



Computer aided evaluation of the value of water for irrigation
by William Glen Greiman

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Agricultural Engineering
Montana State University
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Abstract:

A method of determining a site specific value of water for irrigation is presented. The method presented uses designer interactive computer programs, which incorporate computer aided design (CAD) and spreadsheet software, to aid in the design and economic evaluation of an irrigation system. The value of water is found by budgeting all the costs and benefits of a farming operation before and after irrigation development and comparing them. The difference between the farm's before-and after-development return to land is attributed to the value of the irrigation water.

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APPROVAL

of a thesis submitted by
William Glen Greiman

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

A method of determining a site specific value of water for irrigation is presented. The method presented uses designer interactive computer programs, which incorporate computer aided design (CAD) and spreadsheet software, to aid in the design and economic evaluation of an irrigation system. The value of water is found by budgeting all the costs and benefits of a farming operation before and after irrigation development and comparing them. The difference between the farm's before-and after-development return to land is attributed to the value of the irrigation water.

CHAPTER 1**INTRODUCTION**

"Nature never gives anything to anyone: everything is sold. It is only in the abstraction of ideals that choice comes without consequences." Ralph Waldo Emerson.

Throughout our country's history, water has been, for the most part, perceived as an abundant resource. Water shortage problems have been in distribution rather than in actual water scarcity. This abundance of water has fostered a social and political attitude that demands an adequate supply of good quality water. The high demand for water has spurred the development of large government-subsidized water projects, such as massive dams and water distribution systems in the water-short Southwest. Although multipurpose, water from these projects was primarily allocated to irrigation. Recent droughts and an ever increasing demand for water has focused attention on present and possible future areas of water scarcity.

Today, however, concern for the environment and government spending are making the development of new capital-intensive water projects more and more difficult. Past water projects have already

claimed the most socially, economically, and environmentally acceptable sites. Also, increasing environmental concerns have raised legal questions of minimum stream flows and water quality.

Complicating the problem is our country's antiquated method of water allocation. In the west water has been allocated by the legal doctrines of "first in time first in right" and "beneficial use". In other words, a user can acquire the right to use water for almost any purpose and that use has a priority date based on when the right was acquired. As a result, the early mining and agricultural needs have priority over growing municipal and industrial needs.

All these factors, combined with the recent droughts and ever-increasing water demand, have focused attention on the problem of water scarcity and water allocation. The cost of water has been associated with the cost of development, delivery, and treatment with no value placed on the water itself. The growing demand for water has been accompanied by the realization that water is a natural resource and does have economic value. In many areas, conflicts are developing over competing uses for a limited supply of usable water. There are conflicts between states and among water users. One such conflict is between the allocated rights of irrigation and other water uses in already over-allocated areas. Another conflict is arising over which uses should have priority in future allocation of limited water supplies.

Future allocation or reallocation of water will have to be based on some evaluation of the competing uses. This thesis presents a method of using computers to determine the average, farm specific

value of water for irrigation so that farmers and water planners can objectively evaluate alternatives.

A basic economic maxim is that the marginal value of a limited resource should be equal among competing uses in order to obtain maximum economic efficiency. Marginal value of a resource is the change in benefit realized by the last increment of the resource developed. If economic efficiency is to be the measure of conflicting water uses, the marginal value of these uses must be determined. In a purely competitive market the price for a resource tends toward this equal marginal value. However, water is almost never purchased in a free market situation.

The marginal value of water has been estimated in a number of ways. An analytical approach relates the volume of water, used or consumed, to the value of the end product with an empirical equation (Frank, 79). This demand curve can be differentiated to find water's marginal value, at any use level, and its optimal use level and value. This method is mathematically exact for the empirical function, but the function requires large amounts of information that must be carefully examined to obtain their proper relationships. Another approach budgets all the cost and incomes in an enterprise, including management costs, and attributes the balance to the value of water (Lacewell, 1974). This would give the average value of water for that situation, or an approximation of marginal value in a rational free market. Budgeting, however, is time consuming and requires that all resource and product prices, other than water, be known or estimated.

Also, since it only gives average values for a situation, an optimal value and level of use are difficult to find.

Optimal levels of water use can be determined at different water values by using the variable costs from the budgeting approach with linear programming methods. Linear programming optimizes the solution to a set of linear equations. For example, one can determine the production costs and values for various crops through budgeting. Then linear equations that describe the water cost, crop yield, and crop prices are established. Linear programming can use these equations, subject to the appropriate constraints, to find the optimal level of production for each crop. When this is done, with increasing price levels of water, crops will drop out of the solution until no irrigated crops remain in the optimal solution. The water price at which a crop drops out of the optimal solution is its "optimal marginal water value". Thus, marginal water value can be calculated and compared to the range of crops raised.

Most user water demand is inelastic (Gibbons, 86). This means that for a given change in price a user will use less water; in percentage terms, however, the change in use will be smaller than the change in price. Municipal water use provides a good example. In Colorado, where water is allowed to be traded freely, municipal water has a marginal value of \$300/ac-ft (Gibbons, 86). Many industrial uses have threshold water price levels. For example, the cost of water would need to be \$933 to \$1300/ac-ft before a coal-fired power plant would change from once-through cooling to a dry cooling tower method (Gibbons, 86). In many industrial processes, water only contributes a

small amount to the overall cost of the end product. In coal fired electrical production, for example, a \$200/ac-ft water price increase would only raise the price of the electricity generated by 1-2% (Campbell, 85). The price of water to transport coal in coal slurry pipelines is estimated at \$1600/ac-ft (Campbell, 85).

The demand for water in hydropower facilities is set by the load structure of the utilities. Utilities have the responsibility to meet consumer demand for electricity, which varies during the day and throughout the year. Established hydropower is generally the cheapest way to meet this demand in the Pacific Northwest, but the capacity is limited (Northwest Power Plan, 86). Most hydropower facilities have reservoirs that can store the water's potential energy, allowing power-generating levels to be quickly changed to meet varying load demands. Thus, hydropower is usually used to meet peaking loads, while thermal cycle power units are used to supply the base load. The value of water for hydropower electrical generation is therefore considered, by some, to be the cost at peak load demand. While the amount of power that can be generated by an acre-foot of water is easy to calculate, its value is subject to interpretation.

It is virtually impossible to place a dollar value on water for its environmental and aesthetic utility. Society is recognizing these uses by setting minimum allowable stream flow levels and reservoir draw down elevations, and by restricting water uses that degrade water quality. The value of water in these cases is considered to be zero as long as minimum flows and qualities are maintained. This is also the case with navigational uses of water. However, when minimum flow is

not available, the loss of revenue to an economic system can be estimated for navigational uses of a river system. Alternatively, one can estimate the increased shipping tonnage that is gained by artificially maintaining a minimum required flow.

Irrigated agriculture has been and will continue to be the largest water consumer in the West. However, as water becomes increasingly scarce some reallocation of water from irrigation to other uses seems inevitable. This is important to both the farmer and the resource planner. The farmer needs to know the value of his irrigation water to make rational marketing decisions. Similarly, the resource planner needs to know the value of water for competing uses to make rational water allocation policies.

The value of water for irrigation is extremely variable and difficult to determine. Fluctuating product end prices, varying response characteristics, and operation-specific production costs can cause differing water values for similar crops in the same area. While statistical production functions can determine regional water values these values will at best be aggregate averages. They are of little value for estimating water values for specific situations (Young, 72). Many studies have used production functions to estimate regional water values for irrigation. Frank (1979) found that the value of water for agriculture varied from \$27.79/ac-ft in California, to \$1.71 in Idaho (based on a nine variable Cobb-Douglas production function derived from regional agricultural statistics). Other production functions have indicated a marginal value of \$120 for the first acre-inch of

water applied to corn in Oregon, and no value for water when over 18 inches is applied (Miller, 61).

Lacewell, Sproutt, and Beattie (1974) used the Texas Agricultural Extension Service budget generator to show the value of water for several crops at differing yields and prices. This study shows a water value of \$92/ac-ft for corn (@ 120 bu/ac yield and \$3/bu) and \$61/ac-ft for wheat (@50 bu/ac yield and \$3.50/bu). Willitt, Hathorn, and Roberts (1975) used crop budgets to find water values that ranged from \$7/ac-ft for grain sorghum to \$67/ac-ft for sugarbeets. Using linear programming methods, Condra, Lacewell, and Sproutt (1975) found water values that varied from \$8/ac-ft for wheat to \$72/ac-ft for soybeans in the Texas High Plains. In another linear programming analysis Martin and Snyder (1979) showed irrigation water values varying from \$23/ac-ft for grain sorghum to \$990/ac-ft for dry onions in Arizona.

Griffin (1976) used linear programming methods to show that the value of water ranged from \$17.09 to \$94.62 per acre-foot for crops in Southwestern North Dakota. Anderson (1961) analyzed the active water market in Colorado to determine a value of \$3.50/ac-ft for agricultural water. Young and Gray (1972) concluded that the value of water for irrigation ranged from \$5 to \$25 /ac-ft, with an average value of \$10/ac-ft, for unsubsidized agriculture.

Due to the variability of crops, prices, productivity, and methods of analysis, Young and Gray (1972) questioned the advisability of using regional water values for irrigation. Clearly, a standardized site-specific method of evaluating irrigation water value is needed.

Such a method would require extensive farm budgeting and yield data for each site analyzed.

A method is presented in this thesis that incorporates computer aided design (CAD) and spreadsheet software programs to quickly estimate a site specific value of irrigation water. There are other methods that can be used to determine all the costs for an irrigation development. For example the SCS has developed a FORTRAN program call "IRRISYS" (SCS, 79) that designs distribution systems and calculates the water requirements for a large irrigation development. However, this program doesn't determine the infield system design or costs such as pivot and wheel lines. These costs are entered by the user. King, Sauer, and Busch have developed a comprehensive FORTRAN program on irrigation system programming (King, 87). This program does determine irrigation development costs and system requirements but requires extensive user input for each component in the irrigation system (ex. length and location). Licht has developed a method of using CAD to draft an irrigation design and determine system lengths and areas (Licht, 87). Licht's method doesn't design system components within the CAD program, leaving the designer to manipulate the information (in a spreadsheet) to determine system requirements and costs.

The Cooperative Extension Service at Montana State University uses a computer program that determines the cost of owning and operating farm machinery (Johnson, 84). The purpose of the program is to aid farmers in making machinery management decisions. While this program determines machinery ownership costs, it is not set up to easily determine the total equipment costs for each crop raised on a

specific farm. Washington State University has developed a similar program (Mohasci, 84). The Cooperative Extension Service also produces enterprise cost studies that budget all the costs and revenues of selected farming scenarios (Fogle, 80)

These components can be used to budget the costs and revenues of an irrigation development. However, the process would be cumbersome and time consuming. This thesis presents a method for quickly generating site specific farm budgets. The costs of new irrigation developments are accounted for, including annual irrigation costs. Using the computer aided irrigation design and economic analysis method developed and explained in the following text, the task of evaluating the value of water for irrigation is both less difficult and more accurate. Both farmers and water resource planners will gain by the ability to obtain more site-specific irrigation water values.

CHAPTER 2

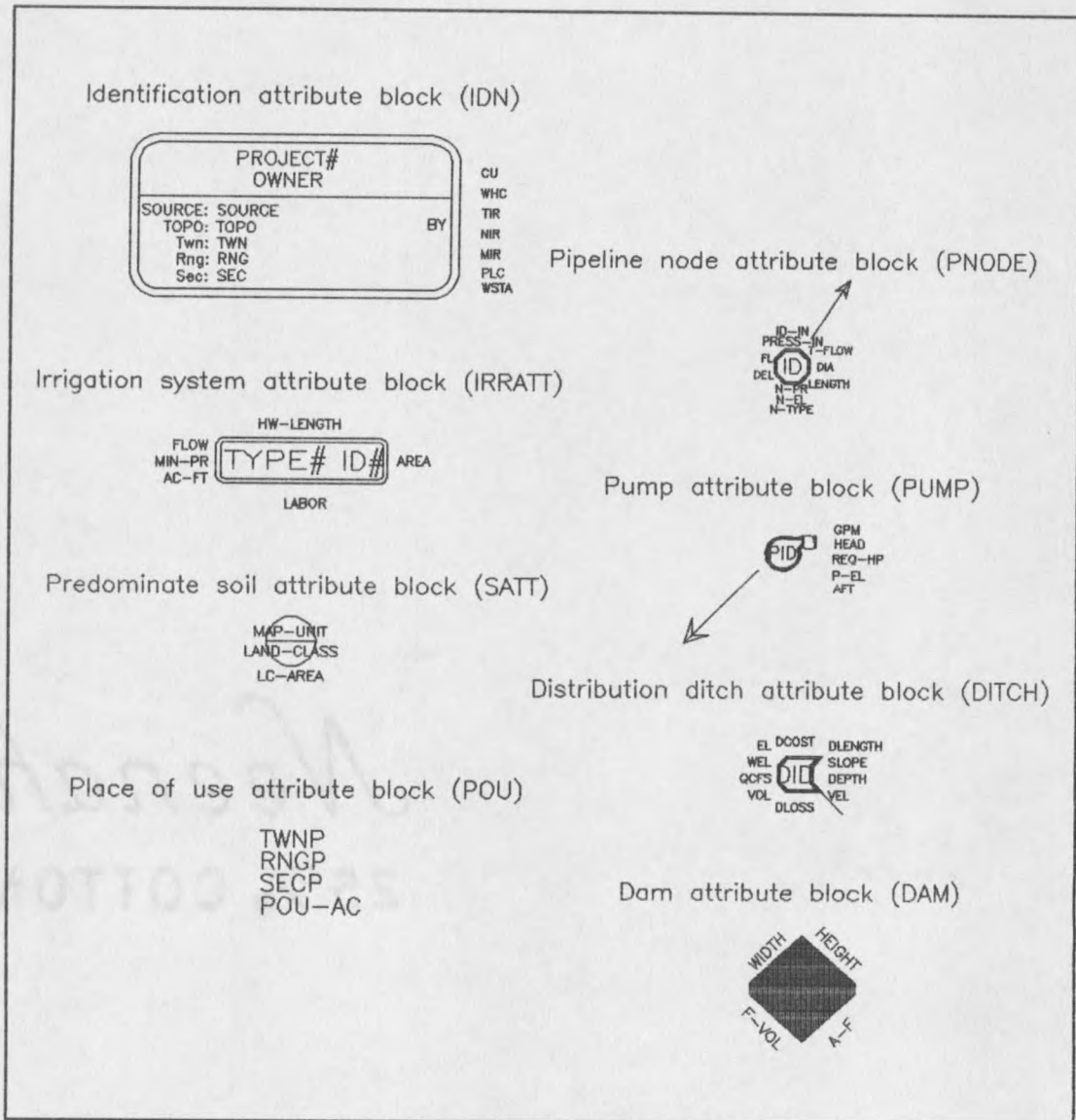
GENERAL COMPUTER SOFTWARE DESCRIPTION

The method of determining the value of water for irrigation developed in this thesis uses commercially available computer aided design and spreadsheet software programs: specifically, AutoCAD computer aided drafting and design (AutoCAD rel. 9.0, 1987) and Lotus computer spreadsheet (Lotus 123 rel 2.01, 1987) software along with a graphics-capable computer. This chapter introduces the basic concepts and nomenclature of these software programs.

AutoCAD

AutoCAD is an open architecture graphics software program that allows the user to modify the program for a specific purpose. In this case, AutoCAD was used to design irrigation systems. With AutoCAD the user can draw points, lines, geometric objects, and perform freehand traces. These drawing components, or "entities" are drafted onto the computer screen using an input device (similar to a keyboard) called a "digitizing tablet". The digitizing tablet can be calibrated to any map scale. Using a digitizing tablet and a printer or plotter, these entities can be drafted and reproduced on a map at any desired scale.

Figure 1. Attribute blocks used in AutoCAD irrigation designs.



AutoCAD also allows the user to enter information or "attributes" associated with each drawing entity. Together, the entities and their attributes are referred to as "blocks". The information in each block

can be written to an ASCII file for use in Lotus 123 spreadsheets. Finally, AutoCAD allows the user to write interactive LISP programs. These programs can draw and manipulate entities and query the user for information used in entities' attributed blocks. There are eight attributed blocks used in the irrigation design process (Figure 1).

Lotus 123

A spreadsheet is a computer program that allows the user to manipulate discrete units of information. It consists of numbered rows and alphabetically headed columns, where each cell has a unique "address" (e.g. A11, Z182 ..). A cell can contain either an alpha-numeric label, a single number, or a mathematical formula. A cell formula can contain numbers, cell addresses, mathematical operators, or functions. The spreadsheet performs formula calculations, using values from other cells where indicated, and stores the result in that cell. The following is a list of mathematical operators in order of precedence:

^	exponentiation
*	multiplication
/	division
+	addition
-	subtraction
=	equal
<	less than
>	greater than

A function enables the user to perform more complex mathematical manipulations. Functions are indicated by the character @ followed by an "argument", or list of values (e.g. @SUM(A1...A10)). The most

commonly used spreadsheet functions are @SUM and @IF. The @SUM function totals the cell values contained within the "range", or group of cell addresses, specified in the argument. The @IF function is a logic statement that evaluates an argument. If the condition is true the spreadsheet calculates the value of the first argument; if it is false, it calculates the last argument. In the example @IF(A1<10,B15,0), if the value in cell A1 is less than 10, the resulting value will be that of B15; but if the value of cell A1 is equal to or greater than 10, the resulting value will be 0. (A listing of functions and their arguments can be found in LOTUS 123 manuals.)

In the spreadsheets developed in this thesis, "label cells" explain parts of the spreadsheet, designate units, or head columns and rows of data. Labels at the head of a row or column describe the data in that column or row. Cell values can be user input variables, standard parameters, calculated data, or summary result data. The spreadsheet is "protected" so that the only easily altered cells are user input variable cells. The spreadsheet is "menu" driven to make it more user friendly. The menu allows the user to view parts of the spreadsheet, change user input variables, and print sections of the spreadsheet without directly accessing the entire spreadsheet.

CHAPTER 3

METHODOLOGY

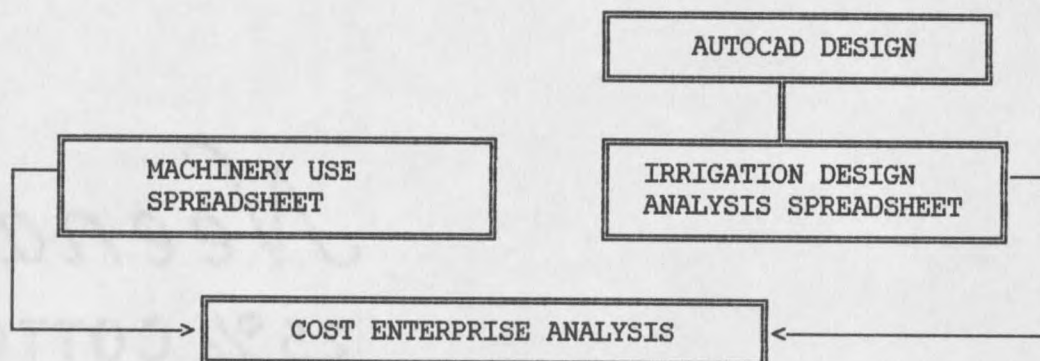
To evaluate the economic feasibility of an irrigation development, one must analyze and compare before- and after-development scenarios. This analysis is done with the Farm Enterprise Analysis spreadsheet. The spreadsheet requires economic input data on crops raised (acres, yield, and prices), chemical use, irrigation costs, and machinery costs. The output to be compared is the farm's return to land, including the break-even price and yield for each crop.

The Machinery Use spreadsheet calculates the costs of owning and operating machinery. This spreadsheet computes for each scenario the fixed and variable costs of machinery ownership based on input variables on acres of crops raised, interest rate parameters, equipment used, number of annual equipment operations, and annual truck use.

AutoCAD and the Irrigation Design Analysis (IDA) spreadsheet are used to determine the annual costs of the irrigation systems. The designer enters the system components while AutoCAD answers program queries about the irrigation development site, storing the information in attribute blocks that are then transferred to Lotus 123. These blocks include information on size of equipment, amount and diameter of pipeline, required flow, number and size of pumps, and total water

required. The IDA spreadsheet then inserts this information into the appropriate spreadsheet location and calculates annual costs by summing annualized component costs. This information is then transferred to the Enterprise Cost Analysis spreadsheet to determine the farm's total budget. The value of water for that farm scenario is the difference in the net return to land from the before- and after-development scenarios. The flow chart in Figure 2 shows the interaction between the spreadsheets and AutoCAD.

Figure 2. Flow chart showing spreadsheet relationships.



This thesis presents and explains the development of these spreadsheets and the AutoCAD programs. The spreadsheets are presented in range sections following the order in which they are accessed within the spreadsheet. The ranges are then briefly explained in terms of the range's function and its relation to the rest of the spreadsheet. There are several levels of named ranges in the spreadsheet: large information blocks and calculating cells that are

used to organize the spreadsheet, titled columns and rows that indicate similar types of cell information or calculations, and individual cells for addressable input or parameter values. These ranges are capitalized and abbreviated as they appear in the spreadsheet when referred to in the major range area explanations. Each range area explanation includes a table, which is a range printout followed by an explanation of calculating cell formulas. Many titled ranges contain similar formulas with addressed cells changing relative to the calculating cell's position, in which cases only the first cell formula in the range is listed and explained. A complete listing of cell formulas for each range presented is listed in Appendix B.

Chapter 8 demonstrates the method of determining the value of water for three irrigation development sites. Four example problems show the variability of irrigation water's value. The first example is for a large cattle ranch that develops a pivot close to the Missouri River. The second example is the same pivot irrigation system used in example one, developed by a dryland grain farming operation. The third example is a small farm-ranch developing two wheel lines on a high terrace of the Missouri river. The last example is for a dryland farm developing a large six pivot irrigation project on a terrace of Belt Creek in Chouteau county.

Each example problem description contains a summary of the machinery use and enterprise cost spreadsheets for the before development scenario. Next, the irrigation development drawing is presented along with its annualized cost summary. This information is

then included in the after-development enterprise cost analysis along with the new machinery costs. The value of water for each irrigation development scenario is then found by subtracting the net return to land of the before-development from the after-development scenario. A more complete listing of each scenario's spreadsheet output is presented in Appendix B.

CHAPTER 4

IRRIGATION DESIGN AND ECONOMIC EVALUATION

To begin the design, the designer calibrates the digitizing tablet to a base map of the proposed irrigation site. Then, with the aid of the AutoCAD LISP programs, the appropriate information is entered. While these programs do not make design decisions, they do make the design process easier, quicker, and more accurate. Once the design is finished, the attribute information is transferred to a spreadsheet that performs the economic analysis and formats the information in a report-ready form.

AutoCAD Irrigation Design Initialization

In order to run the initialization program (INT.lsp) - step one of the design process - the designer must gather basic information on the soils, climate, relief, and location of the project area. This information is obtained from topographic maps, soils maps, and the MT_TR21 consumptive use computer model (USDA 1987). The INT.lsp program asks the designer for site-specific design information and sets default variables for the rest of the design programs. The INT program displays the current values for peak consumptive crop use (PCU), soil water holding capacity (WHC), total crop consumptive use (TCU), net irrigation requirement (NIR), maximum soil intake rate (MIR), miles of required three-phase powerline construction (PLC), and

weather station used (WSTA). The designer must verify and correct, where necessary, the values for WHC, MIR, PLC, and WSTA in response to the program's queries. The program determines the TCU, NIR, and PCU from preprogrammed weather station information and sets the default variables (Table 1). (The default variables can be changed by the designer at any time in the design process.)

Table 1. The default variable identification codes, values, and explanations used in the INT.lsp program.

MAD	0.5	*;max. % of allowable soil water deficit
Peff	0.75	;pivot efficiency
Weff	0.65	;line set efficiency
Feff	0.50	;flood efficiency
WLD	5	;whln dia. (inches) for friction loss calc.
FLF	0.37	;sprinkle lateral friction loss factor
MEP	23	;minimum pivot end pressure in feet
HFD	12	;hours of flooding per day
FDL	2	;hours of seasonal flood labor per acre
PVL	0.75	;hours of pivot seasonal labor/ac.
WSL	0.5	;hours of wheel line set labor/move
DSS	3	;Dam Side Slope ? to 1(vertical)
DTC	16	;Dam Top Crest width (ft)

*the semicolon in LISP separates active code from descriptive text

Next, the designer calibrates the digitizing tablet to correspond with a base map of the design area and digitizes the irrigable soils. Based on the type and size of irrigation system deemed suitable, the designer draws the appropriate geometric shape to depict pivots and wheel lines (circles and rectangles), flood systems, and hand line systems. The designer then inserts the irrigation attribute (IRRATT) blocks. The IRRATT blocks contain information on system type, identification number, insertion point, area, hardware length, required flow (gpm), minimum input pressure, and annual labor

requirement. The designer may either enter this information directly, or use the developed LISP programs. The IRRATT insertion programs use the calculated and set variable from the INT.lsp program and user-queried information to calculate and enter the IRRATT attribute information.

The four IRRATT insertion programs developed for irrigation design are pivot (PIV), wheel line (WL), hand line (HL), and flood (FLOOD). The sample drawing in Figure 4 shows the different types of irrigation equipment, a distribution pipe line, and a storage reservoir (legend shown in Figure 3).

Pivot Design LISP Program (PIV.lsp)

The pivot program (Piv.lsp) queries the user for three points that determine the circumference of the pivot. These are found from the digitizing tablet map. From this circle, the hardware length (HWL) is found by subtracting 100' (end gun radius) from the radius (R) of the circle. The area (A), in acres, is calculated from the circle's radius. The program also queries the user for the in-field elevation head and then calculates the annual pivot labor (PLB), pivot pipe diameter (PDIA), flow (GPM), pivot friction loss (PFL), and required pivot pressure (PPR) as follows:

$$\begin{aligned}
 \text{PLB} &= A * \text{PVL} \\
 \text{GPM} &= 226 * \text{PCU} * A / (12.0 * \text{PEFF}) \\
 \text{PDIA} &= 6" \text{ if } \text{GPM} < 750, 6.625" \text{ if } 750 < \text{GPM} < 1150, \text{ or } 8" \\
 \text{PFL} &= 0.0007 * R * \text{GPM}^{1.82} / \text{PDIA}^{4.87} \\
 \text{PPR} &= \text{MEP} + \text{PFL} + 22 + \text{in-field elevation head}
 \end{aligned}$$

(All pressure rates are in feet of water head and all flows are gallons per minute unless otherwise indicated.)

Figure 3. Legend for AutoCAD irrigation design.

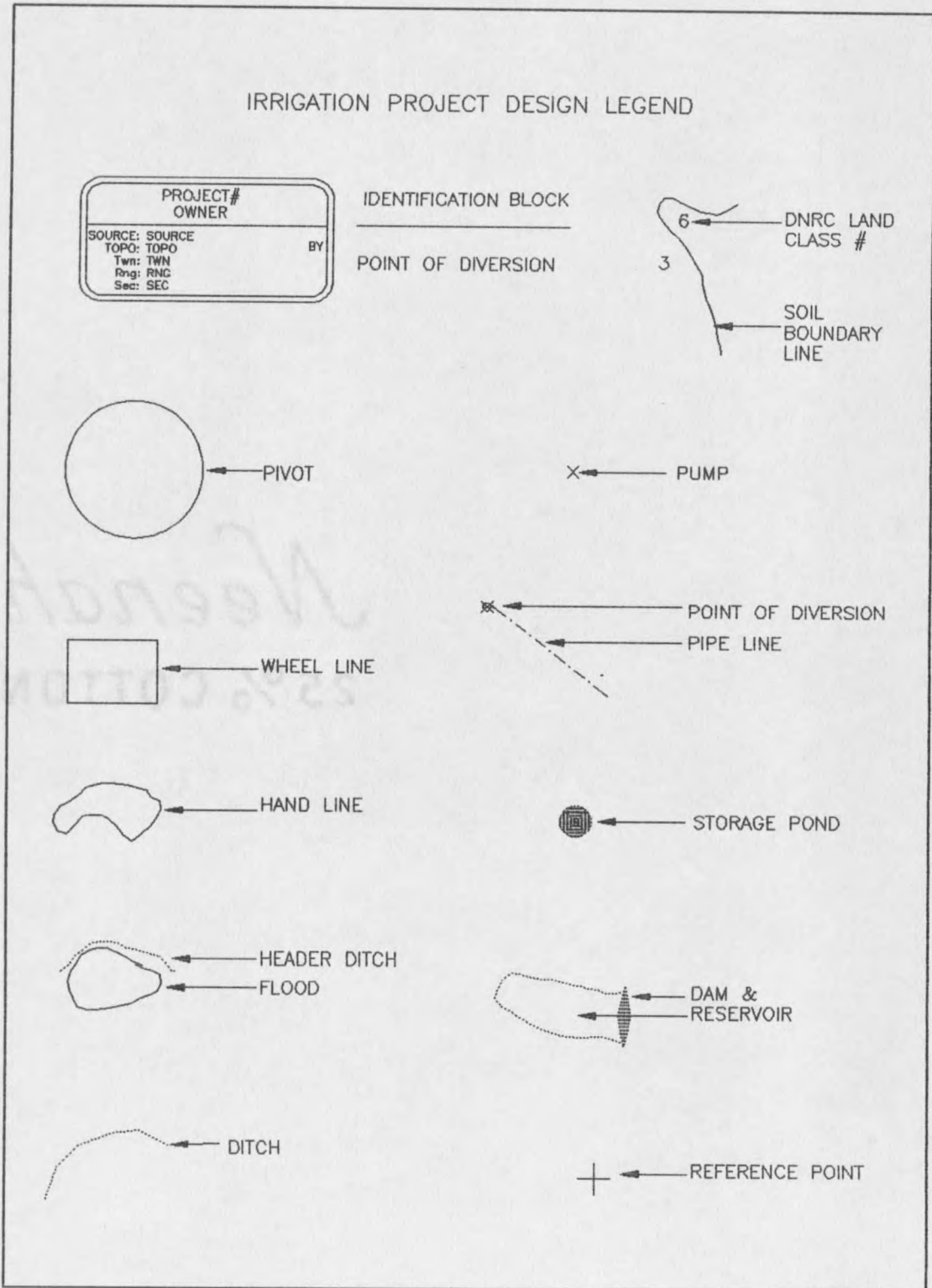
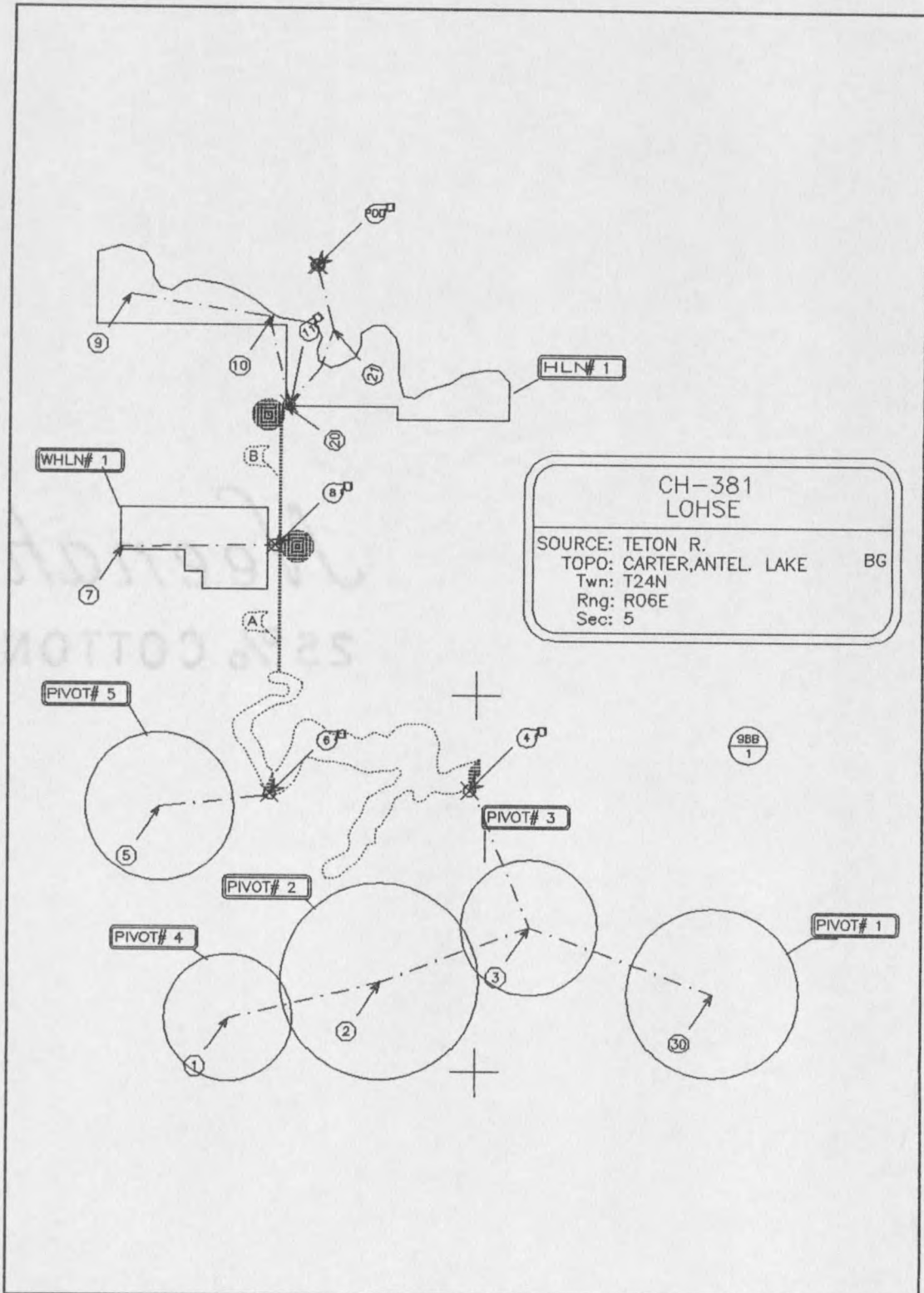


Figure 4. An example AutoCAD irrigation design.



Wheel Line Design LISP Program (WL.lsp)

The designer uses the WL.lsp program to calculate IRRATT attributes for wheel lines. Table 2 lists the calculations used by WL.lsp to determine the maximum roll width (WDTH) and per foot flow rate. The WDTH parameter is dependent on the soil's WHC, the maximum allowable application rate (MAR), and the PCU rate of the selected weather station.

Table 2. The system variable formulas, identification codes, and descriptions used in the HL.lsp & WL.lsp programs.

MAR = MIR(max. of 0.7)	;sets Max. Application Rate ("/hr)
NAP = WHC / MAD	;Net Application per irrigation (")
DPI = NAP / PCU	;Days Per Irrigation
GAP = NAP * WEFF	;Gross line Application per irrigation
(")	
IPS = NIR / NAP	;;# of Irrigations Per Season
ST = GAP / MAR	;min. Set Time for line irrigation (hr)
SPD = 3 (if ST<8)	;Sets Per Days for line irrigation
= 2 (if ST<12)	;this routine selects a practical
= 1 (if ST<24)	;;# of sets per day
= .5 (if ST>24)	
HPS = 24 / SPD - WSL	;Hours of Set time Per irrigation
GPMf= 0.623 * GAP / HPS	;req GPM per Foot of line length
	;the 0.623 factor converts inches per
	;hour of req. application to gpm and
	;assumes 60' lateral spacing
	;0.623 = 24/12 X 60/43560 X 226
APR = GAP / HPS	;actual Application Rate ("/hr)
SPI = DPI * SPD	;whole # of Sets Per Irrigation
WDTH= SPI * 60	;max. roll WIDTH for wheel lines (ft)
MSP = 160 * GPMf +60	;Min. Sprinkler Pressure (ft)

The normal design procedure is to run the WL.lsp program to determine the roll width which, along with flow rate, can be modified

by adjusting the soil WHC or MIR parameters. The program is terminated once a suitable roll length is determined. Next, the designer draws the symbols for the wheel line and the pipeline that feeds it, answering the program queries for: (1) the entity (depicting the wheel line), (2) the wheel line length (WLL), (3) the length of the wheel line from its feed point to the end of the line (LOL), and (4) in-field elevation head (FEH). The WLL and LOL distances can be entered from the keyboard but are more easily picked from the digitizing tablet. The area (A), in acres, of the selected entity and the other insert attributes of flow (GPM), minimum pressure (MPR), and annual labor (LWL) are calculated as:

$$A = \text{area of entity} / 43560$$

$$WLL = \text{picked distance} - 40$$

$$GPM = GPMf * (WLL + 40)$$

$$MPR = MSP + FEH + FLF * LOL * .0015 * (LOL * GPMf)^{1.85} / WLD^{4.87}$$

$$WLB = IPS * SPI * WSL$$

The program pauses for the user to enter the block's location and identification number and inserts the block into the drawing.

Hand Line Design LISP Program (HL.lsp)

The hand line program (HL.lsp) uses the same set-up calculations listed in Table 2. This program queries the designer for the entity that outlines the area to be irrigated. HL.lsp assumes that: (1) any shape can be irrigated, (2) the amount of hardware (HLL) needed is a function of the area (A) irrigated and the number of sets per irrigation (SPI), and (3) it takes two hours of labor to move a

quarter-mile of hand line (personal experience). The calculations for the hand line IRRATT insert block are:

```

A   = selected entity area (ft2) / 43,560 ft2/ac
HLL = 726 ('length/ac/set) * A / SPI
                                     ;(726'length/ac/set = 43560
                                     ;ft2/ac / 60'width/set)
HSL = 0.0015 * HLL
                                     ;Hand Set Labor(hr/ft)
                                     ;(0.0015 hr/ft = 2 hr /
                                     ;1300'handline)
HHPS= 24 / SPD - HSL
                                     ;Handline Hour Per Set
GPM = 0.623 * HLL * GAP / HHPS
                                     ;total flow required
MPR = MSP + 10
                                     ;Minimum PResure
HLB = IPS * SPI * HSL
                                     ;annual Hours of LaBor

```

Like the other irrigation programs, HL.lsp pauses to allow the user to enter the insertion point and identification number.

Flood Design LISP Program (FLOOD.lsp)

The flood (FLOOD.lsp) program queries the designer for the irrigated area entity and the "ditch header entity", the in-field distribution system for the flooded fields entered as a "polyline" from the digitizing tablet. The program calculates the area of the field to be irrigated (A), the length of ditch header (DHL), and queries the user for the per-foot cost of ditch header (DHC). From this information, and from the hours of flood irrigation per day (HFD) and flood labor per acre (FDL) variables, the program calculates total required flow (GPM) and annual required flooding labor (FLB). The calculations are as follows:

$$GPM = (PCU / 12) * (A * 226 / E_{eff}) * (24 / HFD)$$

$$FLB = A * FDL$$

Again, the designer enters these variables in the IRRATT attributed block at the selected location.

Dam Design LISP Program (DAM.lsp)

The dam design program (DAM.lsp) estimates the fill volume (F-VOL) in cubic yards of earth and the volume of water stored in acre-feet (A-F). The designer uses a topographic map to digitize the high-water surface contour line of the proposed reservoir. This program queries the designer for the high-water line entity, the abutment points, the dam's maximum water height in feet (WHTH), the reservoir shape factor (RSF), and the basin shape factor (BSF). The RSF is used to estimate the volume of water stored in the reservoir and is generally between 0.4 and 0.6. The BSF is used to estimate the volume of fill needed to construct the dam. This coefficient depicts the dam's centerline profile and can range from 0.0 (rectangular) to 1.0 (triangular). These factors give the designer some flexibility in estimating the per acre-foot cost of a reservoir when no precise field information is available. The program adds five feet of free board to the WHTH parameter in order to obtain the actual dam height (HTH). The DAM.lsp program determines acres of water surface area (A) and then multiplies this by HTH and RSF to estimate the water storage volume in acre-feet.

To find the fill volume, the program queries the designer for the dam side slope (DSS) and top crest width (DTC). Using the abutment

points previously entered, the program determines the dam's width (WDT) and estimates the cubic yard of earth fill volume (F-VOL) with the following formula:

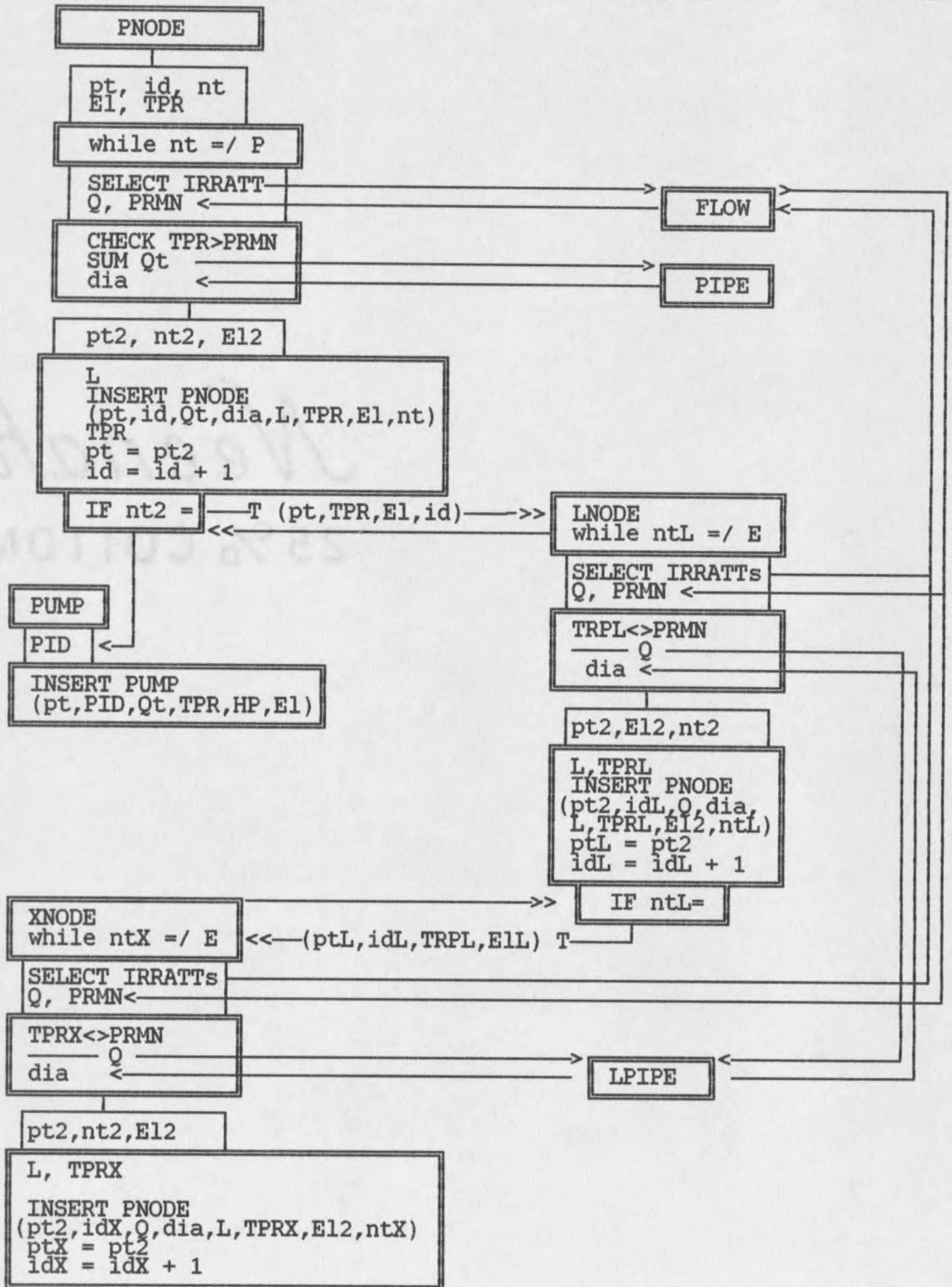
$$F-VOL = ((DSS * HTH^2 + DTC HTH) * (WDT + (2 * WDT * BSF))) / 81$$

(This formula is derived with the assumption that the dam is composed of two pyramidal sections with a uniform center section.) The program enters these variables in the DAM attributed block and inserts a symbol depicting dam length and width between the selected abutment points.

Pipeline Design LISP Program (PNODE.lsp)

The PNODE.lsp program is used after entering all of the irrigation systems that will be serviced by a pipeline and the pipeline location. It determines the total required flow (Qt), pipe diameter (dia), and total pressure head (TPR) at designer-selected pipe node points. Figure 5 shows a flow chart of the PNODE.lsp program. This program queries the designer for node location, irrigation attribute blocks (IRRATT) serviced by the node, node elevation, and node type. PNODE.lsp is a user-interactive program that allows the designer to quickly gather a large amount of information about a distribution system. PNODE uses five sub-programs: PIPE, LPIPE, LNODE, XNODE, and FLOW. The LNODE and XNODE sub-programs function similarly to the PNODE program, except that they work away from the pump-end of a pipeline, while PNODE works toward the pump. LNODE calculates information for main lateral lines off the mainline, while XNODE calculates node information for sub-laterals.

Figure 5. Flow chart of PNODE.lsp LISP program.



The FLOW sub-program transfers information on the required amount of flow (Q) and minimum required pressure (PRMN) from a selected IRRATT block to the NODE programs. The PIPE and LPIPE programs take the current flow value (Qt or Q) and check it against a table of maximum allowable flows for standard PVC pipe sizes. (This table of flows can be based on maximum allowable velocity or on velocity and economic parameters.) The PIPE program selects the appropriate size of pipe (dia) from this table and returns it to the appropriate NODE program.

Working from the low pressure end of the pipeline system toward the pump, PNODE queries the designer for the end node location (pt), elevation (E1), identification number (id), and IRRATT serviced by the node. The total pipeline flow (Qt) and the total required pressure (TPR) is set at this first IRRATT's Q and PRMN values, extracted from the IRRATT block by the FLOW program. From this Qt value, the PIPE program determines the diameter (dia) for the first reach of pipeline. PNODE then queries the designer for the location of the next downstream node location (pt2) to determine the length (L) of this reach of pipeline. The first node type (nt) is assumed to be an end (E) node. Along with the second node location (pt2), PNODE queries the designer for the node's elevation (E12) and node type (nt2). Then, PNODE calculates the second node's total pressure (TPR2) from the from the formula:

$$TPR2 = TPR + (E1 - E12) + (L * 0.00096 * Qt^{1.852} / dia^{4.87})$$

(The last term in the formula is the Hazen-Williams equation for friction loss in feet for PVC pipe with a C value of 150.)

PNODE takes all of this information (pt, id, Qt, dia, L, TPR, E1, nt, tpr2, and nt2), inserting the PNODE block and its attributes at the first node point. (A PNODE block describes the pipeline reach from that node to the next downstream node.) PNODE then sets the values of the first node's variables to those of the second node (p, E1, nt, and TPR = p2, E12, nt2, and Tpr2).

At this point, the program will either (1) repeat the PNODE program, (2) branch to the LNODE program, or (3) insert a pump node, depending on the node type (nt) variable's value. On a simple pipeline with no laterals, it continues to:

1. Query the designer for the IRRATT serviced by the new node
2. Find the pipes reach's Q, summing its Qt
3. Check the node pressure against the IRRATT's minimum allowable pressure
4. Select the reach pipe diameter
5. Query the designer for the downstream node location to determine the pipe reach length
6. Insert the PNODE block
7. Calculate the new node's pressure
8. Transfer the node values to the downstream node

If the minimum allowable pressure for the selected IRRATT is greater than the current node pressure, PNODE asks whether the designer wants to change this value. If so, the designer enters the new node pressure and the desired increase in flow rate Q. If not, the program continues until the designer enters a "P" for the node-type query. When nt is

equal "P", PNODE queries the designer for the pump's identification number and calculates the required pump brake horse power as follows:

$$HP = TPR * Qt / (3960 * 0.75)$$

(The 0.75 factor is pump efficiency.) The program then inserts the PUMP block, along with the attribute values of total flow (Qt), total pressure (TPR), horse power (HP), and pump elevation (El), and then terminates.

For a (T) node type, PNODE branches to the LNODE program. The LNODE program takes the current node location (pt), pressure (TPR), elevation (El), and identification number (id) from PNODE and suffixes the parameter name with an "L". LNODE then queries the designer for the out node location, the node type, elevation, and all the IRRATTs serviced by the node. The FLOW program totals the flow for all irrigation attribute blocks selected and returns this Q, along with the minimum required pressure of the last selected IRRATT. Unlike the PNODE program, LNODE does not change the value of TPR if it is less than the return value of PRMN. Rather, it prints the statement "min. allowable pressure is ____", indicating to the designer that a booster pump is required or that the main pump pressure should be increased. LPIPE selects the pipe-reach diameter. LNODE then finds the TPRL of the out-node by adding the friction loss in the reach length (ptL<->pt2) and the elevation head (ELL-El2) to the total pressure at the tee (TPR). The resulting PNODE block and its attributes are then inserted at the pt2 location, while the values of the second node variables are transferred to the L-suffixed node variables. At this point the LNODE checks the node type (ntL) to see if it should:

1. End the program and return to PNODE (ntL=E)
2. Branch to the sub-lateral program XNODE (ntL=T)
3. Re-enter the LNODE program at the PNODE tee node (ntL=ELT), or
4. Continue the LNODE program loop (ntL=/ E,T,or ELT)

When there is more than one lateral off the main-line at the same point, the program calculates the node variable values to the end of the first lateral. At the end of the first lateral, the designer enters "ELT" at the node-type query. (This code can be thought of as "End Lateral Tee.") When nt equals "ELT", the program re-enters the LNODE program at the PNODE tee location. The mainline variable values are again transferred to the L-suffixed variables, and the process continues until the lateral node type equals "E". Now the PNODE program proceeds to the pump end of the pipeline.

If the lateral node type equals "T", the program transfers values of the L-suffixed variables to X-suffixed variable in the XNODE program. The XNODE program is identical to the LNODE program except for the variable suffixes, and no further tee laterals are allowed. With these programs, all the pertinent information about a complex distribution system can be quickly stored for use in a spreadsheet.

Exporting AutoCAD Information to Lotus 123

Soils information is stored in the SATT attributed block and can be inserted with the SATT.lsp program. This AUTOLISP program queries the designer for the soil mapping unit number and for the DNRC land class number, entering this information along with the area of the last selected entity. Using the "area" AutoCAD command the designer

must select the area of the soils entities before the SATT.lsp program is run.

The identification LISP program (IDN.lsp) inserts, onto the design drawing, the project identification block (ID) and its attributes:

1. Project identification number
2. Project owner
3. Legal land description
4. Designer's initials
5. Maximum soil intake rate (MIR)
6. Net irrigation requirement (NIR)
7. Soil water holding capacity (WHC)
8. Peak consumptive use (PCU)
9. Total consumptive use (TCU)
10. Miles of powerline construction

This information is used in the IDA spreadsheet.

The Extract LISP program (EXT.lsp) extracts information from the attributed blocks and writes it into nine separate ".txt" data files, which can then be imported into the IDA spreadsheet. When the EXT.lsp program is executed, AutoCAD searches each attributed block for the attribute "tags" from template files (Table 3), writing the "tag" values named ".txt" file. These template files are used in the IDA spreadsheet to calculate annual costs.

Table 3. Attribute extract template files for the IDA spread sheet.

ID.TXT	IRR.TXT	NODE.TXT
C:QUOTE "	C:QUOTE "	C:QUOTE "
PROJECT#	TYPE	N-TYPE
OWNER	ID#	FL
TOPO	AREA	DEL
TWN	FLOW	ID
RNG	MIN-PR	N-EL
SEC	HW-LENGTH	N-PR
BY	LABOR	T-FLOW
CU	AC-FT	DIA
WHC		LENGTH
NIR		PRESS-IN
MIR		ID-IN
PLC		
TIR		
WSTA		
SOURCE		
DITCH.TXT	PUMP.TXT	DAM.TXT
C:QUOTE "	C:QUOTE "	C:QUOTE "
DID	PID	WIDTH
EL	P-EL	HEIGHT
WEL	HEAD	F-VOL
VOL	GPM	A-F
SLOPE	REQ-HP	
DEPTH	AFT	
VEL		
QCFS		
DLENGTH		
DCOST		
POD.TXT	POU.TXT	SOIL.TXT
C:QUOTE "	C:QUOTE "	C:QUOTE "
PID	TWNP	MAP-UNIT
BL:X	RNGP	LAND-CLASS
BL:Y	SECP	LC-AREA
	POU-AC	

Irrigation Design Analysis Spreadsheet Explanation

The irrigation design analysis (IDA) spreadsheet uses information from the AutoCAD irrigation design to determine the total system cost, annual costs, and annual per acre costs of that design. The spreadsheet imports information from the ".txt" files, that have been converted to ".prn" files, and inserts the information into the appropriate spreadsheet locations.

The IDA spreadsheet makes extensive use of range names to make spreadsheet documentation easier (Table 4). The ID range of the IDA spreadsheet is used as a project identifier for all output. It imports data from the ID.txt file regarding project number, owner name, legal land description, and designer's name. It also imports data on (1) peak consumptive use (PCU), (2) total consumptive use (TCU), (3) net irrigation requirement (NIR), (4) maximum soil intake rate (MIR), (5) soil water holding capacity (WHC), and (6) miles of required powerline construction (PLC). This information is used to document AutoCAD design process variables and to calculate other spreadsheet variables.

Table 4. IDA range name explanations.

A/C	- annual cost per acre	PCOST	- pump cost range
AC6	- acres of DNRC land class 6	PCT	- pipe cost table
ACS	- total acres of irrigable soils	PCU	- required power line construction
AEC	- annual energy cost	PERC	- percentile feasibility
AFN	- ac-ft of irrigation needed	PLC	- miles of power line construction
ALC	- annual labor cost	PLCC	- power line construction cost
AMF	- pump amortization factor	PN	- pipe node attributes
CCU	- crop consumptive use	PNA	- pipe node attributes
CDM	- contents check	PNT	- pipe node attributes
CDT	- contents check	PO	- project owner
CN	- contents check	POD	- place of diversion
COMMENTS	- project comments	POU	- place of use
CP	- contents check	POUR	- place of use range
CROP	- percent land cropped	PP	- pump attributes
DAM	- dam attribute	PPA	- pump attributes
DCH	- demand charge	PPC	- pump costs
DCR	- demand credit	PPP	- pumping power type
DCT	- dam costs	PPT	- pump attributes
DMA	- dam attribute range	PRJ	- project number
DNT	- dam attribute totals	PTC	- total pivot cost
DOM	- diesel O&M	PVT	- pivot eff.
DSR	- designer	PWC	- power cost
DTCH	- ditch attribute	QSEC	- quarter section
DTCHT	- ditch range	RNG	- range
DWC	- ditch water charge	RRR	- real rate of return
DWSTA	- weather station	SA	- soil attributes
EAC	- energy cost per acre	SAT	- soil attribute range
ECON-AC	- cost per acre	SCHED	- schedule of development
ENA	- engine amortization factor	SEC	- section #
EPC	- pump costs (electrical)	SRC	- source
EPL	- economic pipe life	SUM	- summary
EQC	- total equipment cost	SYSC	- system constants
ERI	- energy rate of inflation	SYSV	- system variables
FCT	- fuel costs	TAI	- total acres irrigated
FDC	- flood land preparation cost	TCU	- total ditch costs
FFL	- financial feasibility life	TDC	- total flow requirement
FIN	- financial interest rate	TEC	- total energy costs
FINC-AC	- financial cost per acre	TFL	- total pumping horse power
FLD	- flood efficiency	THP	- total consumptive use
HOP	- hours of pumping	TLB	- total labor (hrs)
HSC	- total hand set cost	TOPO	- topo name
ICT	- irrigation cost table	TPC	- total pipeline costs
ID	- identification address	TWN	- township
IDN	- identification range	WHC	- soil water holding capacity
INDH	- insert locator	WHL	- wheel and hand line eff.
INIR	- insert locator	WLC	- total costs
INPN	- insert locator	WNAME	- weather stations range
INPP	- insert locator	WSTA	- selected weather station
INTRP	- percentile interpolation range	\A	- editing
IR	- irrigation attributes	\B	- editing
IRA	- irrigation attributes	\C	- calculates feasibility
IRT	- irrigation attributes range	\D	- insert attributes
LCH	- labor costs per hour	\F	- print to file
MACRO	- key board macros	\I	- changes printer defaults
MIR	- maximum soil intake rate	\L	- documenting
NIR	- net irrigation requirement	\O	- exports pou to oracle
OPPS	- error macro	\P	- print to printer
ORA	- oracle range	\T	- exports system types to oracle
ORAV	- oracle export values	\U	- change printer defaults
OWN	- owner	\W	- exports system design values to oracle
PAF	- total cost per ac-ft	\X	- row insert macro
PCL	- pipe class range	\Z	- suppress zero

The irrigation attribute range (Table 5) imports data from the IR.txt file and determines the volume of water needed and the system cost for each IRRATT in the AutoCAD design. It then totals the (1) number of acres irrigated (TIA), (2) flow required (TFL), (3) labor required (TLB), (4) acre-feet of water needed (AFN), and (5) system costs (PTC,WLC,FLC) for all the IRRATT systems imported from the AutoCAD design.

Table 5. Irrigation attribute range of the IDA spreadsheet.

IRRIGATION ATTRIBUTES											
TYPE (system)	ID#	AREA (acres)	FLOW (gpm)	MIN-PR (ft)	HW-L (ft)	LABOR (hours)	WATER USE (af/yr)	PIVOT COST	LINE COST	FLOOD COST	PIVOT POWER kw-hr
PIVOT	1	103.3	697	87	1096	77	239	\$29,756	\$0	\$0	10185
PIVOT	2	138.2	932	93	1284	103	320	\$34,224	\$0	\$0	11947
PIVOT	3	80.0	539	67	953	59	185	\$26,396	\$0	\$0	8864
PIVOT	4	57.3	387	60	791	43	133	\$22,589	\$0	\$0	7367
PIVOT	5	76.5	516	66	930	57	177	\$25,855	\$0	\$0	8645
WHLN	1	40.0	479	130	1100	76	109	\$0	\$9,800		
HLN	1	89.0	883	137	1720	395	239	\$0	\$6,880		
		584.3	4433			810	1402	\$138,819	\$16,680	\$0	\$1,410 PPC

The cost of the systems are calculated as (Triangle Irr. Inc., 88):

$$\text{pivot cost} = \$4,000 + \$23.50 * \text{HW-L} + (\text{if HW-L} > 1280 \\ (\$12.50 * (\text{HW-L} - 1280)))$$

$$\text{Wheel line cost} = \$3,200 + \$6.00 * \text{HW-L}$$

$$\text{hand line cost} = \$4.00 * \text{HW-L}$$

$$\text{flood cost} = \$200 * \text{AREA} + \text{HW-L} * \text{MIN-PR}$$

(For flood costs, the hardware length (HW-L) is the length of the field header ditch entered in the AutoCAD design; the MIN-PR is the header cost per foot entered in the FLOOD.lsp program.)

The Distribution System Attributes range (Table 6) determines the class and per-foot cost of the pipeline at each node and then calculates the total pipeline costs (TPC) for each reach. It imports data from the PNODE blocks of the AutoCAD design through the NODE.txt file. The per-foot cost of the pipe is taken from the Pipe Cost Table (Table 7) for the appropriate size and class of pipe (DNRC, 89).

Table 6. Distribution system range of the IDA spreadsheet.

DISTRIBUTION SYSTEM ATTRIBUTES

ID (OUT)	EL (ft)	HEAD (ft)	FLOW (gpm)	SIZE (in)	LENGTH (ft)	PR-IN (ft)	NODE ID (IN)	PIPE CLASS	COST/ FT	TOTAL COST	F LOSS ft/1000'
1	3080	60	387	8	2170	85	2	80	\$3.41	\$7,406	2.5
2	3060	93	1319	12	2222	110	3	80	\$6.88	\$15,283	3.3
30	3060	78	697	8	2721	110	3	80	\$3.41	\$9,286	7.4
3	3050	110	2555	15	2086	289	4	200	\$20.08	\$41,887	3.8
5	3060	66	516	8	1538	133	6	80	\$3.41	\$5,249	4.2
7	3050	130	479	8	2124	148	8	100	\$3.92	\$8,335	3.7
9	3040	137	883	10	2002	145	10	100	\$6.05	\$12,106	3.9
10	3040	145	883	10	1282	170	11	125	\$7.10	\$9,103	3.9
20	3042	20	4763	22	1265	64	21	80	\$19.24	\$24,335	1.9
21	3000	64	4763	22	931	166	22	100	\$22.97	\$21,386	1.9

\$154,375

Table 7. Pipe cost table of the IDA spreadsheet.

PIPE COST TABLE						
PIPE	133	166	208	266	333	max. allowable head (ft)
OD	80	100	125	160	200	STEEL class
	1	2	3	4	5	6 look up range
4.3	\$1.76	\$1.90	\$2.09	\$2.31	\$2.57	\$4.48
6.1	\$2.41	\$2.70	\$3.08	\$3.53	\$4.06	\$5.68
8.2	\$3.41	\$3.92	\$4.60	\$5.40	\$6.34	\$7.43
10.2	\$5.25	\$6.05	\$7.10	\$8.35	\$9.81	\$10.84
12.2	\$6.88	\$8.03	\$9.55	\$11.35	\$13.45	\$13.54
15.3	\$9.81	\$11.60	\$13.97	\$16.79	\$20.08	\$16.26
18.8	\$14.35	\$17.04	\$20.58	\$24.78	\$29.70	\$20.54
22.0	\$19.24	\$22.97	\$27.89	\$33.74	\$40.57	\$23.58
24.1	\$22.82	\$27.27	\$33.14	\$40.11	\$48.27	\$36.74
27.0	\$28.67	\$34.27	\$41.65	\$50.42	\$60.67	\$43.01
32	\$37.88	\$37.88	\$45.75	\$50.98	\$59.21	\$59.21
36	\$44.79	\$44.79	\$67.99	\$67.99	\$67.99	\$67.99
48	\$78.62	\$78.62	\$78.62	\$110.02	\$110.02	\$110.02
60	\$122.75	\$122.75	\$122.75	\$142.39	\$161.99	\$201.07

The Ditch cost range (Table 8) calculates the cost of each ditch and sums the total ditch costs (TDC). It imports ditch attributes through the DTCH.txt file. The GRADE column indicates the water surface level relative to the ground surface elevation. All the columns in the DITCH range are imported from AutoCAD except the Total Cost column.

Table 8. Ditch attributes range of the IDA spreadsheet.

DITCH ATTRIBUTES										
ID	ELEVATION	GRADE	AC-FT	SLOPE	DEPTH	VELOCITY	FLOW	LENGTH	COST	TOTAL COST
				ft/1000'	ft	ft/sec	(cfs)	ft	\$/FT	
A	3039	3	1108	0.0019	1	1.9	7	3660	\$11.81	\$43,225
B	3042	1	1285	0.0005	1.4	1.2	9	3660	\$12.24	\$44,798
										\$88,023

The Pump Attributes range (Table 9) calculates the pump costs and annual energy costs for both diesel and electrical pumping options. It imports data from the AutoCAD design through the Pump.txt file. The costs of the electrical motor, pump, and panel are obtained from the pump costs table (Table 10)(DNRC, 89). The spreadsheet also calculates the annual power costs for each pump, using the power costs (PWC) and demand charge (DCR) constants from the spreadsheet and the horse power and annual pumping volume attribute values from the pump.txt file. The costs of the diesel engines required to drive each pump are calculated as (USDA, 85):

$$\text{engine cost} = 2816 + (34 * \text{HP}) + (0.3 * \text{HP}^2) - (0.0005 * \text{HP}^3)$$

$$\text{fuel costs} = 0.05 * \text{HP} * \text{hours of pumping (HRS)} * \text{fuel costs(FCT)}$$

$$\text{HRS} = \text{FLOW(gpm)} / \text{AC-FT} / 226(\text{gpm/af-day}) * 24(\text{hr/day})$$

To determine the least-cost pumping alternative, these costs are compared to those of electrical pumping and powerline construction.

Table 9. Pump attributes range of the IDA spreadsheet.

PUMP ATTRIBUTES

ID	EL (ft)	HEAD (ft)	FLOW (gpm)	BHP	AC-FT (annual)	HRS	MOTOR SIZE	ELECTRICAL COSTS		DIESEL COSTS	
								POWER	PUMP	FUEL	ENGINE
4	2880	289	2555	248	877	1862	300	\$15,060	\$32,555	\$23,086	\$22,320
6	3000	133	516	23	177	1861	25	\$1,396	\$5,216	\$2,140	\$3,751
8	3040	148	479	23	109	1234	25	\$1,042	\$5,179	\$1,419	\$3,751
11	3020	170	883	50	239	1468	60	\$2,553	\$9,383	\$3,670	\$5,204
POD	2900	166	4763	267	1521	1732	300	\$4,005	\$34,763	\$0	\$24,030
						0	0	\$0	\$0	\$0	\$0
					611		710	\$24,056	\$87,096	\$30,315	\$59,055

Table 10. Pump cost lookup table.

PUMP HP	COST
0	\$0
1	\$2,900
7.5	\$2,900
10	\$3,200
15	\$3,500
20	\$3,700
25	\$4,700
30	\$5,800
40	\$6,300
50	\$6,700
60	\$8,500
75	\$9,200
100	\$12,000
125	\$14,300
150	\$15,000
200	\$20,000

The Dam Attributes range (Table 11) calculates the total dam construction cost, and then sums the acre-feet of water storage and total dam costs (DCT) for all the reservoirs in the design. It imports data from the Dam attribute blocks of the AutoCAD design through the DAM.txt file. If the dam height is less than 20 feet, the cost is determined by multiplying the fill volume (F-VOL) by \$2.00 per cubic yard of fill required. If the dam is greater than 20 feet high the fill cost is assumed to be \$4.00 per cubic yard (Bergantin, 86).

Table 11. Dam attributes range of the IDA spreadsheet.

DAM ATTRIBUTES					
WIDTH (ft)	HEIGHT (ft)	F-VOL (cyd)	AC-FT	T-COST	COST/AF
211	20	7533	56	\$15,066	\$269
353	30	27331	457	\$109,324	\$239
				\$0	\$0
				\$0	\$0
			513	\$124,390	\$242

The Soil Attribute range (Table 12) is used to document the information used in the design, importing data from the ID and SATT blocks of the AutoCAD design.

Table 12. Soils attributes range of the IDA spreadsheet.

SOIL ATTRIBUTES	
Peak consumptive use	0.27 "/day
Soil water holding capacity	10.1 "
Maximum intake rate	1 "/hr
Predominant soil (Map Unit # / land class #)	98B /1
Acres of irrigable soils in project area	849 ac
# of acres of Class 6 soil in design area	0 ac

The System Constants range (Table 13) sets the value for the spreadsheet variables that are not dependent on the AutoCAD design and so remain constant from one design to the next (SCS, 87).

Table 13. System Constants range of the IDA spreadsheet.

SYSTEM CONSTANTS

Economic pump life	EPL	30 years
Max. Financial F. life	FFL	10 years
Energy rate of inflation	ERI	1.00%
Financing interest rate	FIN	10%
Real rate of return	RRR	4.60%
Pump amortization factor	AMF	6.2%
Ditch water charges	DWC	\$0.00 \$/ac
Pivot eff.	PVT	75%
Whln & handline eff.	WHL	65%
Flood eff.	FLD	70%
Labor costs per hour	LCH	\$5.00 /hr
Power costs	PWC	\$0.030 /kw-hr
Demand charge	DCH	\$15.00 /hp-yr
Demand credit	DCR	\$125 /hp
Power line const. cost	PLCC	\$12,500 /mile
Fuel costs	FCT	\$1.00 /gal
Diesel annual O&M	DOM	5.5%

The System Variables range (Table 14) is the set of variables obtained or calculated from the AutoCAD design and therefore change if the design changes. The print-out of each design summary includes this set of variables. The equipment cost variable is the sum of the pivot, wheel line, and hand line costs. This range also compares the annual pumping cost of electrical and diesel power options, selecting the least-cost pumping power (PPP) alternative and determining the annual energy cost (AEC). The annual calculations are:

$$\text{HOP} = \text{AFN} / \text{TFL} / 226 * 24$$

$$\text{electrical costs} = 0.745 * \text{THP} * \text{HOP} * \text{PWC} + 12500 * \text{PLC} * \text{AMT}$$

$$\text{diesel costs} = (1.055 + \text{ENA}) * \text{ENC} + 0.05 * \text{THP} * \text{FCT} * \text{HOP}$$

$$\text{AEC} = \text{IF PPP=Electrical THEN } (\text{THP} * 0.745 * \text{HOP} * \text{PWC} + \text{THP} * \text{DCR}) \text{ IF NOT THEN } (0.05 * \text{THP} * \text{HOP} * \text{FCT})$$

The pumping power variable (PPP) compares the annualized cost of powerline construction plus the annual electric power cost against the annual cost of owning and operating a diesel engine. Diesel engine life is set at 28,000 hours (ASAE, 84). Therefore, years of engine life is 28,000 hr divided by annual hours of pumping (HOP). The years of engine life is used to set the diesel engine amortization factor (ENA). The ownership costs of an electrical motor and pump are assumed to be equal to that of the engine clutch and pump, and so are not accounted for in the comparison. Diesel fuel consumption is assumed to be 0.05 gal/hp-hr (ASAE, 84).

Table 14. System variables range of the IDA spreadsheet.

SYSTEM VARIABLES

Require power line const.	PLC	5.0 miles			
Total consumptive use	TCU	28 inches			
Net irrigation requirement	NIR	20.9 inches			
Total acres irrigated	TAI	584 ac			
Ac-ft of water needed	AFN	1402 ac-ft	Total pump hp	THP	611
Total flow	TFL	4433 gpm	Hours of pumping	HOP	1715
Equipment costs	EQC	\$155,499	Engine amort.	ENA	8.8%
Flood costs	FDC	\$0	Annual electrical cost		\$28,753
Total pipe cost	TPC	\$154,375	Annual diesel costs		\$46,374
Total ditch cost	TDC	\$88,023	Pumping power	PPP Electrical	
Labor cost	ALC	\$4,050	Ann. energy costs	AEC	\$25,466
TR-21 weather station	WSTA	Fort Benton	Energy cost/ac	EAC	\$43.58

The Irrigation Costs Table range (Table 15) of the IDA spreadsheet annualizes the cost of the irrigation equipment used in the AutoCAD-designed system. (The table separates the on-farm irrigation equipment costs from the water delivery system costs. The engineering and contingency costs are based on the delivery system costs.) The range determines the total cost for each item, calculating

the annual operation and maintenance costs (O&M) from the O&M% column, and adding them to the amortized cost. The amortized cost is calculated on an economic and financial basis: the amortized economic costs are based on the system's life from the LIFE column and the real rate of return (RRR) interest variable; the amortized financial costs are based on the fixed financial life (FFL) and financial interest rate (FIN) variables. The range sums these columns to determine the total annual economic and financial system costs.

The total costs for the pivots, wheel lines and hand lines, and flood systems are taken from the irrigation attributes range (Table 5). The designer can enter "other" on farm cost. The total pump cost is taken from the pump attribute range (Table 9). As before, it is assumed that the cost of a pump, electrical motor, and electrical control panel are equal to the cost of a pump, clutch, mounting frame, and fuel tank for a diesel engine. Therefore, a single cost per horse power variable is used to determine total pump costs. If diesel is the least-cost pumping option, the total diesel engine cost (DEC) from the Pump Attributes range is entered in the TOTAL COST column for engine; otherwise a zero is entered.

The cost of developing a diversion site is assumed to be proportional to the flow diverted. This is a site-specific amount and generally varies between a value of \$1,000 - \$3,000 per cubic foot per second at the designer's discretion. The total costs of the pipelines and ditches are increased by 10% to account for miscellaneous fittings and structures. The total dam costs (DCT) are entered in the total COST column for storage. If all the costs for the dam and reservoir

are not allocated to the irrigation system, the cost per acre-foot of storage from the dam attribute range can be entered in COST/UNIT column for the storage. This number will then be multiplied by the acre-feet needed (AFN) variable from the System Variable range to find total storage costs. The "other" items in the range can be used by the designer to enter costs not accounted for in the IDA spreadsheet (such as land clearing costs). The power development cost is the power-line construction cost less the horse power demand credit (DCR) of the utility company and is calculated as:

$$\text{PLCC}(\$/\text{mile}) * \text{PLC}(\text{miles}) - \text{DCR}(\$/\text{hp}) * \text{hp connected}$$

This total is zero if the PPP variable evaluates to "diesel".

Finally, the Summary range (Table 16) summarizes the annual costs of the IDA spreadsheet. The total annual labor cost is found in the irrigation attributes range (Table 5). The annual energy cost is taken from the system variable range (Table 14). The equipment cost is the total system cost (Table 15). The annual labor and energy costs are the same for both the economic and financial analysis. The annual cost per acre is then compared to a chart developed by Dodds and Tubbs (DNRC, 88) in order to determine economic feasibility.

Table 15. Irrigation costs table range of the IDA spreadsheet.

ITEM	COST/ UNIT	# OF ITEMS	UNITS	IRRIGATION COSTS TABLE			ECON		FINAN.	
				T. COST \$1	% O&M	O&M	LIFE	ANN-COST TOTAL	ANN-COST TOTAL	COST/AC
Flood				\$0	10.0%	\$0	20	\$0	\$0	\$0
Line				\$16,680	1.5%	\$250	10	\$2,369	\$2,965	\$29
Pivot				\$138,819	3.0%	\$4,165	20	\$14,929	\$26,757	\$238
Other				\$0	1.5%	\$0	10	\$0	\$0	\$0
Other		unit		\$0	5.0%	\$0	10	\$0	\$0	\$0
ON-FARM TOTALS				\$155,499		\$4,415		\$17,298	\$29,722	\$266
Pump		710 hp		\$87,096	2.5%	\$2,177	30	\$7,587	\$16,352	\$149
Engine		0 hp		\$0	5.5%	\$0	16	\$0	\$0	\$0
Diversion	\$2,000	9.9 cfs		\$19,702	1.0%	\$197	30	\$1,421	\$3,403	\$34
Pump controls		10%p. cost		\$8,710	1.0%	\$87	20	\$762	\$1,505	\$15
Pipe	\$154,375	110%		\$169,813	0.5%	\$849	50	\$9,582	\$28,485	\$291
Ditches	\$88,023	110%		\$96,825	5.0%	\$4,841	20	\$12,349	\$20,599	\$166
Storage	\$0	513 ac-ft		\$124,390	1.0%	\$1,244	50	\$7,641	\$21,488	\$213
Other		unit		\$0	2.0%	\$0	50	\$0	\$0	\$0
SYSTEM TOTALS				\$506,536		\$9,396		\$39,343	\$91,832	\$867
Power dev.	\$12,500	5.0 miles		\$0			50	\$0	\$0	\$0
Engineering		15%S. total		\$75,980			50	\$3,907	\$12,365	\$130
Contingency		10%S. total		\$50,654			50	\$2,605	\$8,244	\$87
TOTAL				\$788,669		\$13,811		\$63,154	\$142,163	\$1,350
ANNUAL cost/ac	A/C			\$108.08		\$23.64				
ANNUAL cost/ac-ft	PAF			\$45.05		\$9.85				

Table 16. Summary range of the IDA spreadsheet.

TOTAL ANNUAL COSTS	ECONOMIC			FINANCIAL		
	TOTAL	/AC	/AC-FT	TOTAL	/AC	/AC-FT
LABOR	\$4,050	\$6.93	\$2.89			
ENERGY	\$25,466	\$43.58	\$18.16			
EQUIPMENT	\$63,154	\$108.08	\$45.05	\$142,163	\$243.30	\$101.40
TOTAL annual costs	\$92,670	\$158.60	\$66.10	\$171,679	\$293.82	\$122.45

CHAPTER 5**THE MACHINE USE SPREADSHEET**

The costs of owning and operating agricultural equipment vary greatly depending on farm situations and crop. These costs must therefore be estimated to evaluate an irrigation development. The Machine Use spreadsheet, comprised of ten information areas (ranges), determines this information. A flow chart of these ranges is shown in (Figure 6). This chapter explains the use and function of each range.

The Index range

The Index range (Table 17) locates other ranges in the spreadsheet for editing or printing. The user may select a range area by pressing f5 (goto) and the two letter range name listed in the index. The range can be printed by pressing the "alt" key and the single letter print code, also listed in the index.

Figure 6. Flow-chart of Machinery Use spreadsheet.

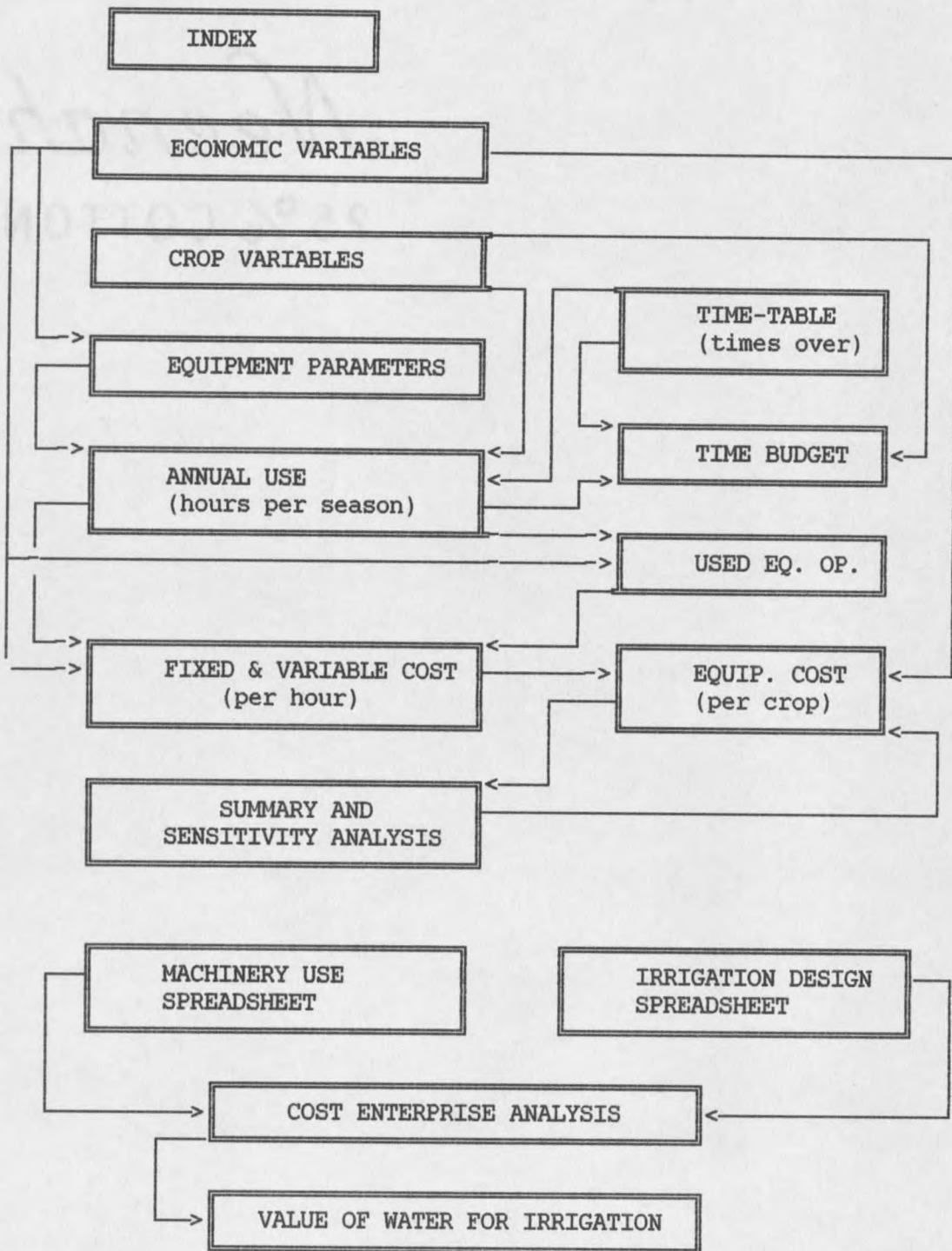


Table 17. INDEX range for the Machine Use spreadsheet.

INDEX	ID CODE	PRINT CODE
Input Variables	IV	I
Equip. Parameters	EP	E
Eq. Use Time-Table	TT	T
Annual Use	AU	U
Time Budget	TB	B
Fixed Costs	FC	F
Variable Costs	VC	V
Eq. Cost per crop	EC	C
Summary	SU	S
All		A

The Economic Variables Range

The Economic Variables range (Table 18) determines amortization values, current year purchase price, and other price information used in other spreadsheet ranges, including: (1) real rate of return, (2) inflation rate, (3) interest rate, (4) purchase prices, (5) dealer discounts, (6) inflation factor, (7) user input price, (8) repair costs, and (9) maximum years of ownership. The spreadsheet calculates the real rate of return (RRR), used to determine amortization values, by subtracting the average annual inflation rate (IFR) from the long term interest rate (INR). Equipment purchase prices (PUP) are found by adjusting the 1984 list prices (Johnson, 85) for inflation and dealer discounts (DIS). The inflation factor (IFF) is the inflation rate raised to the power of the number of years since 1984. The dealer discount rate (DIS) lowers all equipment purchase prices by the discount entered. The designer may also change individual equipment

prices using the user input price (UIP) range. Repair costs (%RC) vary depending on level of maintenance; therefore, the spreadsheet includes a variable (%RC) that adjusts the ASAE repair cost estimate obtained in the VARIABLE COST range. Another variable, the maximum years of ownership (MAX) variable, accounts for replacing all equipment after a designer selected number of years, unless its useful life is reached first.

Table 18. Economic variable range of the Machinery Uses spreadsheet.

ECONOMIC VARIABLES		
Current year		87
Interest rate (.01 = 10.00%)	INR	10.00%
Inflation rate (ave)	IFR	4.00%
Real rate of return	RRR	6.00%
Inflation factor since "84"	IFF	1.12
Discount from list price	DIS	0.80
1984 list price multiplier	LPM	0.90
Taxes and ins. as % of ave. value	T&I	1.5%
Percent of ASAE repair cost used	%RC	75%
Fuel price (diesel)	DFP	\$1.00
Max. yrs of ownership	MAX	10
Labor costs	LBC	\$1.00

The Crop Variables Range

The Crop Variables range (Table 19) establishes the size, cultural practice, and truck usage of the farm including the number of cattle raised. Truck use is the most site-specific equipment variable, dependent on (1) estimated crop yield (ECY), (2) pounds per unit of crop yield (#PU), (3) total truck hours to haul a load to market (HPL), and (4) the number of trucks used (#TU). These variables

determine the number of axle-hours per acre (APA) for each crop used in the ANNUAL USE range to determine the total truck usage. The total straw yield variable (TSY), or number of tons of straw to be removed from a field, is also used to calculate the APA. The spreadsheet assumes one hour of truck time per load and is added to the APA parameter, using the calculation:

$$\text{APA} = (\text{ECY} * \text{\#PU} / 2000 / \text{TPA} * \text{HPL}) + \text{TSY} / \text{TPA}$$

Table 19. Crop variable range of the Machinery Use Spreadsheet.

FARM VARIABLES		EST. YIELD	LBS/UNIT	TR-HR /LOAD	STRAW YIELD	# OF TR USED 1,2,or,3	AX-HR /AC
ACRES	ACS	ESY	\#PU	TPL	TSY	\#TU	
APA							
SUGAR BEETS	100 ac	20 ton/ac	2000	2.5	0	3	5.00
CORN GRAIN	100 ac	125 bu/ac	56	2.5	2	2	1.08
CORN SILAGE	100 ac	20 ton/ac	2000	1	0	3	2.00
BEANS	100 ac	24 cwt/ac	100	2.5	0	1	0.30
ALFALFA	100 ac	5 ton/ac	2000	1	0	1	0.50
IRR. GRAIN	100 ac	100 bu/ac	60	2.5	2	2	0.95
DL GRAIN	1000 ac	45 bu/ac	60	2.5	0.25	2	0.36
COW-CALF	<u>100</u> hd	0.9 calf/h	1500	6	1	2	0.51
	1700 ac						

The Equipment Parameters Range

The Equipment Parameters range (Table 20 - 22) allows the user to enter the size and operating characteristics (SPD & EFF) of the equipment to be used in the scenarios, including horse power parameters (RRC, HPD, HPS, HPU, & HPR), and repair factors (RF1 & RF2) taken from ASAE Standards D230.4 (ASAE, 1984). The designer may change

equipment by entering an implement and its specifications in the appropriate cells, along with its estimated price in the user input price (UIP) range. Once an implement is changed, its named references are also changed in the rest of the spreadsheet the next time the spreadsheet is calculated.

The spreadsheet allows the designer to select either two or three tractors. If the designer enters zero for the first tractor horse power size variable (TR1) the spreadsheet uses the second tractor for all the first tractor-designated operations. The spreadsheet also allows the designer to purchase used equipment (N-U), for small farm operations where new equipment life extensively exceeds maximum years of ownership. The purchase price (PUP) is assumed to have a linear relationship with the equipment size, and is used to determine the cost for any equipment size selected with the calculation:

$$PUP = ("84" \text{ list price} / \text{equip. size}) * SIZ * LPM$$

The designer may change this estimated price with the user input price variable (UIP).

To determine the hours use per acre (HUA), the spreadsheet calculates:

$$HUA = 8.25 / SPD(\text{mph}) * SIZ * \text{unit value} * EFF$$

The equipment operating speed (SPD) and field efficiency parameters (EFF) are set as medium recommended values established by ASAE standard D230.4 (ASAE, 1984). The "unit value" is the row crop spacing width in inches (RWD) converted to feet, and the unit value for "FT" is set equal to 1; thus, SIZ times unit value is the equipment width in feet.

Horse power requirements (RHP) are estimated for each implement from formulas cited in the ASAE Standards D230.4 (ASAE, 1984) and are used as a comparison of entered tractor size (Table 22). The RHP formula correlates rolling resistance (RRC), implement draft (HPD), travel speed (HPS), harvest feed rates (HPR), and size (HPU) to estimate total horse power requirements follows:

$$\text{RHP} = ((\text{HPD} + \text{HPS} * \text{SPD}) * \text{SIZ} * \text{SPD} / 375 / \text{RRC}) + (\text{ESY} * \text{\#PU} / (\text{HUA} * \text{EFF} * 3600) * \text{HPR}) + (\text{HPU} * \text{SIZ})$$

Since feed rate horse power factor (HPR) is yield-dependent, the designer must edit the horse power (RHP) formula for the yield (ESY & #PU) of the desired crop. The selected purchase price (SPP) is used to calculate annual costs; it is equal to the purchase price (PUP) unless the designer enters a value other than zero in the user input (INP) range.

Table 20. Equipment parameter range of the Machinery Use spreadsheet.

EQUIPMENT PARAMETERS	
1 st tractor (input 0 for 1 st)	TR1
2 nd tractor (tractor if using)	TR2
3 rd tractor (only 2 tractors)	TR3
tons per truck axle	TPA
row width	RWD
bottom width	BWD
purchase new or used equipment	N-U
age of purchase used eq.	AGE
if swather self-propelled input 1	SWT

Table 21. Equipment and prices used in the equipment parameters range of the Machinery Use Spreadsheet.

MACHINE	SIZE UNIT	PURCHASE PRICE	USER INPUT	
	SIZ	PUP	INP	
TRUCK 3	2 axle	\$38,695	0	used in remaining tables of the Machinery Use spreadsheet explanation as abridged examples.
TRUCK 2	2 axle	\$38,695	0	
TRUCK 1	2 axle	\$38,695	0	
CORN HEADER	6 row	\$10,799	0	
COMBINE	24 ft	\$85,715	0	
DISK	14 ft	\$10,664	0	
PLOW	4 bottom	\$8,579	0	
BEEF DIGGER	4 row	\$47,994	0	
CORN CHOPPER	4 row	\$35,546	0	
TOOL BAR	20 ft	\$8,099	0	
TRACTOR 1	90 hp	\$32,396	0	
HARROW	30 ft	\$19,123	0	
CULTIVATOR	15 ft	\$3,672	0	
DRILL	20 ft	\$14,511	0	
PLANTER CORN	8 row	\$14,218	0	
PLANTER BEEF	8 row	\$8,519	0	
DEFOLIATOR	4 row	\$6,916	0	
BALER (ROUND)	12 ft	\$16,333	0	
TRACTOR 2	70 hp	\$25,197	0	
LAND PLANE	12 ft	\$4,054	0	
SPRAYER	48 ft	\$3,825	0	
ROLLER PACKER	12 ft	\$4,054	0	
BEEF THINNER	4 row	\$10,799	0	
CORN CULT.	8 row	\$5,190	0	
BEEF CULT.	8 row	\$4,799	0	
BEAN CUTTER	4 row	\$2,040	0	
BEAN WINDROWER	4 row	\$5,246	0	
SWATHER	12 ft	\$10,259	0	
FARMHAND	6 ft	\$3,195	0	
SCROPF	6 ft	\$540	0	
AUGER	8 X41	\$2,814	0	
TRACTOR 3	50 hp	\$16,873	0	

Table 22. Equipment use and horse power parameters used in the equipment parameter range of the Machinery Use spreadsheet.

EQUIPMENT PARAMETERS								
MACHINE	SPEED MPH	FIELD EFF.	HR PER AC	USE POWER UNIT	ASAE			SELECTED PURCHASE PRICE
					REQ. HP	REPAIR RF1	F. RF2	
					RHP			
TRUCK 3					100	0.26	1.6	\$38,695
TRUCK 2					100	0.26	1.6	\$38,695
TRUCK 1					100	0.26	1.6	\$38,695
CORN HEADER	2.5	0.65	0.51	120	99	0.14	2.3	\$10,799
COMBINE	3.0	0.70	0.16	120	79	0.12	2.1	\$85,715
DISK	4.0	0.80	0.18	90	87	0.18	1.7	\$10,664
PLOW	4.5	0.80	0.43	90	68	0.43	1.8	\$8,579
BEEF DIGGER	3.0	0.70	0.59	90	45	0.19	1.4	\$47,994
CORN CHOPPER	2.5	0.65	0.76	90	85	0.23	1.8	\$35,546
TOOL BAR	5.0	0.80	0.10	90	90	0.30	1.4	\$8,099
TRACTOR 1				90		0.012	2.0	\$32,396

	HORSE POWER REQUIREMENT PARAMETERS			
	DRAFT/UNIT		HP/	FEED RATE
	#	SPEED	UNIT	HP/(#/S)
	HPD	HPS	HPU	HR
CORN HEADER			3	13.8 CORN G
COMBINE			0.5	4.6 IRR G
DISK	350			
PLOW	7	0.09		
BEEF DIGGER	700		2	
CORN CHOPPER			10	2 CORN S
TOOL BAR	117	17		
TRACTOR 1				

Rolling resistance coeff. RRC 0.6

Table 24. Time table budget range of the Machinery Use spreadsheet.

TIME TABLE BUDGET									
	M	A	M	J	J	A	S	O	N
T R									1
C H	0	0	0	0	0	0	100	0	0
COM	0	0	0	0	0	100	200	0	0
DIS	100	0	0	0	0	0	0	100	100
PLO	200	0	0	0	0	0	0	0	225
B D	0	0	0	0	0	0	0	100	0
C C	0	0	0	0	0	0	100	0	0
T B	0	0	0	0	0	0	0	0	0

The Annual Use Range

The Annual Use range (Table 25) calculates and sums the total hours that an implement is used for each crop to find the total annual hours of equipment usage (HRS) and years of equipment life (YRS). From this information, the spreadsheet calculates annual costs in the FIXED and VARIABLE COST ranges. The expected years of equipment life (LFY) are estimated by dividing the hours of useful life (LFH) (as recommended in ASAE Standard D230.4 (1984)), by HRS. If this LFY range exceeds the maximum years of ownership (MAX) variable, the smaller value is retained in the years used (YRU) range. The total annual hours of truck usage is found by checking the number of trucks used (#TU) range for the crop raised with the calculations:

TRUCK 3 -IF (#TU = 3, APA * ACS / # of axles /#TU, 0) * TIMES OVER

TRUCK 2 -IF (#TU > 1, APA * ACS / # of axles /#TU, 0) * TIMES OVER

TRUCK 1 -APA * ACS / # of axles /#TU * TIMES OVER

(These formulas divide the truck hours equally over the number of trucks used.) The annual hours of use calculations for the implements are:

IMPLEMENT - ACS * HUA * TIMES OVER

The annual hours of use calculations for the three tractors are:

TRACTOR 1 - (if TR1 = 0,0, sum of annual implement use listed for tractor 1)

TRACTOR 2 - (sum of annual implement use listed for tractor 1 & 2) - 2 * (the annual use of tractor 1)

TRACTOR 3 - (sum of annual implement use listed for tractor 3) - (the annual use of the swather * the value for swather use (SWT))

The SWT variable allows the designer to select either a self propelled (SWT=1) or a pull type swather (SWT=0). If the SWT value entered for SWT is equal to one, its hours of use are not included in the third tractor's hours. The LABOR HR range sums the hours of use for the trucks, combine, and tractors, plus the annual use for the swather times the value for swather use. The total annual labor hours parameter is increased by 10% for equipment maintenance and is used to determine the annual hours of labor for each crop.

The Used Equipment Option Range

The Used Equipment Option range (Table 26) sets the parameters that determine repair costs and purchase price for used equipment. If the designer chooses the used equipment option, the spreadsheet selects used equipment whose remaining life coincides with the maximum years of ownership. The spreadsheet determines the purchase price and yearly repair costs based on the age of purchase used equipment

variable (AGE). The equation for calculating the value of used equipment is derived from the percent of life remaining and the number of years of use:

$$\%value = A * \%life\ remaining + .1$$

$$A = .9 - (.03 * years\ used)$$

Thus, the remaining value of a implement has a linear relationship with its percent of remaining life with a slope related to its obsolescence. The value of the used equipment will not go below its salvage value, since the remaining life parameter is limited to values between 1 and 0. This equation is an estimate of equipment resale value and is used in this spreadsheet to determine average annual equipment costs.

Table 25. Annual use range of the Machinery Use spreadsheet.

ANNUAL USE	TOTAL HOURS EACH MACHINE IS USED FOR						
	S B	CORN G	HRS	LIFE HR	LIFE YR	YEARS USED	
TRUCK 3	83	0 ~	117	2000	17.1	10.0	
TRUCK 2	83	27 ~	271	2000	7.4	7.4	
TRUCK 1	83	27 ~	311	2000	6.4	6.4	
CORN HEADER	0	51 ~	51	2000	39.4	10.0	
COMBINE	0	51 ~	282	2000	7.1	7.1	
DISK	18	0 ~	239	2000	8.4	8.4	
PLOW	43	43 ~	183	2000	11.0	10.0	
BEET DIGGER	59	0 ~	59	2500	42.4	10.0	
CORN CHOPPER	0	0 ~	76	2000	26.3	10.0	
TOOL BAR	0	0 ~	413	2000	4.8	4.8	
TRACTOR 1 10.0	120	43 ~	970	10000	10.3		

The percent of life used (LU%) range is the percent of total equipment life that would be used in the maximum years of ownership (MAX), and is used to determine the used purchase price (UP%). Its maximum value is limited to 75% of the total expected life (LFY) to eliminate the ambiguities of purchasing almost new equipment. The used purchase price range calculations are:

$$UP\% = .9 - (.03 * AGE) * LU\% - 0.1$$

The total repair cost of equipment increases with age and is based on a percentage of original purchase price (PUP). The total equipment repair and maintenance costs are estimated by the equation (in accordance with ASAE (1984) Standard D230.4):

$$TOTAL\ REPAIR\ COST = PUP * RF1 * (hour\ use/1000)^{RF2}$$

(The repair factors RF1 and RF2 are taken from Table 22.) The TOTAL REPAIR COST for used equipment is found by subtracting the total estimated repair cost of the used equipment at time of purchase (PU%) from the total at its wearout life (WO%):

$$Total\ repair\ costs = PUP * (WO\% - PU\%)$$

Table 26. Used equipment option range of the Machinery Use spreadsheet.

USED EQUIPMENT OPTION	PERCENT OF NEW PURCHASE PRICE					
	%LIFE USED	%LIFE REM.	PURC. PRICE USED	TOTAL REPAIR COSTS WEAROUT	PURC. NEW	PURC. USED
	LU%	LR%	UP%	WO%	PN%	PU%
TRUCK 3	58%	42%	54%	79%	33%	59%
TRUCK 2	75%	0%	66%	79%	79%	70%
TRUCK 1	75%	0%	66%	79%	79%	70%
CORN HEADER	25%	75%	29%	69%	3%	34%
COMBINE	75%	0%	66%	51%	51%	49%
DISK	75%	0%	66%	58%	58%	53%
PLOW	75%	9%	66%	150%	127%	137%
BEEF DIGGER	24%	76%	28%	69%	9%	21%
CORN CHOPPER	38%	62%	39%	80%	14%	46%
TOOL BAR	75%	0%	66%	79%	79%	68%
TRACTOR 1	75%	3%	66%	120%	113%	113%

The Time-Budget Range

The Time-Budget range (Table 27) establishes the number of hours each implement is used per month. If the implement hours for a particular month are excessive, the implement size, time of use, and/or crop rotation should be changed. The spreadsheet calculates an implement's monthly use by multiplying use (in hours per acre from Table 22) times number of acres the implement is used on in that month (from Table 24). The tractor and labor hours per month are found as noted earlier in the ANNUAL USE range. The total monthly truck hours equal the sum of the annual truck use for each crop, times the TIMES OVER factor for each crop for that month.

Table 27. Time-budget range of the Machinery Use spreadsheet.

TIME-BUDGET	TOTAL NUMBER OF HOURS EACH MACHINE IS USE EACH MONTH						TOTAL HRS
	MARCH	APRIL	MAY	JUNE	NOV.		
TRUCK 3	0	0	12	0	~	0	117
TRUCK 2	4	0	14	7	~	57	271
TRUCK 1	4	0	18	7	~	57	311
CORN HEADER	0	0	0	0	~	0	51
COMBINE	0	0	0	0	~	0	118
ISK	18	0	0	0	~	18	55
PLOW	86	0	0	0	~	97	183
BEEF DIGGER	0	0	0	0	~	0	59
CORN CHOPPER	0	0	0	0	~	0	76
TOOL BAR	0	0	0	0	~	0	0
TRACTOR 1	104	0	0	0	~	115	373

The Fixed and Variable Cost Ranges

The Fixed and Variable Cost range (Table 28 & 29) calculates the hourly fixed and variable costs associated with the equipment selected. The definition of fixed and variable costs is dependent on the production period that is in effect for and analysis. Determining the value of water for irrigation has a long run production period and so cost are variable except for land costs. The short run interpretations of fixed and variable costs are retained in this thesis although they are more appropriately interpreted as operation and ownership costs. The range value calculations are:

PURCHASE PRICE (PCP) = selects new or used purchase price.

RESALE VALUE (RSV) = $IF(USED, 0.1, (0.9 - 0.03 * YRU) * LR\% + 0.1) * SPP$

PAYMENT/HR (PPH)	=	((PCP - RSV) * amortization factor(@RRR & YRU) + RSV * RET) / HRS
TAXES & INS.	=	(PCP + RSV) / 2 * T&I / HRS
FIXED COST/HR	=	PPH + TAXES & INS.
ASAE REPAIR COST/HR	=	NEW or USED REPAIR COST % * PCP / HRS
FUEL & LUBE	=	DFP * 1.1*estimated fuel consumption rate
VARIABLE COST/HR	=	REPAIR COST/HR + FUEL & LUBE

Fuel use is estimated from the following equation (in accordance with ASAE Standard D230.4 (1984)):

$$\text{Fuel consumption} = 2.64X + 0.77 - 0.04 * (738X + 173)^{.5}$$

where X = required hp / power unit used

Table 28. Fixed cost range of the Machinery Use spreadsheet.

MACHINE	SIZE	NEW		LIFE YRS	ANNUAL HR	P* PMT /HR PPH	TAX&INS 1.5% COST/HR	FIXED
		PURCHASE PRICE	RESALE VALUE					
		PCP	RSV					
TRUCK 3	2 axle	\$38,695	\$13,543	10.0	117	\$35.10	\$3.36	\$38.45
TRUCK 2	2 axle	\$38,695	\$3,870	7.4	271	\$22.78	\$1.18	\$23.96
TRUCK 1	2 axle	\$38,695	\$3,870	6.4	311	\$22.13	\$1.03	\$23.16
CORN HEADER	6 row	\$10,799	\$5,914	10.0	51	\$18.90	\$2.47	\$21.37
COMBINE	24 ft	\$85,715	\$8,571	7.1	282	\$50.02	\$2.51	\$52.53
DISK	14 ft	\$10,664	\$1,066	8.4	239	\$6.46	\$0.37	\$6.83
PLOW	4 bot.	\$8,579	\$1,305	10.0	183	\$5.77	\$0.41	\$6.17
BEEF DIGGER	4 row	\$47,994	\$26,808	10.0	59	\$71.59	\$9.52	\$81.11
CORN CHOPPER	4 row	\$35,546	\$16,761	10.0	76	\$44.52	\$5.15	\$49.67
TOOL BAR	20 ft	\$8,099	\$810	4.8	413	\$4.41	\$0.16	\$4.57
TRACTOR 1	90 hp	\$32,396	\$3,831	10.0	970	\$4.20	\$0.28	\$4.48

(* The PYMNT/HR column is hourly amortized cost of the equipment.)

Table 29. Variable costs range of the Machinery Use spreadsheet.

VARIABLE COSTS	ASAE		75%	FUEL & LUBE	Variable COST/HR	TOTAL COST/HR	ANNUAL COSTS
	REPAIR COST/HR	REPAIR COST/HR	REPAIR COST/YR				
TRUCK 3	\$11.04	\$8.28	\$966	\$9.43	\$17.71	\$56.16	\$6,552
TRUCK 2	\$15.25	\$11.44	\$3,094	\$9.43	\$20.87	\$44.83	\$12,129
TRUCK 1	\$15.25	\$11.44	\$3,552	\$9.43	\$20.87	\$44.02	\$13,671
CORN HEAD	\$0.63	\$0.47	\$24		\$0.47	\$21.83	\$1,109
COMBINE	\$22.05	\$16.54	\$4,657	\$11.00	\$27.53	\$80.07	\$22,546
DISK	\$3.12	\$2.34	\$560	\$8.40	\$10.74	\$17.57	\$4,206
PLOW	\$5.97	\$4.48	\$818	\$7.97	\$12.45	\$18.63	\$3,401
BEEF DIGG	\$7.38	\$5.54	\$326	\$9.56	\$15.10	\$96.21	\$5,669
CORN CHOP	\$6.57	\$4.93	\$376	\$8.29	\$13.22	\$62.89	\$4,789
TOOL BAR	\$3.21	\$2.40	\$992	\$8.55	\$10.95	\$15.52	\$6,401
TRACTOR 1	\$3.77	\$2.83	\$2,741		\$2.83	\$7.31	\$7,085

The Equipment Cost Range

The Equipment Cost range (Table 30) allocates the selected equipment's fixed and variable costs per acre to the crops raised, calculated by multiplying the FIXED and VARIABLE COST/HR by the equipment's annual use (HRS) for each crop and dividing this value by the acres of that crop raised (ACS). By totaling these equipment costs, the spreadsheet obtains the total annual fixed and variable equipment cost per acre for each of the crops raised.

Table 30. Equipment costs range of the Machinery Use spreadsheet.

EQUIPMENT COSTS	SUGAR BEETS		CORN GRAIN	
	FIXED	VAR.	FIXED	VAR.
TRUCK 3	\$32.05	\$14.76	\$0.00	\$0.00
TRUCK 2	\$19.97	\$17.39	\$6.44	\$5.61
TRUCK 1	\$19.30	\$17.39	\$6.22	\$5.61
CORN HEADER	\$0.00	\$0.00	\$10.85	\$0.24
COMBINE	\$0.00	\$0.00	\$26.67	\$13.98
DISK	\$1.26	\$1.98	\$0.00	\$0.00
PLOW	\$2.65	\$5.35	\$2.65	\$5.35
BEEF DIGGER	\$47.80	\$8.90	\$0.00	\$0.00
CORN CHOPPER	\$0.00	\$0.00	\$0.00	\$0.00
TOOL BAR	\$0.00	\$0.00	\$0.00	\$0.00
TRACTOR 1	\$5.39	\$3.40	\$1.93	\$1.21

The Summary and Sensitivity Analysis Range

The Summary and Sensitivity Analysis range (Table 31) summarizes the totals from the EQUIPMENT COST range and analyzes the changes from the last spreadsheet recalculation. The spreadsheet saves the summary totals in a separate part of the spreadsheet for comparison with the next recalculation. This sensitivity analysis is also calculated for the total ANNUAL COSTS obtained in the VARIABLE COST range.

Table 31. Cost summary and sensitivity analysis range of the Machinery Use spreadsheet.

COST SUMMARY OF MACHINERY					
	RAISED	FIXED	VARIABLE	TOTAL	LABOR
SUGAR BEETS	100 ac	\$178.34	\$90.67	\$269.01	\$6.66
CORN GRAIN	100 ac	\$79.11	\$44.26	\$123.37	\$3.12
CORN SILAGE	100 ac	\$95.18	\$52.70	\$147.88	\$4.24
BEANS	100 ac	\$56.94	\$33.72	\$90.66	\$2.79
ALFALFA	100 ac	\$34.56	\$25.27	\$59.83	\$2.64
IRR. GRAIN	100 ac	\$42.65	\$33.42	\$76.07	\$2.46
DL GRAIN	1000 ac	\$22.32	\$19.16	\$41.47	\$1.24
COW-CALF	100 ac	\$13.54	\$21.22	\$34.76	\$2.29
SENSITIVITY ANALYSIS		change from last option - new			
SUGAR BEETS		\$0.00	\$0.00	0.00%	\$0.00
CORN GRAIN		\$0.00	\$0.00	0.00%	\$0.00
CORN SILAGE		\$0.00	\$0.00	0.00%	\$0.00
BEANS		\$0.00	\$0.00	0.00%	\$0.00
ALFALFA		\$0.00	\$0.00	0.00%	\$0.00
IRR. GRAIN		\$0.00	\$0.00	0.00%	\$0.00
DL GRAIN		\$0.00	\$0.00	0.00%	\$0.00
COW-CALF		\$0.00	\$0.00	0.00%	\$0.00

CHAPTER 6

ENTERPRISE ANALYSIS SPREADSHEET

With the Enterprise Analysis Spreadsheet, the designer develops the individual crop budgets and total farm enterprise analyses. This chapter explains the use and function of the six ranges within this spreadsheet: index, system variables, crop variables, user entered variables, crop budgets, and summary.

The Index Range

As explained in chapter 5, the Index range (Table 32) locates other ranges in the spreadsheet for editing or printing.

Table 32. Index range of the Enterprise Analysis spreadsheet.

INDEX	RANGE NAME	PRINT CODE
INPUT	IN/PUT	N
Sugar B.	SB	B
Corn G.	CG	C
Beans	BN	E
Wheat	SG	G
Alfalfa	AF	F
Irr. past.	IP	I
Barley	DG	J
W Wheat	WW	D
S Wheat	SW	H
Cow-Calf	CC	K
Summary	SU	S

The System Variables Range

The System Variables range (Table 33) sets up the basic economic parameters used to develop each crop budget. For each of three land-use types the spreadsheet calculates the current amount of land debt by multiplying the land debt percentage by the land values. The three land use types considered are: (1) irrigated land (ILD), (2) dryland (DLD), and (3) grassland (GLD). This amount of land debt is used along with the (1) long term interest rate (INR), (2) land repayment terms (TRM), and (3) land values (ILV, DLV, & GLV) to determine the amortized land repayment cost for each crop. In order to determine the amount of leased grassland that is required in the cow-calf enterprise range, the spreadsheet determines the total carrying capacity of the grassland owned (GLO) from the amount of grass available in annual animal unit months per acre (GAV).

The interest on operating capital (OCI) variable calculates annual interest charges for all variable costs. The return to farm (RET) variable determines land values in the summary range. Return to management (RTM) is the amount paid to farm management (not including labor cost), prorated on a weighted basis for the three land types. Vehicle miles (VMI) and other fixed costs (OTH) are also prorated on this same basis. The miscellaneous variable (MIS) allows the designer to increase the crop variable costs by a selected percentage, depending on confidence in the data. The designer may also choose the rate for land tax (LTX), federal crop insurance (CIN), and labor cost (LCT).

Table 33. System variable range of the Enterprise Analysis spreadsheet.

SYSTEM VARIABLES	PERCENT LAND DEBT			
Irr. land value	ILV	\$1,000 /ac	ILD	10%
Dryland value	DLV	\$200 /ac	DLD	50%
Grass land value	GLV	\$50 /ac	GLD	10%
Interest rate	INR	10.00%		
Terms	TRM	40 year	AMF	0.10
Interest on operating capital	OCI	10.00%		
Return to farm (opportunity costs)	RET	5.00%		
Percent of dryland cropped	PDC	50% cropped/yr		
Range land capacity	RLC	0.50 ann aum/ac		\$100
Amount of grassland owned	GLO	2,000 acres		
Vehicle miles charged to farm/yr	VMI	20,000 /yr @	\$0.20 \$/mile	
Return to management	RTM	\$ /yr		
Other fixed costs	OTH	\$1,000 /yr	housing	
Misc. costs	MIS	5%		
Land taxes (% of land value)	LTX	0.30%		
Insurance (% of crop value)	CIN	2.0%		
Labor costs	LCT	\$7.50 \$/hr		
Irrigation labor hrs/ac	ILA	1.0 hr/ac		

The Crop Variables Range

In the Crop Variable range (Table 34), the designer sets the number of cropped acres (ACS) and cattle raised for each farm scenario. The range also establishes yield, price, and government support level for each scenario. The designer estimates both the expected crop yield (ECY) and the expected crop price (EPR), established from yields and current crop price: or, a user entered estimate of an expected future price can be used. The designer also enters a secondary crop yield and price (SCY & SPR) if straw or another stover-type crop is produced. The target price (GPR) and

established crop yield variables (GCY) establish direct farm subsidy payments. There are several variables defining each cow-calf enterprise: (1) size of cow herd (HD), (2) steer market price (SMP), and (3) calf market weight (CWT). In order to minimize the number of input variables heifer calf, cull cow, and cull bull prices are calculated as a percent of SMP. These variables are used in the summary range to determine total farm income.

The general farm costs are weighted for each farm enterprise. The weighted land total acreage (WLT) sums irrigated acres and head of livestock then adds the sum of the dryland acres divided by four (this allocates farm costs more heavily to the irrigated acres). This WLT acreage is then used to allocate management, utility vehicle, and other fixed costs not directly allocable to an enterprise. These per weighted acre costs are found by dividing the management (WMC), vehicle WVC, and user entered fixed cost (EWC) by the WLT.

The User Entered Variable Ranges

The Equipment Variable range (Table 35) sets annual farm equipment and irrigation costs for each farm enterprise. It allows the designer to adapt the spreadsheet to analyze crops for site specific situations. For established flood irrigation systems the water charge is entered as a fixed cost and incidental irrigation costs such as ditching and canal cleaning are entered as variable costs.

Table 34. Crop variable range of the Enterprise Analysis spreadsheet.

CROP VARIABLES	EXPECTED			SECONDARY CROP		GOVERNMENT PAYMENT	
	ACRES AC	PRICE EPR	YIELD ECY	PRICE SPR	YIELD SCY	PRICE GPR	YIELD GCY
IRRIGATED							
Sugar B.	100	\$38.00	20 ton				Sugar B.
Alf est	100	\$65.00	1.0 tons				Alf est
Grain	100	\$2.00	80 bu	\$2.00	20.0 tons	\$2.60	80 Grain
Alfalfa	100	\$65.00	4.5 tons				Alfalfa
Grass hay	100	\$55.00	2.0 tons				Grass hay
Irr. past.	100	\$67.00	9.0 aum				Irr. past
	600						
DRYLAND							
Barley	100	\$2.00	45 bu		ton	\$2.60	35 Barley
W Wheat	100	\$3.00	30 bu		ton	\$4.38	25 W Wheat
S Wheat	100	\$2.50	35 bu			\$3.50	30 S Wheat
	300						
LIVESTOCK							
	HD	SMP	CWT				
Cow-Calf steer	100	\$77.70	500 #/hd				
heifer		\$69.93	450 #/hd				
weighted land total			WLT	775 ac			
wt. mngt. cost/ac			WMC	/ac			
wt. veh. mile/ac			WVC	12.9 mile/ac			
fixed wt. cost/ac	other	FWC		\$1.29 /ac			

There are ten crops listed in this range; for each there are seven user-entered fixed and variable enterprise costs, each requiring an input explanation, price per unit, and rate per acre. Also within this range the designer can easily enter the seed and fertilizer costs and application rates. These are accessed by the individual crop cost budget ranges to determine total annual costs. It is important that the unit cost times the rate per acre equals the desired cost per acre, because the user entered variables will appear as entered in the crop budgets. The application rate for nitrogen is determined from the

crop estimated yield, soil nitrogen, and the yield response by the equation:

$$\text{rate} = \text{yield} \times \text{response} - \text{soil nitrogen}$$

(This equation is inconsistent because input and output prices are ignored.)

Table 35. User entered variable range of Cost Enterprise spreadsheet.

EQUIPMENT VARIABLES									
	MACHINERY COSTS				IRRIGATION COSTS				
	FIXED	VAR.	TOTAL	LABOR (hr/ac)	FIXED	LABOR	ENERGY	TOTAL	
Sugar B.					\$122.31	\$4.94	\$78.49	\$205.74	
Grass hay	\$6.53	\$11.06	\$17.59	3.75					
Alf est	\$18.94	\$30.20	\$49.14	7.05	\$122.31	\$4.94	\$78.49	\$205.74	
Grain	\$28.78	\$28.70	\$57.49	5.16	\$122.31	\$4.94	\$78.49	\$205.74	
Alfalfa	\$17.97	\$31.20	\$49.17	10.52	\$122.31	\$4.94	\$78.49	\$205.74	
Irr. past.					\$122.31	\$4.94	\$78.49	\$205.74	
Barley	\$19.38	\$28.59	\$47.97	5.18					
W Wheat									
S Wheat									
Cow-Calf	\$7.70	\$12.39	\$20.09	5.58					

USER ENTERED ENTERPRISE COSTS						
INPUT	PRICE /UNIT		CROP	INPUT	PRICE /UNIT	RATE/UNIT
-----Alfalfa			-----Cow-Calf			
soil nitrogen	\$0.25 lb	-12.5	Hay	\$65.00 ton		1.4
Furdan	\$1.00 oz	8.0	Straw	ton		0.6
V	ac		Salt & minerals	\$25.00 cwt		0.2
V	ac		Protein sup.	\$8.00 cwt		2.9
TWINE	ton	4.5	V	\$1.00 ac		
F	ac		F	\$1.00 ac		

FERTILIZER AND SEEDING VARIABLES										
INPUTS		Sugar B.	Grass hay	Alf est	Grain	Alfalfa	Irr. past	Barley	W Wheat	S Wheat
Soil N	lb/ac	60.0	60.0	60.0	60.0	60.0	60.0	22.0	22.0	22.0
Response	lb-N/unit	8.0			2.0		12.2	1.0	2.0	2.0
nitrogen	\$0.25 /lb act.						50		38	48
phosphate	\$0.30 /lb act.	125.0	50.0	50.0	28.0	50.0	60.0	15.0	15.0	15.0
potash	\$0.15 /lb act.									
fert appl	\$1.25 /ac	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
seed cost	\$/lb	\$10.00	\$4.00	\$2.00	\$0.10		\$16.00	\$0.10	\$0.10	\$0.10
seed rate	lb/ac	2.0	5.0	15.0	120.0		0.1	45.0	45.0	45.0

The Crop Enterprise Cost Analysis

There are ten crop enterprise ranges (Tables 36 to 38) in this spreadsheet. Each of these ranges is standardized so a user can easily change crops by entering the crop name in the crop variable range and modifying the inputs for that crop. In most cases, the designer only needs to modify information in the first four ranges. The irrigated pasture and cow-calf crop ranges, however, are crop specific: they require the designer to enter extra site-specific data. All other crop ranges can be modified in the crop and user entered variable ranges.

The format used in the crop enterprise cost analysis ranges is patterned after the Cooperative Extension Service's Enterprise Costs studies (Fogle, 80). The first row in the range lists the crop name and acres raised. The first column describes the information in that row, followed by the price of the item, measurement units, per acre quantity used, and per acre item cost (the price per unit times the quantity used). These values are taken from the system, crop, equipment, and user entered ranges. All variable and fixed costs are listed and totaled separately.

The "interest on variable costs" line item sums all the variable costs, entering the total in its price column. It is then multiplied by the operating capital interest (OCI) variable, and entered in the system variable range, which determines both the short term interest rate and the level of short term farm debt. Miscellaneous costs, other

then operating debt costs, are calculated as a percent of total variable costs. This percentage is entered as the MIS variable in the system variable ranges. These per acre costs are summed to find the annual variable cost.

The spreadsheet sums all fixed and variable costs to find the total annual per acre cost for each crop, and subtracts it from the gross revenue to find the per acre return to land. (Gross revenue is the expected crop yield (ECY) times its expected price (EPR) plus the SCY times the SPR). The break even price is calculated by dividing the total cost of the crop by its ECY; break even yield is total cost divided by EPR. Interest on land debt is found by multiplying the long term interest rate times the per acre land debt. The land debt is the land value times the land debt percentage entered in the system variable range. This land debt interest amount is used for cash flow considerations and is not included return to land calculations. The crop summary at the end of each range lists the return over variable cost (ROVC), return to land, labor costs, benefit cost ratio (return to land/total costs), government payment, and total farm expense.

The sugar beet crop budget (Table 36) shows the format used in the first five crop budgets. The enterprise budget for irrigated pasture requires more information. In this budget steers are purchased in the spring, fattened on the irrigated pasture, and sold in the fall. To determine the number of steers purchased per acre (STR), the spreadsheet divides the pasture's carrying capacity (in animal unit months (AUM)) by four months per season and by .7 animal units (AU)

per steer. The result is multiplied by the weight of the steer at purchase (SMW) and the purchase price, to find the total per acre livestock investment. The designer also enters the rate of gain (ROG) and steer death loss (SDL).

Table 36. Sugar beets range of the Enterprise Analysis spreadsheet.

Sugar B.	COST OF PRODUCTION		100.0 ACRES	
	PRICE /UNIT	QUANT.	COST	
VARIABLE COSTS				
Nitrogen	\$0.25 lbs	100.0	\$25.00	
Phosphate	\$0.30 lbs	125.0	\$37.50	
Fert. Appl.	\$1.25 ac	1.0	\$1.25	
Seed	\$10.00 lbs	2.0	\$20.00	
SB-1	\$47.15 oz	0.6	\$27.82	
SB-2	\$0.98 oz	10.0	\$9.80	
SB-3	\$0.45 oz	16.0	\$7.20	
Hoe Beets	\$25.00 ac	1.0	\$25.00	
Vehicle	\$0.20 miles	26	\$5.16	
Machinery	\$90.67 ac	1.0	\$90.67	
Farming Labor	\$7.50 hr	6.66	\$49.95	
Irr. Labor	\$7.50 hr	1.0	\$7.50	
Irr Sys Op Costs	\$10.00 ac	1.0	\$10.00	
Irr Energy Cost	\$5.00 ac	1.0	\$5.00	
Int. On Op. Costs	\$321.85 \$	12.00%	\$38.62	
Misc. Costs	\$321.85 \$	5%	\$16.09	
TOTAL VARIABLE COSTS				\$376.56
FIXED COSTS				
Machinery	\$178.34 ac	1.0	\$178.34	
Management	\$25.81 \$	1.0	\$25.81	
housing	\$1.29 \$	1.0	\$1.29	
Taxes (land & imp)	\$1,000 ac	0.3%	\$3.00	
Insurance	\$760 ac	2.0%	\$15.20	
Irr Sys Costs	\$0.00 ac	1.0	\$0.00	
TOTAL FIXED COSTS				\$223.63
TOTAL COSTS	Sugar B.			\$603.20
Land debt interest	\$100 ac	0.10	\$10.23	
	PRICE	YIELD		
Return/acres @	\$38.00	20.0 ton	\$760.00	
Break Even	\$30.52	16.1 ton		
	/ACRE	/FARM	B/C	
ROVC	\$383.44			
Return to land	\$139.34	\$13,934	1.25	
Labor Cost	\$57.45	\$5,745		
Gov pmnt	\$0.00	\$0		
TOTAL EXPENSES		\$60,020		

The variable costs for an irrigated pasture are determined in the same manner as the other irrigated crops except that steer purchase

and interest costs (accrued for four months) are included. Gross revenue per acre is calculated as fall market steer price times total gain per acre (GPA). In order to account for seasonal price changes the fall market steer price is assumed to be ten cents lower than the entered spring steer price. The fall market steer weight (FMW), required to determine GPA, is shown below:

$$\text{FMW} = \text{SMW} + (\text{ROG} * 120 \text{ days})$$

$$\text{GPA} = (\text{FMW} * (1 - \text{SDL}) - \text{SMW}) * \text{STR}$$

The dryland crop budget costs are calculated in the same manner as irrigated crop budget costs except that the costs are calculated based on cropped acres. The machinery costs (calculated in the Machinery Use spreadsheet) are also determined on a per cropped acre basis and include fallow costs. The costs of owning fallow land are included in the land taxes and land payment variable, calculated by dividing the per unit costs by the percent dryland cropped (PDC) variable. Any other fallow costs (i.e. chemical fallow costs) can be included in the user entered variable costs range on a per cropped acre basis.

In the cow-calf enterprise budget range, the designer may either use default values or enter site-specific information. This budget range requires the designer to enter more information than the other enterprise budgets. The user entered variables and their default values are (Peterson, 86):

Rangeland capacity	RLC	0.5	aum/ac
Cow death loss	CDL	1.5	%
Steer market weight	SMW	500	lbs
Steer market price	SMP	\$80	/cwt
Heifer market weight	HMW	450	lbs
Cull cow weight	CCW	1000	lbs

Cull bull weight	CBW	2000	lbs
Cow to bull ratio	C-B	20	to 1
Bull costs	BUL	\$2,000	
Useful life of bull	LBU	4	years
Replacement rate	RPM	13	%
Calving rate	PCR	90	%
Amount of pasture req.	APR	9.2	aum/hd
Amount of hay req.	AHR	1.2	ton/hd
Non feeding labor	NFL	1.0	hr/hd

The spreadsheet-calculated variables in the cow-calf enterprise budget variables are:

Heifer market price	HMP = SMP * 0.9
Cull cow market price	CCP = SMP * 0.5
Cull bull market price	CBP = SMP * 0.5
Number of bulls	NUB = integer(HD / C-B)
Total herd size	THD = HD + NUB + (HD * RPM)
Cow to herd size ratio	H/C = THD / HD
Aum's of pasture req.	RAM = THD * APR
Amount of hay req.	THR = THD * AHR
Repl. heifer value	RHV = HMW * HMP / 100
Breeding cow life	LCW = 1 / RPM
Pasture deficit	PDF = RAM - (RLC * GLO)

These variables determine the annual costs per head of breeding stock (HD).

The costs are calculated on a per head basis instead of a per acre basis. Pasture rent is charged at \$10 per AUM if the PDF evaluates to be positive. Other nonstandard budget line items are:

Pasture rent	\$10 * positive values of PDF
Vet. supplies	\$5 * H/C
Fencing o&m	\$.40 * GLO / HD
Labor (misc)	LCT * NFL * H/C
Bull costs	BUL * NUB / LBU / HD
Opportunity cost	(RHV + (BUL / C-B)) * RET
Marketing	\$4
Insurance	(RHV + (BUL / C-B)) * CIN
Taxes (per. prop.)	\$3.50
Land payment	GLV * GLD * GLO / HD * AME

Table 37. Cow-calf parameters range of the Enterprise Analysis spreadsheet.

Cow-Calf	COST OF PRODUCTION		100 head	
Range capacity	RLC	0.5 aum/ac	CDL	1.5%
Ave steer selling wt Nov 1	SMW	500.0 #/hd	SMP	\$77.70
Ave heifer selling wt Nov 1	HMW	450.0 #/hd	HMP	\$69.93
Cull cow	CCW	1000.0 #/hd	CCP	\$38.85
Cull bull	CBW	2000.0 #/hd	CBP	\$38.85
Cow to bull ratio	C-B	20 to 1	NUB	5.0
Replacement rate	RPM	13%	THD	118
Calving rate %	PCR	90%	H/C	1.2
Amount of pasture required	APR	9.2 aum/hd	RAM	1085.6
Amount of hay required	AHR	1.2 ton/hd	THR	141.6
Bull cost	BUL	\$2,000 buy/hd	LBU	4.0
Replacement heifer value	RHV	\$315 not sold	LCW	8
Aums of pasture needed	PDF	85.6	HCL	1.0

All of the budget line item costs are summed to obtain the total annual fixed and variable costs for the cow-calf enterprise. To determine the enterprise's total annual revenue, the spreadsheet sums the revenue generated by the sales of the steers, heifers, cull cows, and cull bulls. Revenue is calculated by multiplying price by weight by the average number of animals sold. The calculations for the average number of animals sold are:

Steers	HD * PCR * 0.5
Heifers	HD * (PCR * 0.5 - RPM - CDL)
Cull cows	HD * (RPM - CDL)
Cull bulls	NUB / LBU

The return per head of breeding stock is calculated by dividing the total annual revenue by the number of breeding animals (HD). All cattle market prices are based on steer prices, so the spreadsheet estimates the break even steer market price by solving the ratio:

$$\text{Break even SMP} / \text{SMP} = \text{total costs} / \text{total revenue}$$

Return to land is the difference between total revenue and total cost per head of breeding stock.

The Summary and Sensitivity Range

The summary range (Table 39) lists individual crop enterprise budget totals and sums total farm information. The sensitivity analysis (Table 40) shows the changes that result from modifications made since the last spreadsheet recalculation.

The maximum per person subsidy payment is \$50,000. This spreadsheet totals the government payments for each crop and, where in excess, reduces each crop payment by the factor of the maximum payment divided by the calculated total payment.

The total farm return to land is the sum each crop's return to land plus its government payment. The total labor cost sums all listed labor line items. The total farm expense is the sum of all farm crop budget expenses; it determines the B/C ratio (return to farm/total farm expenses) for the individual farm, and can also be used to determine secondary benefits to the local economy. Again, the interest on land debt is totaled for the farmers cash flow considerations.

Table 38. Cow-calf budget range of the Enterprise Analysis spreadsheet.

Cow-Calf	COST OF PRODUCTION			100 head
	PRICE /UNIT	QUANT.	COST/HD	
VARIABLE COSTS				
Pasture rent	\$10.23 aum	0.9	\$8.75	
Hay	\$65.00 ton	1.4	\$92.04	
Straw	\$20.00 ton	0.6	\$11.80	
Salt & minerals	\$25.00 cwt	0.2	\$4.43	
Protein sup.	\$8.00 cwt	2.9	\$23.60	
Vet. supplies	\$5.00 hd	1.2	\$5.90	
Fencing o&m	\$0.40 ac	2000	\$8.00	
Vehicle	\$0.20 miles	25.8	\$5.16	
machinery	\$21.22 hd	1.0	\$21.22	
Labor(mics)	\$7.50 hr	1.2	\$8.85	
Labor (feeding)	\$7.50 hr	2.3	\$17.18	
Bull costs	\$2,000 hd	1.3	\$25.00	
Opportunity cost	\$414.69 hd	5.00%	\$20.73	
Int on op cost	\$231.92 \$	12.00%	\$27.83	
Marketing	\$1.00 hd	1	\$1.00	
Mics. costs	\$231.92 ac	5%	\$11.60	
TOTAL VARIABLE COSTS				\$293
FIXED COSTS				
Machinery	\$13.54 ac	1.0	\$13.54	
Management	\$25.81 \$	1.0	\$25.81	
housing	\$1.29 \$	1.0	\$1.29	
Taxes (land & imp)	\$0.15 ac	2000	\$3.00	
Insurance	\$415 hd	2.0%	\$8.29	
Taxes (per. Prop)	\$3.50 hd	1.0	\$3.50	
TOTAL FIXED COSTS				\$65.66
TOTAL COSTS	Cow-Calf			\$359
Land debt interest	\$100 hd	0.10	\$10.23	
	PRICE	YIELD	# SOLD	
Steer	\$77.70	500.0	45 hd	\$17,483
Heifer	\$69.93	450.0	31 hd	\$9,598
Cull cow	\$38.85	1000.0	12 hd	\$4,468
Bull	\$38.85	2000.0	1 cwt	\$971
				\$32,519
Return /hd	\$325			
Break even steer	\$85.72 /CWT			
	/HEAD	/FARM	B/C	
ROVC	\$32.11			
Profit(loss)	(\$33.55)	(\$3,355)	0.91	
Labor costs	\$26.03	\$2,603		
Gov pmnt				
TOTAL EXPENSES		\$35,874		

Table 39. Summary range of the Enterprise Analysis spreadsheet.

SUMMARY	ROVC	Return to land		B/C	(BREAK EVEN	
		/ACRE	FARM		PRICE	YIELD
Sugar B.	\$383	\$150	\$14,957	1.25	\$30.52	16.1
Corn G.	\$194	\$57	\$5,699	1.16	\$2.86	119.3
Beans	\$199	\$95	\$9,514	1.29	\$13.54	18.6
Wheat	\$74	(\$21)	(\$2,086)	0.92	\$2.61	130.4
Alfalfa	\$157	\$76	\$7,604	1.31	\$49.79	3.8
Irr. past.	\$52	(\$30)	\$0	0.98	\$68.32	9.2
total irr.		\$59	\$35,688			
Barley	\$46	(\$10)	(\$968)	0.91	\$2.44	54.8
W Wheat	\$40	(\$14)	(\$1,440)	0.87	\$3.81	38.1
S Wheat	\$35	(\$20)	(\$2,016)	0.83	\$3.36	47.1
total dryland		(\$15)	(\$4,423)			
Cow-Calf steer	\$32	(\$34)	(\$3,355)	0.91	\$85.72/cwt	
Government payment		\$27,890				
Return to land		\$55,799				
Return to management		\$75,799				
Labor costs		\$19,457				
Total farm exp.		\$381,587		1.15 B/C		
Debt payment		8,160				

Table 40. Summary and sensitivity analysis range of the Enterprise Analysis spreadsheet.

SUMMARY	GOV. PAYMNT /ac	SENSITIVITY ANALYSIS			
		CHANGE FROM LAST RUN	ROVC	PROFIT(L)	LAND VALUE
					GOV.
Sugar B.	\$0.00	0%	\$0.00	\$1,563	\$1,563
Corn G.	\$3.00	0%	\$0.00	\$657	\$687
Beans	\$0.00	0%	\$0.00	\$1,030	\$1,030
Wheat	\$190.40	0%	\$0.00	(\$104)	\$1,758
Alfalfa	\$0.00	0%	\$0.00	\$844	\$844
Irr. past.	\$0.00	0%	\$0.00	(\$190)	(\$190)
Barley	\$21.00	0%	\$0.00	\$5	\$211
W Wheat	\$34.50	0%	\$0.00	(\$41)	\$297
S Wheat	\$30.00	0%	\$0.00	(\$97)	\$196
Cow-Calf	\$0	0%	\$0.00	\$5	\$5

CHAPTER 7

IRRIGATION DESIGN EVALUATION EXAMPLES

This chapter describes three potential irrigation sites that are included in Cascade and Chouteau Conservation Districts Missouri River water reservation applications. (These applications were prepared by the Department of Natural Resources and Conservation.) There are four irrigation development examples presented which demonstrate the procedures explained in this thesis. The farm/ranch size and agricultural practices used in the before- and after-development scenarios are hypothetical.

Each example shows the net return to irrigation water and includes a table summarizing the machinery cost and farm enterprise analysis spreadsheet for the before- and after-development scenarios. The farm machinery summary includes: acreage of each crop raised, the major equipment parameters, and the annual equipment cost associated with each crop. The farm enterprise analysis summary includes: the expected price and yield of each crop, the government support payment, net farm return to land, and the value of water. This value is calculated by dividing the acres of irrigated crops into the net return of the irrigated crops. This value does not compare the before- and after-development scenarios.

Each example presentation also includes a design drawing of the proposed irrigation development and a cost summary of the Irrigation

Design spreadsheet for that development. The design drawings show the irrigated area and type of irrigation, as well as pipeline and pump location. The Irrigation Design spreadsheet summary includes the number of acres irrigated, water requirements, and project costs.

For each example, the value of water for irrigation is found by subtracting the revenue netted in the before-development scenario from the revenue netted in the after-development scenario. There are two assumptions made within these examples. The first is that the crop raised on the developed acres is alfalfa, on an eight year rotation. The second is that, the alfalfa is assumed to be well managed, so that yield is a function of the total consumptive water use for the site. The total consumptive use is found using the Soil Conservation Service's TR21 computer model (USDA, 87). The yield is then calculated using an empirical function developed by the Department of Natural Resources and Conservation (DNRC, 88). The price and yield information for other crops are ten-year averages for Montana (MDA, 87). The yields and prices used in the following examples are intended for comparison purposes only.

Example 1. A Low Lift Pivot Developed on a Ranch

The first example is a cattle ranching operation with 100 acres of irrigated grain, 300 acres of dryland hay, 1000 acres of dryland grain, and 500 head of cattle.

Tables 41 and 42 show the machinery costs and summarize the enterprise budget of the before-development scenario. This farm would return \$37,196 to land per year, including the government subsidy payment.

Figure 7 diagrams the irrigation development (drawing legend shown in Figure 5), with its cost summarized in Table 43. This project would develop a 146 acre center pivot on a terrace adjacent to the Missouri River in Cascade County, with total annual irrigation costs of \$63.78/ac. It is assumed that the developed land was previously in dryland grain. Tables 44 and 45 show the machinery costs and farm enterprise budget for the after-development scenario. After irrigation development the farm would have a return to land of \$45,557, an increase of \$8,561. The resulting value of water is \$58.64 per acre or \$28.63 per acre-foot of water diverted.

Table 41. Before-development machinery costs for example 1.

CROP VARIABLES		EST. YIELD	LBS/UNIT	TRUCK-HR /LOAD	TON STRAW YIELD	# OF TR USED	AX-HR/AC
ACRES	EST. YIELD	#PU	TPL	TSY	1,2,or,3 #TU	APA	
IRR BARLEY	100 ac	70 bu/ac	56	2.5		2	0.49 IRR BARLEY
GRASS	300 ac	2 ton/ac	2000	1		1	0.20 GRASS
DL G	1000 ac cpd	25 bu/ac	60	2.5		2	0.19 DL G
C-C	500 hd	0.9 calf/hd	1500	6	1	2	0.51 C-C
	1900 ac						

EQUIPMENT PARAMETERS

1 st tractor (input 0 for 1 st)	TR1	150 hp	
2 nd tractor (tractor if using)	TR2	100 hp	
3 rd tractor (only 2 tractors)	TR3	50 hp	
tons per truck axle	TPA	10 ton	
row width	RWD	20 "	1.7 ft
bottom width	BWD	16 "	1.3 ft
purchase new or used equipment	N-U	USED	
age of purchase used eq.	AGE	5 yr	
if swather self-propelled input 1	SWT	1	

COST SUMMARY OF MACHINERY

	RAISED	FIXED	VARIABLE	TOTAL	LABOR
IRR BARLEY	100 ac	\$24.37	\$25.79	\$50.16	\$4.52
GRASS	300 ac	\$9.77	\$13.77	\$23.54	\$5.24
DL G	1000 ac	\$21.34	\$27.14	\$48.48	\$4.75
C-C	500 ac	\$8.60	\$12.90	\$21.50	\$5.58

Table 42. Before development enterprise budget for example 1.

CROP VARIABLES	ACRES AC	EXPECTED		SECONDARY CROP		GOVERNMENT PAYMENT	
		PRICE EPR	YIELD ECY	PRICE SPR	YIELD SCY	PRICE GPR	YIELD GCY
IRRIGATED							
Irr. barley	100	\$1.94	70 ton				
Grass hay	300	\$55.00	2.0 tons			\$2.60	70
	400						
DRYLAND							
Barley	500	\$1.94	34 bu		ton	\$2.60	34
W Wheat	500	\$3.36	29 bu		ton	\$4.38	29
	1000						
LIVESTOCK	HD	SMP	CWT				
Cow-Calf steer	500	\$77.70	500 #/hd				
heifer		\$69.93	450 #/hd				
weighted land total			WLF	1150 ac			
wt. mngt. cost/ac			WMC	/ac			
wt. veh. mile/ac			WVC	8.7 mile/ac			
fixed wt. cost/ac		housing	FWC	\$0.87 /ac			
<hr/>							
SUMMARY							
	acres	ROVC	PROFIT (LOSS) /ACRE FARM	B/C	(BREAK EVEN PRICE	YEILD	
Irr. barley		\$33	(\$6) (\$577)	0.96	\$2.02	73.0 bu	
Grass hay		\$31	\$17 \$5,089	1.18	\$46.52	1.7 tons	
total irr.			\$11 \$4,512				
Barley		\$16	(\$9) (\$4,322)	0.88	\$2.20	38.1 bu	
W Wheat		\$38	\$13 \$6,304	1.15	\$2.93	25.6 bu	
total dryland			\$2 \$1,982				
Government payment		\$30,702					
Return to land		\$37,196					
Return to management		\$37,196					
Labor costs		\$9,595					
Total farm exp.		\$122,070		1.30 B/C			
debt payment		\$6,115					

Figure 7. Irrigation design drawing for examples 1 and 2.

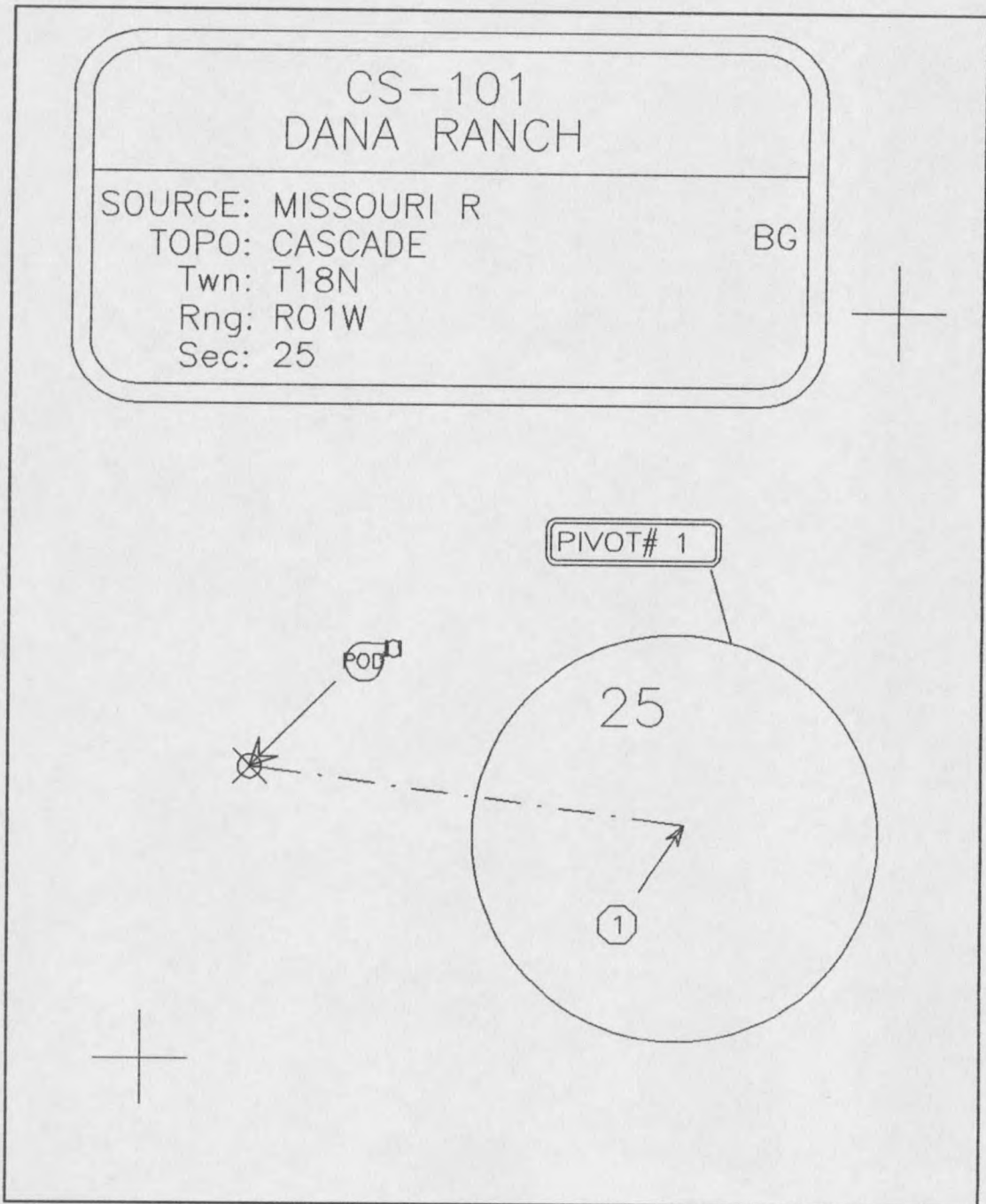


Table 43. Irrigation development costs for examples 1 and 2.

Project# :	CS-101	TOPO: CASCADE
Owner :	DANA RANCH	SOURCE: MISSOURI R
Location :	T18N R01W 25 NE,NW,SW	27-Jul-89

SYSTEM VARIABLES

Require power line const.	PLC	1.0 miles		
Total consumptive use	TCU	25.8 inches		
Net irrigation requirement	NIR	18.5 inches		
Total acres irrigated	TAI	146 ac		
Ac-ft of water needed	AFN	299 ac-ft	Total pump hp	THP 31
Total flow	TFL	948 gpm	Hours of pumping	HOP 1711
Equipment costs	EQC	\$35,592	Engine amort.	ENA 8.8%
Flood costs	FDC		Annual electrical cost	\$2,661
Total pipe cost	TPC	\$16,112	Annual diesel costs	\$3,877
Total ditch cost	TDC		Pumping power	PPP Electrical
Labor cost	ALC	\$545	Ann. energy costs	AEC \$2,106
TR-21 weather station	WSTA	Cascade	Energy cost/ac	EAC \$14.44

ITEM	COST/ UNIT	# OF ITEMS	UNITS	IRRIGATION COSTS TABLE			LIFE	ECON	FINAN.
				T. COST \$1	% O&M	O&M		ANN-COST TOTAL	ANN-COST TOTAL
Flood Line					10.0%		20		
Pivot				\$35,592	1.5%		10		
Other					3.0%	\$1,068	20	\$3,828	\$6,860
Other		unit			1.5%		10		
					5.0%		10		
ON-FARM TOTALS				\$35,592		\$1,068		\$3,828	\$6,860
Pump		40 hp	\$7,248	2.5%	\$181		30	\$631	\$1,361
Engine		hp		5.5%			16		
Diversion	\$2,000	2.1 cfs	\$4,213	1.0%	\$42		30	\$304	\$728
Pump controls		10%p. cost	\$725	1.0%	\$7		20	\$63	\$125
Pipe	\$16,112	110%	\$17,723	0.5%	\$89		50	\$1,000	\$2,973
Ditches		110%		5.0%			20		
Storage		ac-ft		1.0%			50		
Other		unit		2.0%			50		
SYSTEM TOTALS			\$29,909		\$319			\$1,999	\$5,187
Power dev.	\$12,500	1.0 miles	\$8,625				50	\$444	\$1,404
Engineering		15%S. total	\$4,486				50	\$231	\$730
Contingency		10%S. total	\$2,991				50	\$154	\$487
TOTAL			\$81,603		\$1,387			\$6,655	\$14,667

TOTAL ANNUAL COSTS	ECONOMIC			FINANCIAL		
	TOTAL	/AC	/AC-FT	TOTAL	/AC	/AC-FT
LABOR	\$545	\$3.74	\$1.82			
ENERGY	\$2,106	\$14.44	\$7.05			
EQUIPMENT	\$6,655	\$45.61	\$22.26	\$14,667	\$100.53	\$49.06
TOTAL annual costs	\$9,306	\$63.78	\$31.12	\$17,319	\$118.70	\$57.92

Table 44. After development machinery costs for example 1.

CROP VARIABLES		EST.	LBS/UNIT	TRUCK-HR	TON STRAW	# OF TR	AX-HR/AC
		YIELD		/LOAD	YIELD	USED	
ACRES						1,2,or,3	
ACS	ESY	#PU	TPL	TSY	#TU	APA	
IRR BARLEY 100 ac	70 bu/ac	56	2.5		2	0.49	IRR BARLE
CORN G ac	125 bu/ac	56	2.5		2	0.88	CORN G
ALF. EST 18 ac	1.0 ton/ac	2000	1		1	0.10	ALF. EST
GRASS 300 ac	2 ton/ac	2000	1		1	0.20	GRASS
ALF 110 ac	4.5 ton/ac	2000	1		1	0.45	ALF
IRR G 18 ac	70.0 bu/ac	56	2.5		2	0.49	IRR G
DL G 927 ac cpd	25 bu/ac	60	2.5		2	0.19	DL G
C-C 500 hd	0.9 calf/hd	1500	6	1	2	0.51	C-C
1973 ac							

percent flood irrigation %FI calls for use of land plane

EQUIPMENT PARAMETERS

1 st tractor (input 0 for 1 st)	TR1	150 hp	
2 nd tractor (tractor if using)	TR2	100 hp	
3 rd tractor (only 2 tractors)	TR3	50 hp	
tons per truck axle	TPA	10 ton	
row width	RWD	20 "	1.7 ft
bottom width	BWD	16 "	1.3 ft
purchase new or used equipment	N-U	USED	
age of purchase used eq.	AGE	5 yr	
if swather self-propelled input 1	SWT	1	

COST SUMMARY OF MACHINERY

	RAISED	FIXED	VARIABLE	TOTAL	LABOR
IRR BARLEY	100 ac	\$24.07	\$25.72	\$49.78	\$4.52
ALF. EST	18 ac	\$23.29	\$29.80	\$53.08	\$7.05
GRASS	300 ac	\$8.68	\$13.64	\$22.32	\$5.24
ALF	110 ac	\$18.23	\$28.09	\$46.32	\$10.52
IRR G	18 ac	\$24.07	\$25.72	\$49.78	\$4.52
DL G	927 ac	\$21.48	\$27.09	\$48.57	\$4.75
C-C	500 ac	\$8.38	\$12.90	\$21.28	\$5.58

Table 45. After development enterprise budget for example 1.

CROP VARIABLES	ACRES AC	EXPECTED		SECONDARY CROP		GOVERNMENT PAYMENT	
		PRICE BPR	YIELD ECY	PRICE SPR	YIELD SCY	PRICE GPR	YIELD GCY
IRRIGATED							
Irr. barley	100	\$1.94	70 ton			\$2.60	70 Irr. barl
Alf est	18	\$60.88	1.4 tons				Alf est
Grain	18	\$1.94	70 bu	\$2.00	20.0 tons	\$2.60	70 Grain
Alfalfa	110	\$60.88	4.4 tons				Alfalfa
Grass hay	300	\$55.00	2.0 tons				Grass hay
	546						
DRYLAND							
Barley	464	\$1.94	34 bu		ton	\$2.60	34 Barley
W Wheat	464	\$3.36	29 bu		ton	\$4.38	29 W Wheat
	927						
LIVESTOCK							
Cow-Calf steer	500	\$77.70	500 #/hd				
heifer		\$69.93	450 #/hd				
weighted land total			WLT	1278 ac			
wt. mgmt. cost/ac			WMC	/ac			
wt. veh. mile/ac			WVC	7.8 mile/ac			
fixed wt. cost/ac		housing	FWC	\$0.78 /ac			

SUMMARY						
acres	ROVC	PROFIT (LOSS)		B/C	(BREAK EVEN	
		/ACRE	FARM		PRICE	YEILD
Irr. barley	\$33	(\$5)	(\$509)	0.96	\$2.01	72.6 bu
Grass hay	\$31	\$18	\$5,547	1.20	\$45.76	1.7 tons
Alf est	(\$49)	(\$120)	(\$2,155)	0.42	\$146.40	3.4 tons
Grain	\$82	\$6	\$100	1.03	\$2.43	87.8 bu
Alfalfa	\$172	\$103	\$11,322	1.62	\$37.49	2.7 tons
total irr.		\$26	\$14,304			
Barley	\$16	(\$9)	(\$4,014)	0.88	\$2.20	38.1 bu
W Wheat	\$38	\$13	\$5,838	1.15	\$2.93	25.7 bu
total dryland		\$2	\$1,824			
Government payment	\$29,630					
Return to land	\$45,757					
Return to management	\$45,757					
Labor costs	\$11,098					
Total farm exp.	\$140,616			1.33 B/C		
debt payment	\$6,115					

Example 2: Low Lift Pivot Developed on a Dryland Farm

Example 2 is a dryland farm with 1000 cropped acres of winter wheat and barley. It uses the same irrigation development as Example 1. The before- and after-development scenarios are presented in Tables 46 through 49. As in Example 1, this scenario develops 146 acres of dry farmland for irrigating alfalfa. This farm's return to land is \$22,235 before development, and \$29,392 with irrigation development: a \$7,285 benefit attributable to irrigation. Therefore, the value of irrigation water in this scenario is \$49.71 per irrigated acre or \$24.27 per acre-foot of water diverted. (When government subsidy payments are ignored the value of the water increases to \$57.05 per irrigated acre. This occurs because fewer acres of subsidized crops are raised in the irrigation development scenario.)

Table 46. Before development machinery costs for example 2.

CROP VARIABLES		EST. YIELD	LBS/UNIT	TRUCK-HR /LOAD	TON STRAW YIELD	# OF TR USED	AX-HR/AC
ACRES ACS	ESY	#PU	TPL	TSY	1,2,or,3 #TU	APA	
DL G 1000 ac cpd 1000 ac	29 bu/ac	60	2.5			2	0.22 DL G

EQUIPMENT PARAMETERS				
1 st tractor	{ input 0 for 1 st }	TR1	hp	
2 nd tractor	{ tractor if using }	TR2	150 hp	
3 rd tractor	{ only 2 tractors }	TR3	50 hp	
tons per truck axle		TPA	10 ton	
row width		RWD	20 "	1.7 ft
bottom width		BWD	16 "	1.3 ft
purchase new or used equipment		N-U	used	
age of purchase used eq.		AGE	5 yr	
if swather self-propelled input 1		SWT	1	

COST SUMMARY OF MACHINERY		RAISED	FIXED	VARIABLE	TOTAL	LABOR
DL G	1000 ac	\$22.98	\$28.61	\$51.59	\$4.83	

Table 47. Before development enterprise budget for example 2.

CROP VARIABLES	ACRES AC	EXPECTED		SECONDARY CROP		GOVERNMENT PAYMENT	
		PRICE EPR	YIELD ECY	PRICE SPR	YIELD SCY	PRICE GPR	YIELD GCY
DRYLAND							
Barley	500	\$1.94	34 bu				
W Wheat	500	\$3.36	29 bu		ton	\$2.60	34 Barley
	1000				ton	\$4.38	29 W Wheat

weighted land total	WLT	250 ac
wt. mngt. cost/ac	WMC	/ac
wt. veh. mile/ac	WVC	40.0 mile/ac
fixed wt. cost/ac	housing FWC	\$4.00 /ac

SUMMARY	ROVC	PROFIT (LOSS)		B/C	BREAK EVEN	
		/ACRE	FARM		PRICE	YEILD
Barley	\$13	(\$14)	(\$7,248)	0.82	\$2.37	41.1 bu
W Wheat	\$34	\$7	\$3,300	1.07	\$3.14	27.4 bu
total dryland		(\$4)	(\$3,947)			

Government payment	\$26,082	
Return to land	\$22,135	
Return to management	\$22,135	
Labor costs	\$3,627	
Total farm exp.	\$85,931	1.26 B/C
Debt payment	\$3,706	

Table 48. After development machinery costs for example 2.

CROP VARIABLES		EST.	LBS/UNIT	TRUCK-HR	TON STRAW	# OF TR	AX-HR/AC
ACRES	ACS	YIELD	/LOAD	YIELD	USED		
	ESY	#PU	TPL	TSY	1,2,or,3	#TU	APA
ALF. EST	18 ac	1.4 ton/ac	2000	1		1	0.14 ALF. EST
ALF	110 ac	4.4 ton/ac	2000	1		1	0.44 ALF
IRR G	18 ac	70.0 bu/ac	60	2.5		2	0.53 IRR G
DL G	927 ac cpd	29 bu/ac	60	2.5		2	0.22 DL G
1073 ac							

EQUIPMENT PARAMETERS				
1 st tractor	{ input 0 for 1 st }	TR1	hp	
2 nd tractor	{ tractor if using }	TR2	150 hp	
3 rd tractor	{ only 2 tractors }	TR3	50 hp	
tons per truck axle		TPA	10 ton	
row width		RWD	20 "	1.7 ft
bottom width		BWD	16 "	1.3 ft
purchase new or used equipment		N-U	used	
age of purchase used eq.		AGE	5 yr	
if swather self-propelled input 1		SWT	1	

COST SUMMARY OF MACHINERY		RAISED	FIXED	VARIABLE	TOTAL	LABOR
ALF. EST	18 ac	\$26.35	\$34.96	\$61.30	\$7.96	
ALF	110 ac	\$23.40	\$32.93	\$56.33	\$10.29	
IRR G	18 ac	\$35.64	\$27.98	\$63.62	\$4.61	
DL G	927 ac	\$22.82	\$28.51	\$51.34	\$4.83	

Example 3: High Lift Wheel Line Development on a Farm/Ranch

Example 3 presents a dryland farm and small cattle ranching operation, with 1500 cropped acres, 1500 fallow acres, 200 acres of irrigated grass, and 200 head of cattle. The development scenario for this farm irrigates 77 acres of alfalfa, pumping Missouri River water up 280 feet to two wheel lines (Figure 8). The alfalfa is farmed on an eight year rotation: in the first year the crop is established, followed by six years of full production, and an eighth year of small grain production. The wheel lines service 77 acres of alfalfa at peak use, supplying water to the grain and first-year alfalfa in the spring and fall.

The before- and after-development scenarios for Example 3 are presented in Tables 50 through 54. Without development this farm would produce an annual return to land of \$57,847; with the irrigation development the return to land would be \$50,693. Therefore, the value of the irrigation water is a negative \$92.91 per irrigated acre, or a negative \$34.73 per acre-foot of water diverted.

Table 50. Before development machinery costs for example 3.

CROP VARIABLES		EST. YIELD	LBS/UNIT	TRUCK-HR /LOAD	TON STRAW YIELD	# OF TR USED 1,2,or,3	AX-HR/AC
ACRES ACS	ESY	#PU	TPL	TSY	#TU	APA	
GRASS 200 ac	3 ton/ac	2000	1		1	0.30 GRASS	
DL G 1500 ac cpd	45 bu/ac	60	2.5		2	0.34 DL G	
C-C 200 hd 1900 ac	0.9 calf/hd	1500	6	1	2	0.51 C-C	

EQUIPMENT PARAMETERS

1 st tractor (input 0 for 1 st)	TR1	hp	
2 nd tractor (tractor if using)	TR2	150 hp	
3 rd tractor (only 2 tractors)	TR3	50 hp	
tons per truck axle	TPA	10 ton	
row width	RWD	20 "	1.7 ft
bottom width	BWD	16 "	1.3 ft
purchase new or used equipment	N-U	USED	
age of purchase used eq.	AGE	5 yr	
if swather self-propelled input 1	SWT	1	

COST SUMMARY OF MACHINERY

	RAISED	FIXED	VARIABLE	TOTAL	LABOR
GRASS	200 ac	\$12.16	\$20.76	\$32.92	\$7.01
DL G	1500 ac	\$19.44	\$28.59	\$48.03	\$5.18
C-C	200 ac	\$7.79	\$12.46	\$20.25	\$5.58

