the project. There are also details available on each pump station. In addition the pump foreman maintains a materials and parts inventory. All of this contributes to the ability of the district to deal with problems before they occur or within hours after they occur. Harker claimed that, with the equipment he has available, he could have a six unit station torn down and partially transported to the district shop in one day.

SUBJECT: ROUTINE MAINTENANCE

The pump foreman or his assistant visited each pump station every Monday. In order to avoid habitual oversights, they alternated routes; one route being pump stations 1 through 9 (the upper division) and the other 9A through 17 (the lower division). They lubricate the units and give the station a general inspection (packing, water cooled bearings, heat, voltages, "noises", surprises, etc.). They apparently do <u>not</u> measure pressure between the pump and valve or routinely record station power consumption. The pump foreman has necessary equipment in his shop or on his truck to quickly remove or install equipment on short notice.

SUBJECT: PUMPS TO BE TESTED

The pumps on pump station 14 and 15 supply two higher laterals. There is a water control (measurement) problem that Harker would like resolved. Because there has not been a positive water measurment device at these two stations, the pump discharge has been set with an ammeter; verification of the flow estimate involves over a mile of ditch rider travel.

PUMP TESTING

Field Facilities Description.

Some of the pump banks share the same foundation and pump bays with pumps that deliver to adjacent areas above the main Roza (Yakima Ridge) Canal. Pumped spill and waste water returns to the Yakima Canal. Water delivered from Roza canal may also be spilled or wasted into the Sunnyside Canal.

Pumps, motors, and service lights, etc. are owned and maintained by the district. Electrical service panels are accessed by both USBR and district maintenance personnel. The district operates and maintains service panel equipment exclusive of meters; USBR owns and maintains the electrical delivery system through the transformers including station watt hour meters. It was not clear to the investigator as to who owned the service panels and equipment. Table 4-A contains some additional information on the pump units tested on 7-10-79.

TABLE 4-A

PUMP NO.	PUMP HP	Q (cfs)	PUMP MOD	MOTOR MAKE	PUMP MAKE
R14-1	301	11.02@ 241 ft	12-LC-3	Allis Chalmers	Worthington
R14-2	301	11.02@ 241 ft	12-LC-3	Allis Chalmers	Worthington
R14-3	301	11.02@ 241 ft	12-LC-3	Allis Chalmers	Worthington
		(Low Lift)			
R15-1	364	11.69@ 275 ft	12-LC-3	Allis Chalmers	Worthington
R15-2	235	14.01@ 148 ft	14-LC-3	Allis Chalmers	Worthington
R15-3	235	14.01@ 148 ft	14-LC-3	Allis Chalmers	Worthington
		(High Lift)			
R15-4	365	11.69@ 275 ft	12-LC-3	Allis Chalmers	Worthington
R15-5	365	11.69@ 275 ft	12-LC-3	Allis Chalmers	Worthington
R15-6	365	11.69@ 275 ft	12-LC-3	Allis Chalmers	Worthington

Test Procedure

The OBJECTIVE of these tests was to not only determine the open valve capacity of the pump and the motor-pump efficiency of each unit as the other units were operating but to measure single unit capacity and efficiency at several points in the normal operating range of the pump (ie., valving).

The PROCEDURE was to read station voltage, station KW demand and individual adjacent motor amperage while the dye samples were being taken and the test motor amperage read. This procedure was repeated at three to four valve settings on units R14-1, -2, -3, and R15-4, -5, -6. Single points were measured for units R15-1 and -2. After the test, the valve was returned to its original setting.

Flow measurement was by the dye dilution method. Dye injector calibration was checked before and after the test. Power consumption was determined from metering at the site; service panel meter calibration was not verified. Two dye samples with a check sample were taken. All dye sample measurements were double checked. There were before and after watt-, volt-, ammeter readings to check for constant values during each test.

Dye was injected into a hose and fed to the pump by allowing the end of the feeder hose to be swept upward into the intake of each pump. Samples were generally taken from cooling water taps.

Discussion (electrical). The calculated Power Factor at station 14 is consistent from motor to motor (ie., ammeter to ammeter). The electrical metering calibration is probably consistent at station 14 and a reasonable assumption would be that it is accurate since the overall station efficiency is in the same range as the individual units. Adjacent pumps were open valved as the tested unit was being operated. In addition, the watt-meter registered a corresponding change in demand as pumps were throttled.

The calculated power factor at station 15 is not consistent and in one case, improbable. The calibration from ammeter to ammeter is probably not the same. The ammeter may be reading high on unit R-15-1 and low on unit R-15-5. In addition, throughout the test, the watt-meter did not reflect a change in station kw demand (it registered a constant 1325 kw).

Discussion (hydraulic). In general, the most serious problem with the flow measurement technique used in these tests was the use of cooling water as the diluted dye sample point. Another problem was that the dye

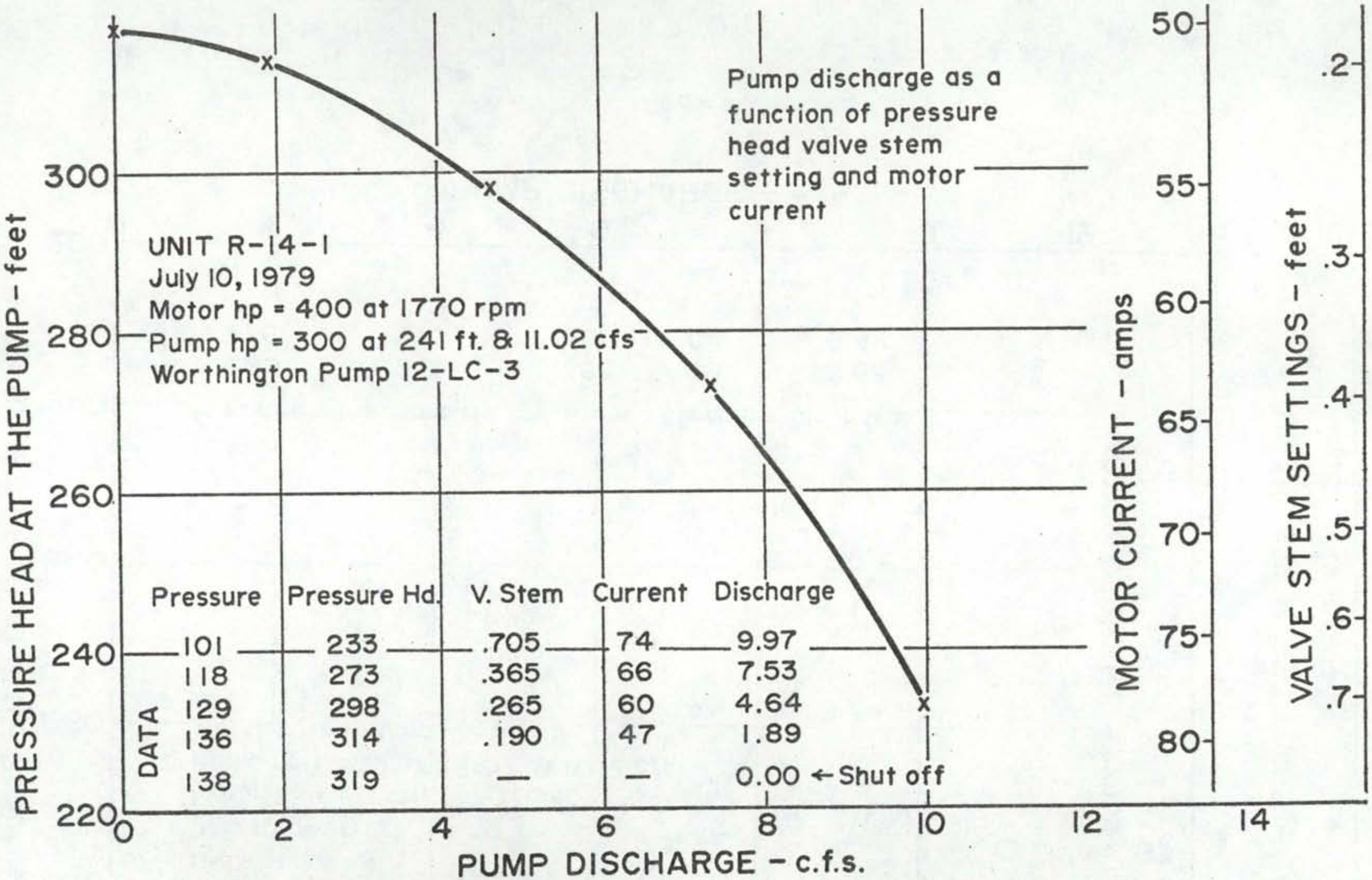

FIGURE 4-A: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-14-1.

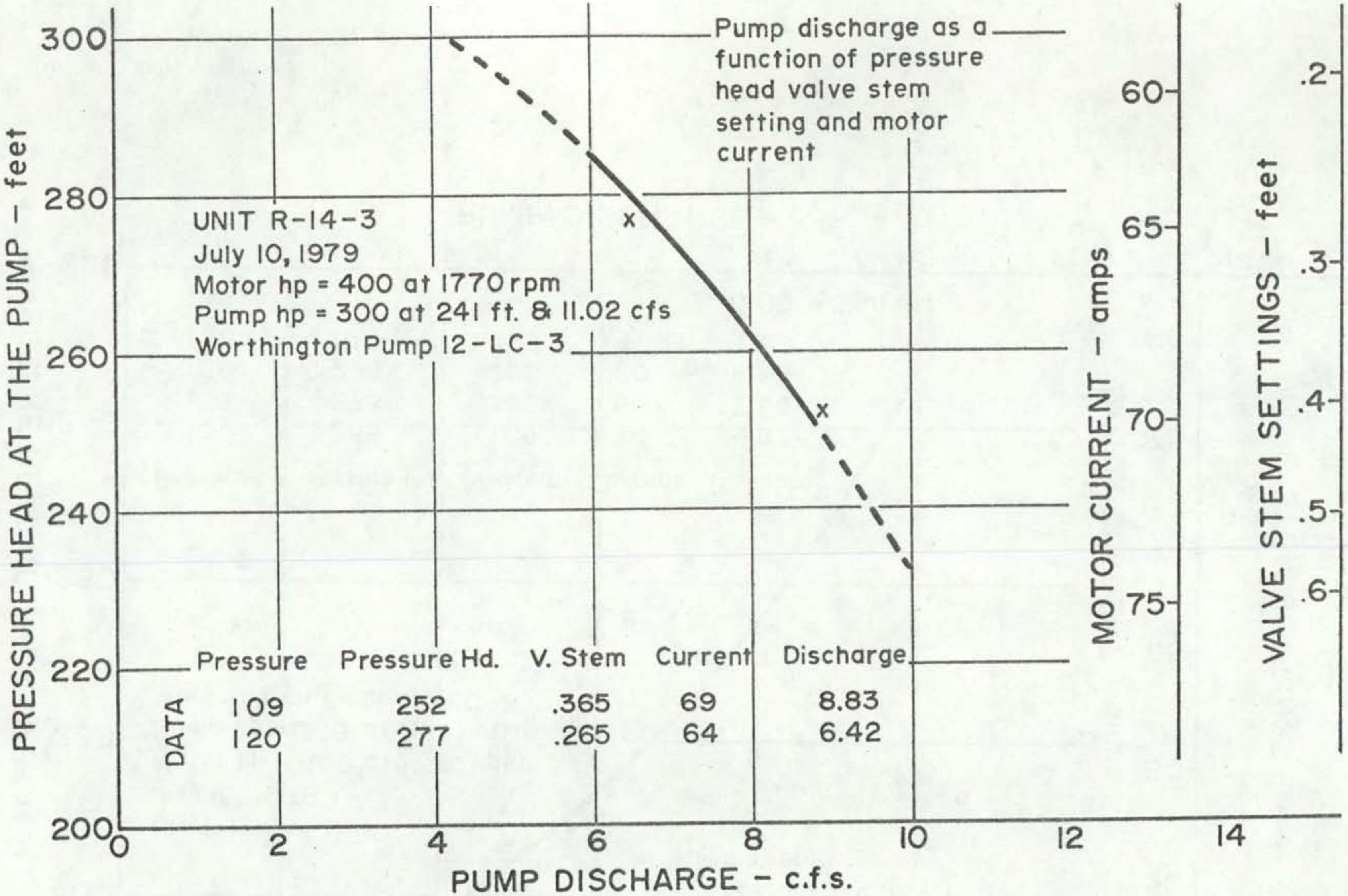

FIGURE 4-B: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-14-3.

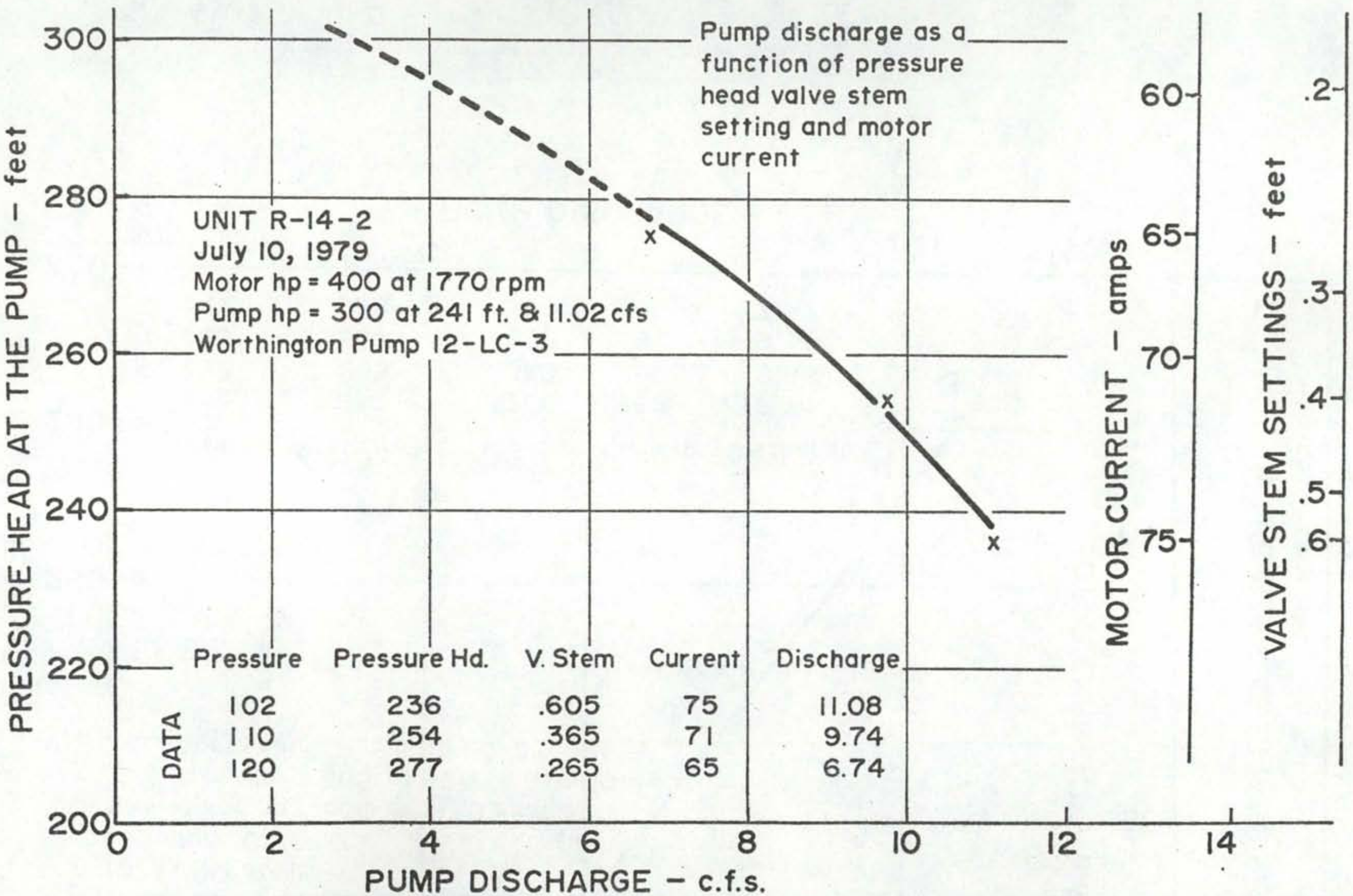

FIGURE 4-C: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-14-2.

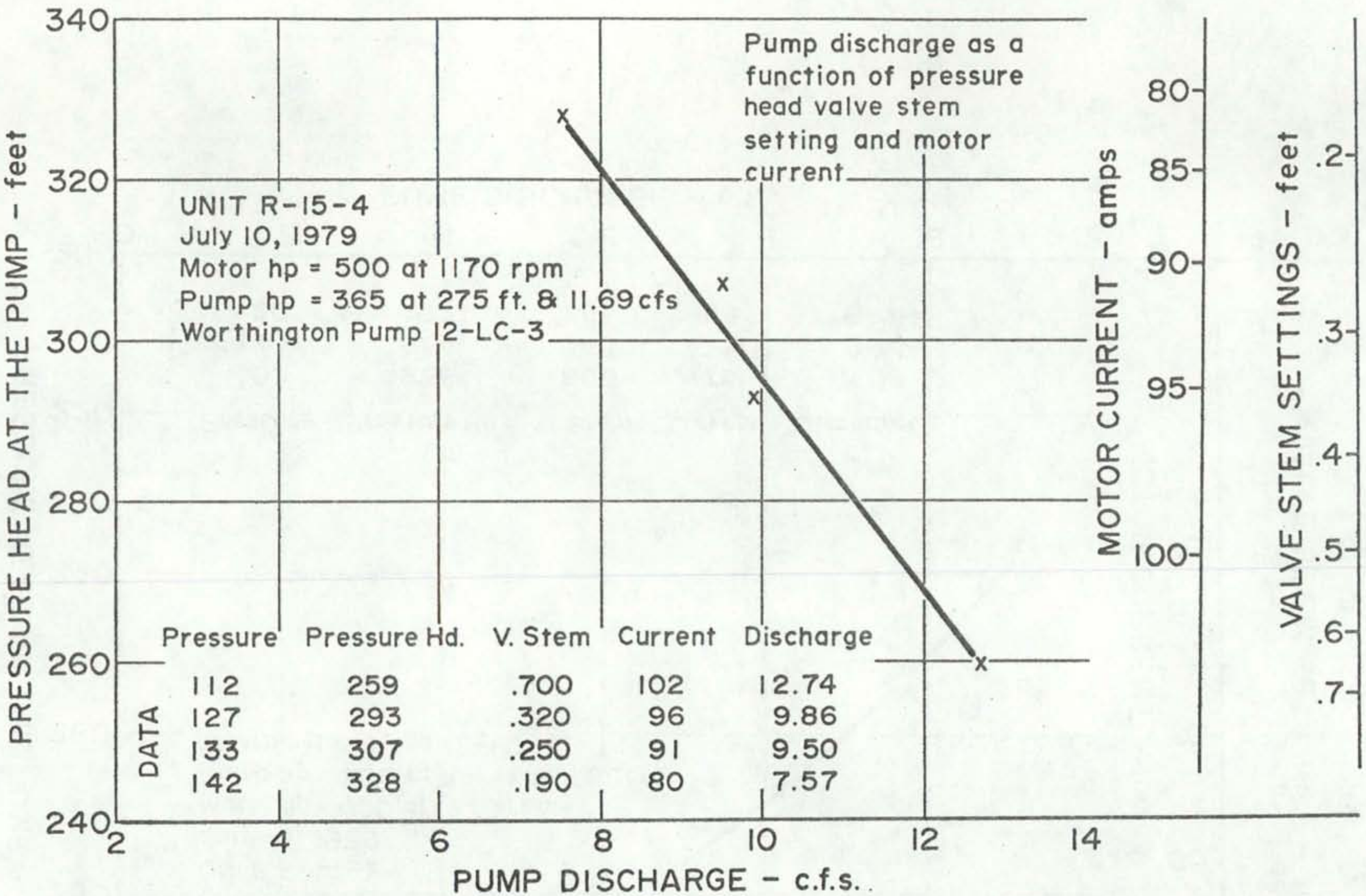

FIGURE 4-D: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-15-4.

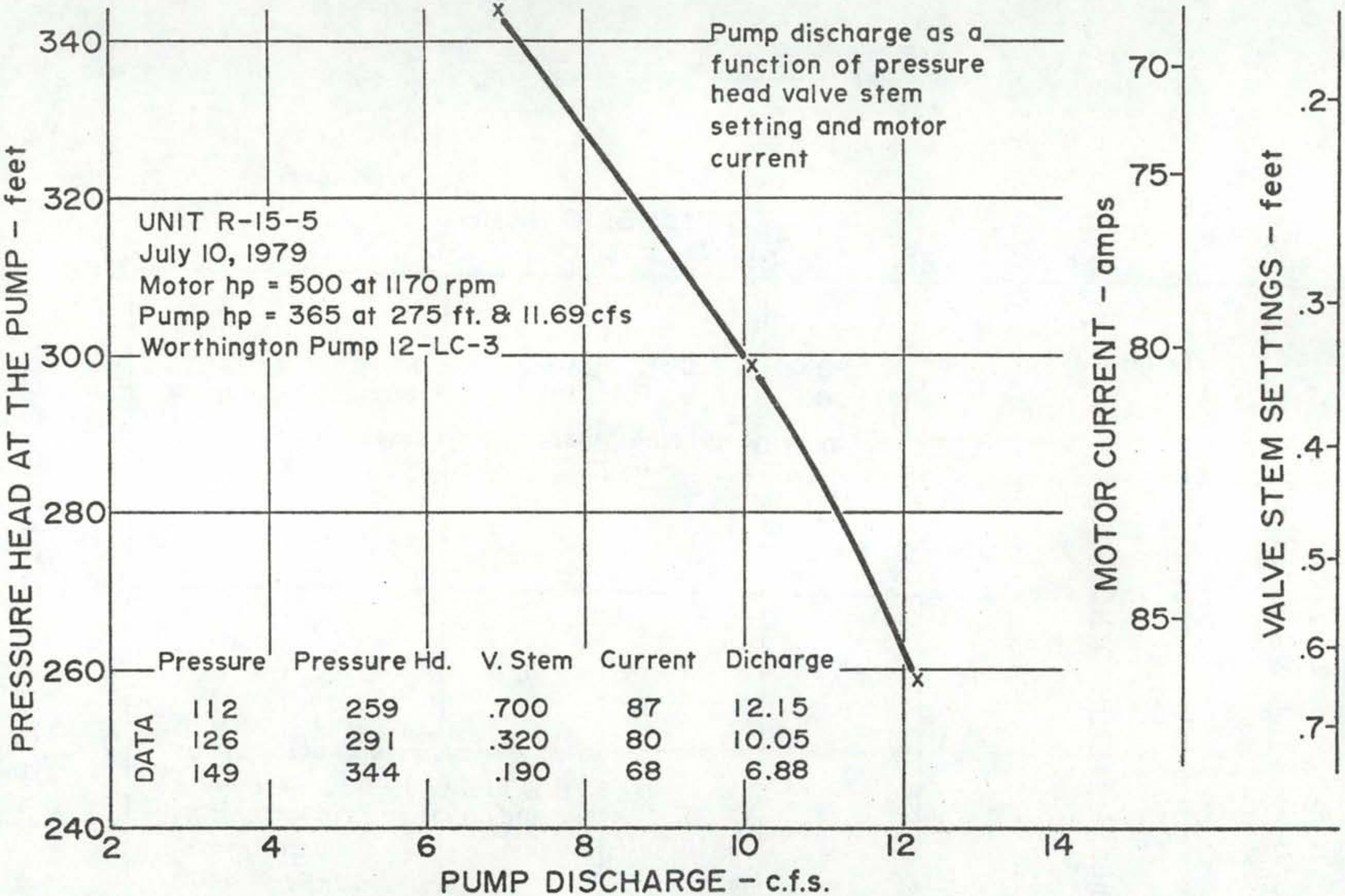

FIGURE 4-E: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-15-5.

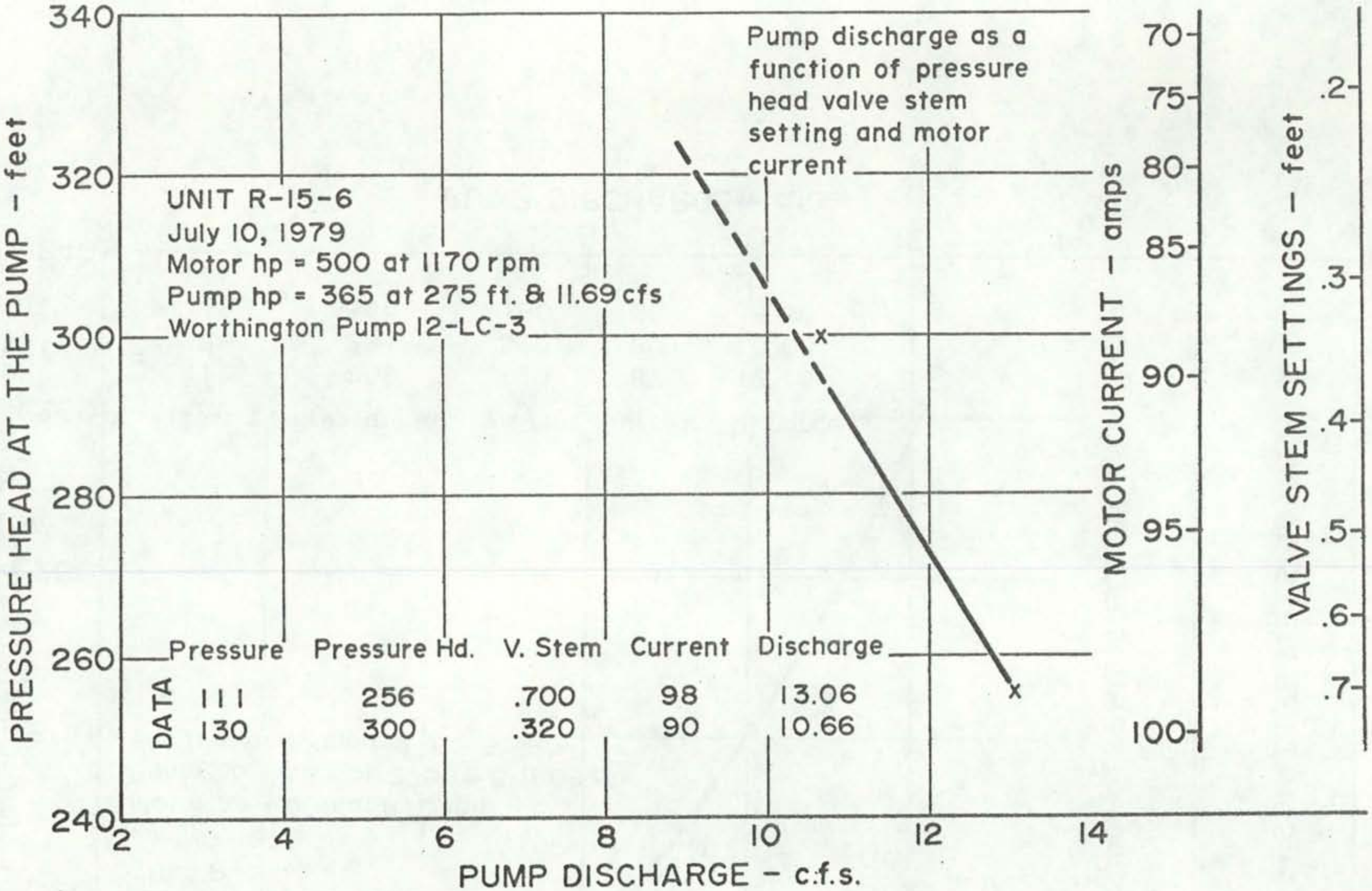

FIGURE 4-F: PUMP UNIT CHARACTERISTICS OF ROZA UNIT R-15-6.

feeder hose was held at the pump intake by upsweeping water; it was difficult to keep the hose in the intake at low flows and especially where swift water tended to pull the hose toward other pumps.

Improvements in the test prodedure for these tests would be to feed dye to the pump with a "J" tube on a stick or pipe. Sampling could be done farther downstream of the pump than was done on 7-10-79. If other methods of flow measurement are considered by the district, a tap in the pipe before the manifold incorporating a small valve would be convenient.

Flow measurements at station 14 were generally better than at station 15. Units R-15-1 and R-15-2 were tested at open discharge only. The open valve flows from 7-10-79 are compared in Table 4-B with flows measured by the district measuring discharge from single units with all other units off. The 7-10-79 test were made with all other units on.

With no pumping plant pre-preparation, the dye dilution method of water measurment made testing the Roza pumps possible while adjacent pumps were operating. If the district were to consider "pitot" type measurment equipment for their own use, permanent access ports installed on the pump discharge pipes would make flow measurment simpler than the dye method. "Collins", "Hall", and "Annubar" gages all require perpendicular pipe taps, at least eight pipe diameters downstream and two diameters upstream of restrictions or bends. The manifold arrangement on some Roza pumps may prohibit the use of pitot type meters.

TABLE 4-B

Roza Irrigation District

Peak pump capacity in c.f.s. at station 15.

Test Date	Unit 1	2	3	4	5	6
Fall 1977	14.77	15.05	15.93	13.13	12.29	13.33
Fall 1978	15.25	15.25	15.82	12.46	11.71	11.07
7-10-79	10.90	14.50	12.74	12.74	12.15	13.06

PUMP TEST DISCUSSION AND RESULTS

The results for the open valve settings are in Table 4-C1 and 4-C2. Results for the single pump-multi-point tests requested by the pump foreman are presented in Figures 4-A through 4-F.

In Table 4-C2, station KW demand (ie., "watt-meter") should be less than the sum of individual demand because each pump at its turn in the test was open valved and adjacent pumps were partially valved.

Air buildup in the eye of pump impellers has been a routine problem. An attempt was made to purge each pump of air before the tests (this attempt may or may not have been completely successful). The values in Table 4-C are the first of a set of four readings as the main valves were progressively closed within the normal operating range of the valve.

Best fit scales have been inserted in Figure 4-A through 4-F assuming that pressure head is related inversely and exponentially to motor current and valve stem settings. Correlation coefficients are listed in the Figures. Motor current here does show a close relationship to pump discharge but if the ammeters are not calibrated, the particular relationship is "ammeter-pump unit specific" (ie., change the motor, pump, or ammeter and the same relationship does not exist). The ammeter and valve stem are comparable devices when used as indicators of pump discharge.

A more direct relationship is pressure or pressure head versus discharge. A pressure gage between the pump and main valve would give field personnel immediate feedback as to the effect of maintenance, repairs, flushing, or air removal in addition to daily flow regulation.

Discussion (by-pass flow control).

The foreman discussed installing extra piping on pumping units to control net pump discharge as an alternative to throttling the pump with a valve. The reason for this was to reduce pump wear by keeping internal pump pressure low. There are factors affecting the advisability of this method of pump control. 1/ On at least one station, two of the larger units have mis-matched motors and pumps. If the pumps were allowed to operate with open valves and "spill" water, the motor would be loaded over the design safety factor 100% of the time. 2/ The power costs to the district are very low, but valving is usually slightly more efficient than spilling (or by-pass control). 3/ If spilling were to be used it should be started after valving has increased internal pump pressures to an established threshold value. If further reduction of net discharge were to be required, spilling or bypassing would be appropriate. 4/ Definite limits should be set on the degree of spill or valve to avoid wasted pump duty and energy. Established pump control operating procedures taylored to specific stations should be considered.

Discussion (pump throttling). Figure 4-A through Figure 4-F is a graphic representation of measured data; it was plotted as pressure head versus discharge and the auxillary scales were intended to give an alternative to ammeter estimates of pump discharge.

Discussion (pump efficiencies). The efficiency values shown in Table 4-B1 are probably correct. The efficiencies shown in Table 4-B2 are probably not correct. The efficiencies here are power output divided by the power input (WHP/EHP). The values from R15-4, 5 and 6 are not realistic but they have been included should the calibration factor of the electrical meters become known.

RECOMMENDATIONS

1. Have the electrical meters checked.
2. Carefully consider "by-pass pump control" in addition to throttling. Operate the majority of pumping units in a station at their most efficient operating point.
3. Install pressure measurement taps between the pump and its valve on all pumps. Put a small hand valve on each tap.
4. Use pressure gage readings to estimate single unit discharge Verify those estimates with ammeter readings or valve stem settings using Figures 4-A through 4-F.
5. Consider methods of measuring pump flow from a single pump independent of other units.
6. Calibrate units on other pump stations for operational purposes and as a check on wear and capacity.

CASE STUDY NO. V

OBSERVATIONS FROM A DITCH RIDER INTERVIEW AND RIDE

Project: Burley Irrigation District

Manager: Vaughn Egan

Ditch Rider: Gordon Davis

Date: September 27, 1979

Background. The office is in Burley, Idaho and the district serves 41,438 acres surrounding the town of Burley. The land is south of the Snake River at an approximate elevation of 4150 feet.

Project water supply is from the Snake River. Minidoka dam is the diversion point and gravity water flows through the South Minidoka canal to the first of three pumping lift stations in series, each lifting 30 feet. Water is diverted to the project above stations 1, 2, and 3 (15 pump units total) and peak station capacities are 1015, 830 and 540 cfs. The average tested energy efficiency of station 3 was 60 percent and 70 percent for station 2 in 1979. There is a maintenance foreman and crew employed by the district, and a pump plant operator on duty full time during the irrigation season.

Electric power for the main plants is generated at the federally owned Minidoka dam operated by the United States Bureau of Reclamation. Power costs at this time are approximately 4 1/2 mills per KWH. There are 18 small well and drainage pumps throughout the project which were installed primarily to relieve seepage problems.

In 1979, farm deliveries averaged 3.95 feet per acre and total diversioned were 6.11 feet. The estimated irrigation requirement was 1.70 feet and the total consumptive requirement was 2.25. Diversified crops are irrigated mostly by furrow and some border irrigation.

The Burley District was federally constructed and began operation in 1909. The present supply pumps are original and in very good condition. A new switching, monitoring, and control system on the pumping plants was tested and became operational in 1979. Forty automatic canal check controllers have been installed through out the system and the result is a very predictable canal water surface.

The office is well organized; the atmosphere is business like and there is an up to date map posted on a bulletin board. Records are orderly and up to date. There are 1100 farm accounts handled through the office by two full and one part time secretary. The district does not own or operate an office computer.

In 1978, the assessment to water users was $15.75 and $20.18 in 1979. The single largest portion of the increase was $2.40 per acre for controls and switching improvements. The present manager, Vaughn Egan, has compiled unit operation costs and calculated break-even points for district owned equipment.

Investigator Wells met Mr. Davis at the district office in Burley at 0645 and proceeded to the tail end of the "J" canal. Davis did have about 30 streams to deliver but during mid-season he will deliver 63 streams. The route covers the tail end of the J, G, and H canals.

Mr. Davis is about 55 and has worked for the district as rider for nine years. He has a practical knowledge of water measurement. His estimate of flow is from tabled values associated with specific measurement devices. As a rider on the tail end of three canals, he has had to deal with fluctuating water flow; he suspects that part of the "losses" on his route have been due to flow estimates from submerged orifices and flooded devices. He would prefer to deal with trapezoidal or at least sharp crested weirs that were not flooded but this is not always possible.

SUBJECT: Canal Response Time. From the main pumping plants, turn out delivery lags pumping plant delivery by 10 to 12 hours. One-half hour "down time" on pumping delivery means 3 hours of low water on the tail end.

SUBJECT: Automatic Canal Water Leveling. Davis' route covering the tail end of three canals would not be possible without automatic float controlled gates on the canals. Sensitivity on the controls is about one inch before an automatic adjustment is made. Only the last reach on the

J canal had low water; the others had sufficient water to maintain water surfaces. (The low water problem on the J canal was resolved between Davis and another ditchrider over the radio.) During early morning and late afternoon, gates were constantly readjusting due to flow changes, but the levels were maintained. A simple but most impressive system!

Power to gates is unmetered and supplied by South Side Electric and Unity Power REA's (non-Bureau power). The canal gates are subject to the same trashing problems as manually installed canal checks. The gates do result in less waste and better water service.

SUBJECT: Weed Control. The district does not chain its canals. Land and water weeds are treated chemically. The D. R. claims that since chaining has ceased, the canal banks have been more stable. The district was behind in its weed control program. Weeds are burned in the spring and sprayed throughout the irrigation season. Xylene is used for moss control.

SUBJECT: Erosion and Silt Loading. The district requires some sort of outfall for return flow to the canal in order to prevent bank sloughing. In extreme cases of point sediment contribution, the party responsible may be charged for maintenance but this is very rare. Water in canals was clear; it looked very clean.

Where canals have been cleaned with a backhoe, the fill has been deposited on the downstream bank. This has resulted in a more convenient, wider bank but creates an additional weed breeding problem.

SUBJECT: Canal Access. Since the district does not chain canals, the upper bank roads are not necessarily maintained. The upper bank had more weeds than the lower. The lower bank road surface along Davis′ route was well graded, graveled and heavily traveled by incidental routine traffic. The upper bank did have a road but at several locations weeds and fences blocked access.

SUBJECT: Water Measurement. Almost all water is measured on the district. Observed devices were submerged orifices of wood or steel and concrete, sharp crested trapezoidal weirs of wood, or steel and concrete. Broad crested weirs are used for water control. Most of the control and measurement devices were in good conditions with the exception of a few of the older wooden structures that are to be replaced. The district does a good job on maintenance.

SUBJECT: Drainage, Ditch Level and Gradient. Davis claimed that some of the early ASC funded ditch improvements were too high in elevation and resulted in measurement and delivery difficulties. This project is old so that major channel gradient problems have been resolved. Drainage remains a problem. High groundwater near Burley is a reoccuring seasonal problem but is significantly better since sump-canal pumpback units were installed and tailwater rechanneling (drying up Goose Creek) has occurred. The drain pumps do aid during peak water demand when pump plant capacity is fully utilized.

SUBJECT: The Ditch Rider and His Route. Mr. Davis drives his own pickup and receives $0.22/mile. He averages 60 miles per day with a daily route high of 145 miles and a two week high of 2200 miles. The pickup has a district radio which is used effectively.

The route runs seven days per week throughout the season, starts at 6:00 a.m. and can usually be completed before noon at peak demand. Water orders for the following day are taken over the phone at the Davis home from 12:00 to 13:30. Davis phones his orders to the district office and the office relays to Minidoka Dam and the B.I.D. pump plants. Davis himself operates from his home during the irrigation season. The overall impression is that the system is organized and smooth; trashing problems, surprise power supply outages (especially with the current season's experience with new supply switching and control equipment) has kept Davis out until early morning, but these are the exceptions and not the rule. When any of the ditch riders has a problem, prompt maintenance or help is a radio call away. To emphasize, this tail end route itself would not be possible without the automatic canal level control system. Eight routes cover the Burley canal system; consolidating and "stacking" otherwise laterally, long routes has been ditchrider time and mile efficient.

APPENDIX D

PUMP TEST RESULTS

Owsley Canal Company Pump Test Results

6-5-79

Pump	HP	Type*	Rated Speed[5]	Rated Voltage	Rated Amp	Amp	Voltage	PF[3]	KW	EHP[4]	TDH	Q	WHP	EPP[2]
M2	200	-	-	-	-	187	(462)	-	123.	165.	10	81.7	92.7	56 F
M3	200	MF	585	480	263	241	(452)	-	159.	213.	10	82.9	94.0	44 L
M4	150	MF	705	460	191	220	(462)	-	145.	194.	10	-	-	-

4. K_h = 0.6, CTR = 160, PTR = 4, N = 10, T = 32.5 sec. Electrical power estimates are by proportial division of total through watthour meter.

3. A blank indicates the power factor was not metered

5. Motor Speed was measured by strobe: M2 - 534 rpm, M3 - 534 rpm, M4 - 640 rpm

*. MF = Mixed flow pump

2. Pumps were not valved. Efficiency ratings in percent according to standards developed by Pacific Gas and Electric (ie, E = Excellent, G = Good, F = Fair, L = Low)

6-4-79

Osgood Canal Co. Pump Test Results

Pump	HP	Type*	Speed[5]	Rated Voltage	Amp	Amp	Voltage	PF[3]	KW	EHP[4]	TDH	Q	WHP	EFF[2]
U1	250	CDS	690	440	292	258	-	-	187	251.	62	24.08	169.	67 G
U3	125	CDS	860	440	151	135	-	-	99	131.	62	10.68	75.1	57 F
U4	250	CDS	690	440	292	265	-	-	212	284.	62	22.45	158.	56 F

4. K_n = 0.6, CTR = 160, PTR = 4, N = 10, T = 29sec. Electrical power estimates are by proportional division of total through watthour meter.
3. A blank indicates PF was not metered
5. Motor speed was measured by strobe: Ul - 648 rpm, U3 - 830 rpm, U4 - 637 rpm
2. Pumps 1 and 4 were not valved. Efficiency in percent ratings according to standards developed by Pacific Gas and Electric (ie, E=excellent, G=Good, F=Fair, L=Low)

OSGOOD CANAL COMPANY PUMP TEST RESULTS 8-1-79

PUMP[Ø]	HP	TYPE*	RATED SPEED	RATED VOLTAGE	RATED AMP	AMP	VOLTAGE	PF[3]	KW	EHP	TDH[7]	Q[8]	WHP	EFF[2]
U-K2	100	T	1775	440	119	106	503	(.82)	74	99	177	225	45.3	46 L
U-K3	125	T	1780	440	148	128	488	(.84)	91	122	193	3.14	68.8	57 F
U-K4$^{N}_{S}$	100	T	1775	440	119	109	475	(.87)	156	209	186	5.28	112.	53 L
U-K5E	100	T	1775	440	119	103	485	(.92)	80	108	147	3.44	57.3	53 L
U-K6$^{E}_{W}$	50	C	1780	440	62	57	462	Est .87	91	122	153	3.44	59.8	49 L
(U-K7)$^{E}_{W}$	50	C	1780	440	62	59	---	---	81	109	142	(3.49)	56.1	51 L
U-K8$^{E}_{W}$	50	T	1775	440	63	56	476	(.80)	73	98	164	1.33	24.7	25 L
U-K10$^{E}_{W}$	50	C	1780	440	62	--	---	---	41	55	141	2.42	38.7	70 E

* T = Turbine Pump; C = Centrifugal pump

Ø Canal pumping stations were tested rather than individual units. Indicated units were operating at test.

2. Efficiencies here are rated according to standard developed by Pacific Gas and Electric. (i.e., E = Excellent, G = Good, F = Fair, L = Low)

3. Except for K6, Power Factor here is the ratio of metered KW to measured KVA. The reading from K6 meter appears to be wrong.

7. "Total Dynamic Head" here is in feet and includes pressure head and distance from gage to water surface.

8. Flow is in Cubic Feet per Second.

Burley Irrigation District, Pump Test Results, Third Lift Pumps 7-19-79

PUMP	HP	TYPE*	SPEED	RATED VOLTAGE	AMP	AMP	VOLTAGE	PF[3]	KW	EHP	TDH[7]	Q[8]	WHP	EFF[2]
BD-3-1	720	C	200	2200	150	173	2380	.99	706	946	27	175	536	57 F
BD-3-2	900	C	360	2200	185	202	2380	.99	824	1105	27	205	628	57 F
BD-3-3	720	C	300	2200	150	177	2380	.99	722	968	27	205	628	65 G
Sum of Individual						552	2380	(.99)	2253	3020		585	1792	59
Total Station, Measured (by ammeter)						535	2380	.99	2183	2927	27	585	1792	61
Total Station, Measured (by wattmeter)									2127	2851		585	1792	63

* Pumps are submerged, feed to the eye from both sides and discharge from a "snake" into the penstock. The impellers rotate in a horizontal plane.

2 Efficiency in percent here are rated according to Pacific Gas and Electric Standards (i.e., E = Excellent, G = Good, F = Fair, L = Low).

3 The power factor was metered. Station 3 had a watt-meter but to be consistent, electrical demand was calculated using PF at both stations.

7 "Total Dynamic Head" was measured but does not include velocity head here.

8 Discharge was in cfs. Valve stems on BD-3-1 indicated 175 and on BD-3-3 indicated 180.

Burley Irrigation District, Pump Test Results, Second Lift Pumps 7-10-79

PUMP	HP	TYPE*	SPEED	VOLTAGE	AMP	AMP	VOLTAGE	PF[3]	KW	EHP	TDH[7]	Q[8]	WHP	EFF[2]
BD-2-1	720	C	300	2200	150	176	2410	.973	714	958	31	196	689	72 E
BD-2-2	720	C	300	2200	150	166	2410	.973	674	904	31	183	644	71 E
BD-2-3	720	C	300	2200	150	187	2410	.973	739	1018	31	196	689	68 G
BD-2-4	720	C	300	2200	150	174	2410	.973	707	947	31	197	693	73 E
BD-2-5	360	C	300	2200	75.1	100	2410	.973	406	544	31	-	-	-
BD-2-6	350	MF	450	2300	69.5	62	2410	.973	252	338	31	-	-	-
Sum of Individual						865			3513	4709				
Total Station, Measured							2410	.973						

* Refer to Table IIA. Information on the mixed flow was not taken.

7 The lift was measured and "TDH" does not include friction or velocity head.

8 Discharge was in c.f.s. Valve stems on BD-2-3 indicated 162 and BD-2-4 indicated 165.

NORTHSIDE PUMP COMPANY, NO. 2 PLANT PUMP TEST RESULTS 6-26-79

Pump[6]	HP	Type*	Speed[5]	Rated Voltage	Amp	Amp	Voltage	PF[3]	KW	EHP[4]	TDH	Q	WHP	EFF[2]
NP2-1	150	CDS	870	2200	34.8	29.2	--	--	115	154	64	15.74	114	74E
NP2-2	150	CDS	870	2200	34.8	29.5	--	--	116	156	64	16.29	118	76E
NP2-3	150	CDS	870	2200	34.8	31.7	--	--	125	167	64	18.12	132	79E
NP2-4**	150	CDS	870	2200	34.8	26	--	--	102	137	64	11.92	87	63G
NP2-5**	150	CDS	875	2200	35.3	23	--	--	91	121	64	4.70	34	28L
Overall	750					139.4			549	735	64	66.77	485	66

* Pump Type: CDS = Centrifugal, double suction

3 A blank indicates no metered power factor

4 Kn = 1.2, PTR = 20, CTR = 40, N = 10, T = 63 sec

6 Valve stem setting in feet were the following in order: 1.47, 1.42, 1.37, 1.43, 1.32

5 Motor speed was measured by strobe: 825, 825, 825, 825, 875

2 Efficiency in percent ratings a-cording to PG and E standards (i.e., E=Excellent, G=Good, F=Fair, L=Low

** Pumps cleaned the following day were found to be full of river trash

King Hill Irrigation District. Glenn's Ferry Plant Pump Test Results 6-27-79

PUMP	Hp	Type	Speed[5]	Rated Voltage	Rated Amp	Amp	Voltage	PF[3]	Kw	EHP	TDH	Q	WHP	EFF[2]
GF 1	400	T	1769	2300	92	95	2350	(.87)	336.	451.	178	14.35	290.	64 G
GF 2	400	T	1769	2300	92	96	2350	(.87)	340.	456.	178	14.73	297.	65 G
GF 3	400	T	1769	2300	92	94	2350	(.87)	333.	446.	179	14.73	299.	67 G
GF 4	400	T	1769	2300	92	101	2350	(.87)	358.	479.	179	15.00	305.	64 G
GF 5	900	T	1184	2300	199	196	2350	(.93)	741.	994	182	38.64	798.	80 E
GF 6	400	T	1769	2300	92	92	2350	(.87)	326.	437.	179	13.40	272	62 F
Total, Individual Measured						674						110.85		
Total Plant, Measured						663	2350				(179)	111.93		
Total Plant, Design					659							111.36		

2. Pump were not valued. Efficiency ratings in percent according to standards developed by Pacific Gas and Electric (ie. E = Excellent, G=Good, F=Fair, L=Low).

3. For Calculations, PF is assumed to be as indicated, ( ). The watt hour meter was not accessible. The PF values are in the working range as measured by the area electric power utility on similar motors.

5. Speeds here are rated motor speeds.

King Hill Irrigation District, King Hill Plant, Pump Test Results 6-27-79

Pump	HP	Type	Rated Speed[5]	Rated Voltage	Rated Amp	Amp	Voltage	PF[3]	KW	EHP	TDH	Q	WHP	EFF[2]
KH1	200	T	1775	460	224	208	--	-	148	199	197	6.92	155	78 E
KH2	200	T	1775	460	224	218	--	-	156	208	197	6.28	140	67 E
KH3	200	T	1775	460	224	212	--	-	151	203	197	6.68	149	74 E
KH4	200	T	1775	460	224	212	--	-	151	203	197	6.89	154	76 E
Total, Individual Measured						850			606	813		26.77	598	
Total Plant, Design												28.75		

3/ King Hill Plant's watt-hour meter was accessible

King Hill Irrigation District, Black Mesa Plant. Pump Test Results 6-28-79

Pump	Hp	Type	Speed[5]	Rated Voltage	Amp	Amp	Voltage	PF[3]	KW	EHP	TDH	Q	WHP	EFF[2]
BM1	600	T	1775	2300	130	89	2270				265	--		
BM2	900	T	1184	2300	199	192	2270	(.90)	679	911	266	23.12	698	77E
BM3	900	T	1184	2300	199	195	2270	(.90)	690	925	267	22.50	682	74E
BM4	900	T	1184	2300	199	192	2270	(.90)	679	911	267	22.96	696	76E
BM5	900	T	1184	2300	199	189	2270	(.90)	669	896	266	21.53	650	72E
BM6	900	T	1184	2300	199	196	2270	(.90)	694	930	267	22.50	682	73E

3. For calculation, PF is assumed to be as indicated, ( ). The watt hour meter was not accessible.

King Hill Irrigation District, Wiley Plant, Pump Test Results 6-28-79

Pump	Hp	Type	RATED Speed[5]	RATED Voltage	RATED Amp	Amp	Voltage	PF[3]	KW	EHP	TDH	Q	WHP	EFF[2]
W1	200	T	1775	460	224	220	--	--	160	214	209	-	-	-
W2	200	T	1775	460	224	196	--	--	142	191	208	-	-	-
W3	200	T	1775	460	224	214	--	--	156	209	208	6.54	154	74E
W4	200	T	1775	460	224	213	--	--	155	208	208	6.98	165	79E
W5	200	T	1775	460	224	214	--	--	156	209	208	-	-	-
W6	200	T	1775	460	224	211	--	--	153	206	208	7.07	167	81E
Total Plant, Individual						1268								
Total Plant, Measured									921	1235				

3/ Wiley Plant's watt-hour meter was accessible.

South Board of Control, "Old" Gem Pumps, Pump Test Results 7-16-79

				RATED										
PUMP	HP[1]	TYPE*	SPEED	VOLTAGE	AMP	AMP	VOLTAGE	PF[3]	KW	EHP	TDH[7]	Q	WHP	EFF[2]
SB-A1	1025	CDS	870	2200	232	220	2240	.988	843	1130	179	43.85	891	79 E
SB-A2	1025	CDS	865	2200	232	222	2240	.988	851	1141	(179)	40.75	828	73 E
SB-A3	1025	CDS	865	2200	232	190	2240	.988	728	976	(179)	-	---	----
SB-A4	1025	CDS	865	2200	232	232	2240	.988	889	1192	(179)	-	---	----
SB-B1	700	CDS	700	2200	160	139	2240	.988	533	714	111	37.79	478	67 G
SB-B2	700	CDS	700	2200	160	138	2240	.988	529	709	111	37.74	475	67 G
SB-B3	600	CDS	600	2300	150	[82]	2240	.988	[314]	[421]	(111)	30.82	388	----
SB-C1	330	CDS	495	2200	83	87	2240	.988	333	447	(70)	-	---	----
SB-C2	330	CDS	495	2200	83	87	2240	.988	333	447	(70)	-	---	----
SB-L2	xxx	xxx	xxx	xxxx	xx	20.5	2240	.988	79	105	xx	xx	xx	xx
Sum of Individual						1417.5	2240	.988	5433	7283				
Total Station, Measured						1320	2240	.988	5060	6782				

* Centrifugal Double Suction = CDS

1 Motor Horse Power

2 Efficiency in percent are rated according to Pacific Gas and Electric Standards (i.e., E = Excellent, G = Good, F = Fair, L = Low).

3 Power Factor was metered and used in calculating KW

7 "Total Dynamic Head" was measured and estimated (values in parenthesis) and does not include velocity head.

Roza Irrigation District, Plant 14, Pump Test Results 7-10-79

PUMP	HP[1]	TYPE*	RATED SPEED[5]	RATED VOLTAGE	RATED AMP	AMP	VOLTAGE	PF[3]	KW	EHP[4]	TDH[7]	Q[8]	WHP	EFF[2]
R14-1	400	CDS	1770	2300	89.5	74	2380	(.92)	333	446	240	9.97	271	61 F
R14-2	400	CDS	1770	2300	89.5	75	2380	(.92)	337	452	242	11.08	304	67 E
R14-3	400	CDS	1770	2300	89.5	73	2380	(.92)	328	440	240	10.0 Est.	272 Est.	62 F Est.
Total, Individual Measured (14)						219	2380		998	1338	241	31.05 Est.	841	63
Total Plant, Measured (14) - Watt meter									985	1321				

* Centrifugal Double Suction Pump

1 Rated Motor Horse Power

2 Wire to water efficiencies measured upstream of a main valve. Ratings according to standards developed by Pacific Gas and Electric (i.e., E - Excellent, G = Good, F = Fair, L = Low).

3 Power Factor has been calculated; parenthesis here indicates calculated, not metered value.

4 Individual Electrical Horse Power has been calculated by distributing total plant according to amp function. EHP listed is peak demand during series of tests.

5 Rated motor speed

7 Total Dynamic Head without correction for velocity head.

8 Flow in c.f.s. with all pump running open. Valve stems at .705, .605, and .605 ft. after burping pump and during test. The motor amps of units not being tested were approximately 74, 75, and 73.

Roza Irrigation District, Plant 15, Pump Test Results 7-10-79

PUMP	HP[1]	TYPE*	SPEED[5]	RATED VOLTAGE	AMP	AMP	VOLTAGE	PF[3]	KW	EHP[4]	TDH[7]	Q[8]	WHP	EFF
R15-1	350	CDS	1170	2300	80.5	59	2250	[(1.08)]	248	[332]	136	[10.9]	168	[51]
R15-2	350	CDS	1170	2300	80.5	62	2250	[(.89)]	215	[288]	136	14.5	225	[78]
R15-3	350	CDS	1170	2300	80.5	OFF								
R15-4	500	CDS	1170	2300	109	102	2250	[(.89)]	354	[474]	265	12.74	383	[81]
R15-5	500	CDS	1170	2300	109	87	2250	[(.90)]	306	[[411]]	265	12.15	365	[[89]]
R15-6	500	CDS	1170	2300	109	98	2250	[(.92)]	353	[473]	262	13.06	389	[83]
Sum of EHP and WHP individual test loads						408	2250		1476	1978			+530	77
Watt-meteter registered electric demand throughout tests.									1325	1776			(1530)	(87)

Refer to previous sheet for additional notes. Brackets indicate value may not be accurate (see Pump Test Results.

Parenthesis indicates duplicate and additional table listing.

8 Flow in c.f.s. indicated pumps running, and all pumps except test pump running at following approximate amperage: R1=53 amps, R2=53, R4=91, R5=92, R6=94. Test pump during the test had been burped and was running fully open valved. Valve stems during tests were R1=.90, R2=.94, R4=.700, R5=.700, and R6=.700.

Dalles Irrigation District Pump Test Results

5-24-25-79

Pump	HP	Type*	Speed[1]	RATED Voltage	RATED Amp	Amp	Voltage	PF	Kw	EHP	TDH	Q	WHP	EFF[2]
R1	150	T	-	2300	30.6	28	2400	1.0	116.	156.	211	4.74	114.	73 E
R2	150	T	-	2300	30.6	29	2400	1.0	121.	162.	211	5.26	126.	78 E
R3	300	T	-	2300	59	56	2400	1.0	233.	312.	211	8.53	204.	65 G
R4	600	T	-	2300	118	107	2400	1.0	445.	596.		18.87	-	-
R5	600	T	-	2300	118	107	2400	1.0	445.	596.	211	-	-	-
A1	300	CDS	1800	2300	59.7	55	2400	.99	226.	303.	388	4.12	181.	65 G
A2	300	CDS	1800	2300	59.7	54	2400	.99	222.	298.	388	4.62	203.	68 G
A3	600	CDS	1800	2300	118.5	100	2400	.99	411.	552.	388	7.18	316.	57 F
A4	1250	CDS	1200	2300	247	208	2400	.99	856.	1147	388	16.83	741.	65 G
A5	1250	CDS	1200	2300	247	219	2400	.99	901.	1208	388	18.68	822.	68 G
B1	75	CDS	1800	440	91	92	480	-	77.0	103.	249	1.77	50.0	49 L
B2	125	CDS	1800	440	149	151	480	-	126.	168.	252	3.59	103.	61 F
B3	200	CDS	1800	440	246	220	480	-	183.	245.	252	4.62	132.	54 L
C1	50	CDS	1800	460	60	49	470	-	40.0	54.0	210	1.16	28.0	51 L
C2	50	CDS	1800	460	60	45	470	-	37.0	49.0	210	1.13	27.0	55 L
D1	100	CDS	1800	460	120	115	450	-	89.6	120.	201	2.74	62.5	52 L
D2	100	CDS	1800	460	120	112	450	-	87.3	117.	201	3.09	70.5	60 G
D3	200	CDS	1800	440	246	245	450	-	191.	256.	201	5.62	128.	50 L
D4	250	CDS	1800	460	299	285	450	-	222.	298.	201	10.68	244.	82 E
D5	250	CDS	1800	460	299	280	450	-	218.	293.	201	10.68	244.	83 E
E1	60	CDS	1800	440	73	70	470	-	57.0	76.4	168	2.15	41.0	54 F
E2	60	CDS	1800	440	73	68	470	-	55.4	74.2	162	2.30	42.3	57 F
E3	100	CDS	1800	440	123	95	470	-	77.3	104.	162	3.52	64.7	62 F
E4	150	CDS	1800	460	182	170	470	-	138.	186.	159	5.64	102.	55 L
F1	200	CDS	1800	2300	40.2	35	2375	-	144.	193.	300	4.34	148.	77 E
F2	200	CDS	1800	2300	40.2	33.5	2375	-	138.	185.	300	4.49	153.	83 E
F3	350	CDS	1800	2300	69.3	61	2375	-	251.	336.	300	5.23	178.	53 L

5-24-25-79

Dalles Irrigation District Pump Test Results, cont.

Pump	HP	Type*	Speed[1]	Rated Voltage	Rated Amp	Amp	Voltage	PF	Kw	EHP	TDH	Q	WHP	EFF[2]
F4	700	CDS	1200	2300	138	116	2375	-	477.	640.	300	9.71	301.	52 L
F5	700	CDS	1200	2300	138	130	2375	-	535.	717.	300	11.12	379.	53 L
J1	30	CDS	1800	440	38.1	28	475	-	23.0	30.9	104	1.21	14.3	46 L
J2	40	CDS	1800	475	51.5	34	475	-	28.0	37.5	104	1.36	16.0	43 L
J3	40	CDS	1800	445	51.5	36	475	-	29.6	39.7	104	1.58	18.6	47 L

* CDS = Centrifugal Pump, Double Suction

* T = Vertical Turbine

1 Approximate! Speed, not from name plate

2 Efficiency in percent, Ratings according to standards developed by Pacific Gas and Electric (i.e. E = Excellent, G=Good, F=Fair, L=Low)

South District, Columbia River Irrigation Project, Pump Test Results 5-30-79

Pump	Hp	Type	Rated Speed	Rated Voltage	Rated Amp	Amp	Voltage	PF[3]	KW	EHP	IDH	Q	WHP	EFF[2]
S4	450	CDS	720	2400	89.1	82	2390	.985	337	452	92	30.73	322.	77-E
S5	450	CDS	720	2400	89.1	79	2390	.985	321	430	92	31.56	330.	75-E