CENTER PIVOT EVALUATION AND DESIGN

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INTRODUCTION

The Center Pivot Evaluation and Design Program (CPED) is a simulation model. It is based on the first model presented by Heermann and Hein (1968) which was verified with field data. Their simulation model required input of the sprinkler location, discharge, pattern radius and an assumed stationary pattern shape of either triangular or elliptical. The application depth versus distance along a radial line from the pivot was determined and application rates at a specified distance from the pivot were determined. The hours per revolution were input and each tower was assumed to move at a constant speed for the complete circle. Kincaid, Heermann and Kruse (1969) used the model to calculate potential runoff for different system capacities and infiltration rates. Kincaid and Heermann (1970) added the calculation of the flow resistance and verified with measured pressure distribution along the center pivot lateral. Chu and Moe (1972) studied the hydraulics of a center pivot system and developed a quick approximation for determining the pressure loss from the pivot to the outer end of the lateral as a constant (0.543) times the loss that would occur if the entire discharge flowed the total length of the lateral.

The model was adapted by Beccard and Heermann (1981) to include the effect of topographic differences in the resulting application depths along radii of the center pivot in non level fields. The model included the pump and well characteristics and calculated the hydraulic equilibrium point as the system moved to different positions on a rough terrain. The model was exercised to determine the uniformity changes when converting from high pressure to low pressure on rough terrain. Edling (1979), and James (1984) also used simulation models to study the performance of center pivot systems on variable topography and with different pressures.

The current simulation model has been expanded to include donut shaped stationary patterns that can be used to represent many of the low pressure spray heads. The start-stop of the electric motors and the speed variation in hydraulic drives can also effect the uniformity in the direction of travel (Heermann and Stahl, 1986). The input of the start-stop sequence for each tower replaces the assumption of a constant speed and the variability of application depths in the direction of travel has been simulated.

EXAMPLES OF SIMULATION EVALUATION

The uniformity of application depths can be calculated by inventorying the sprinkler head models, nozzles sizes and distance from the pivot. The pump curve and drawdown, or pivot pressure, or discharge is also needed. Figure 1 illustrates a simulation as designed and the distribution if the sprinkler heads were reversed between 2 towers made at the time of installation. The application rate and potential runoff are illustrated in Figure 2.

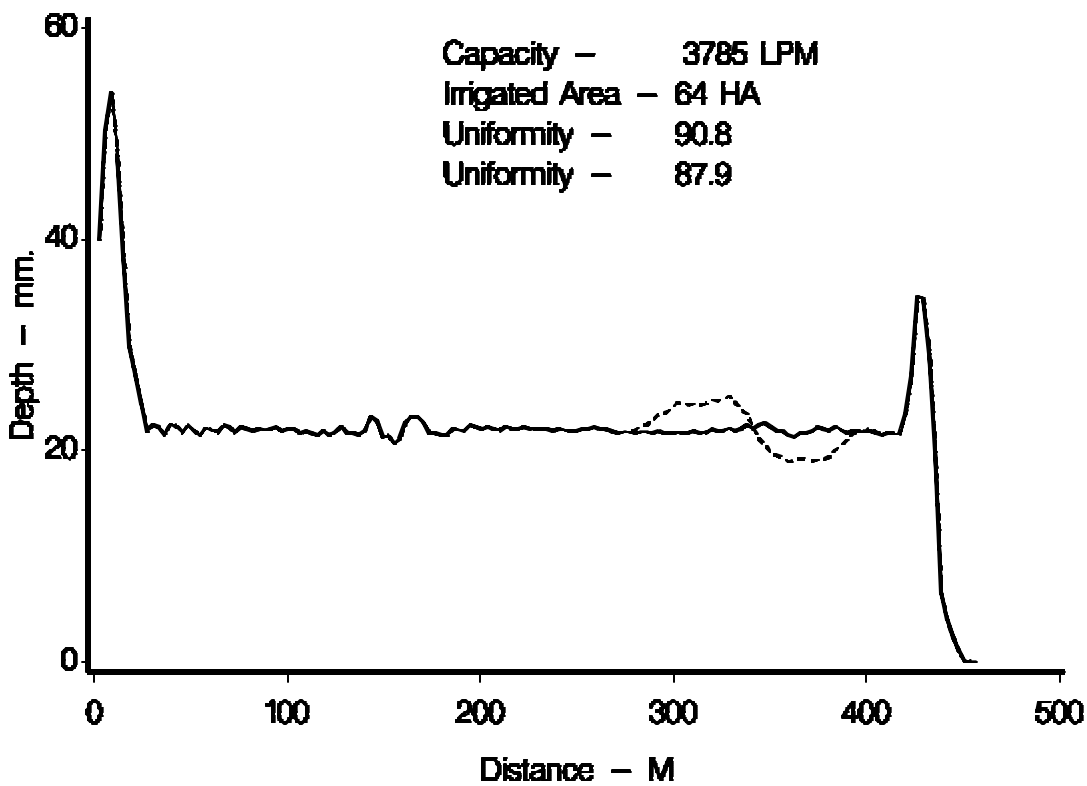


Figure 1. Typical center pivot as designed (CU = 90.8) and with 10 sprinkler heads incorrectly installed shown as a dashed line (CU = 87.9).

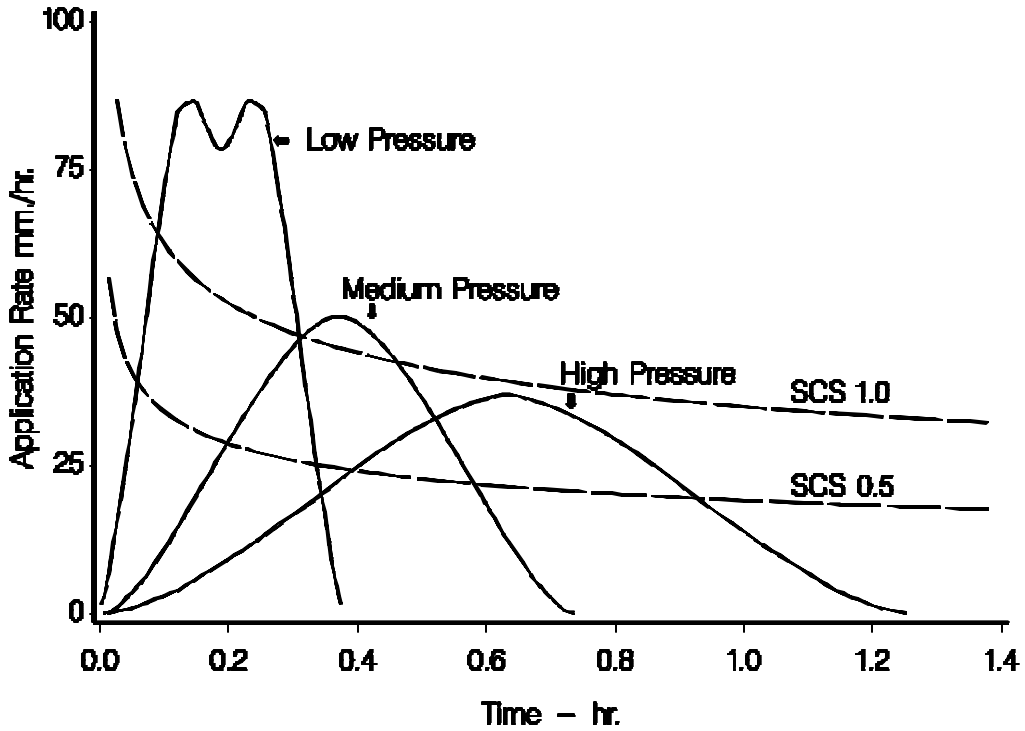


Figure 2 Example application rate curve versus 0.5 and 1.0 SCS intake curve.

EVALUATION OBJECTIVES

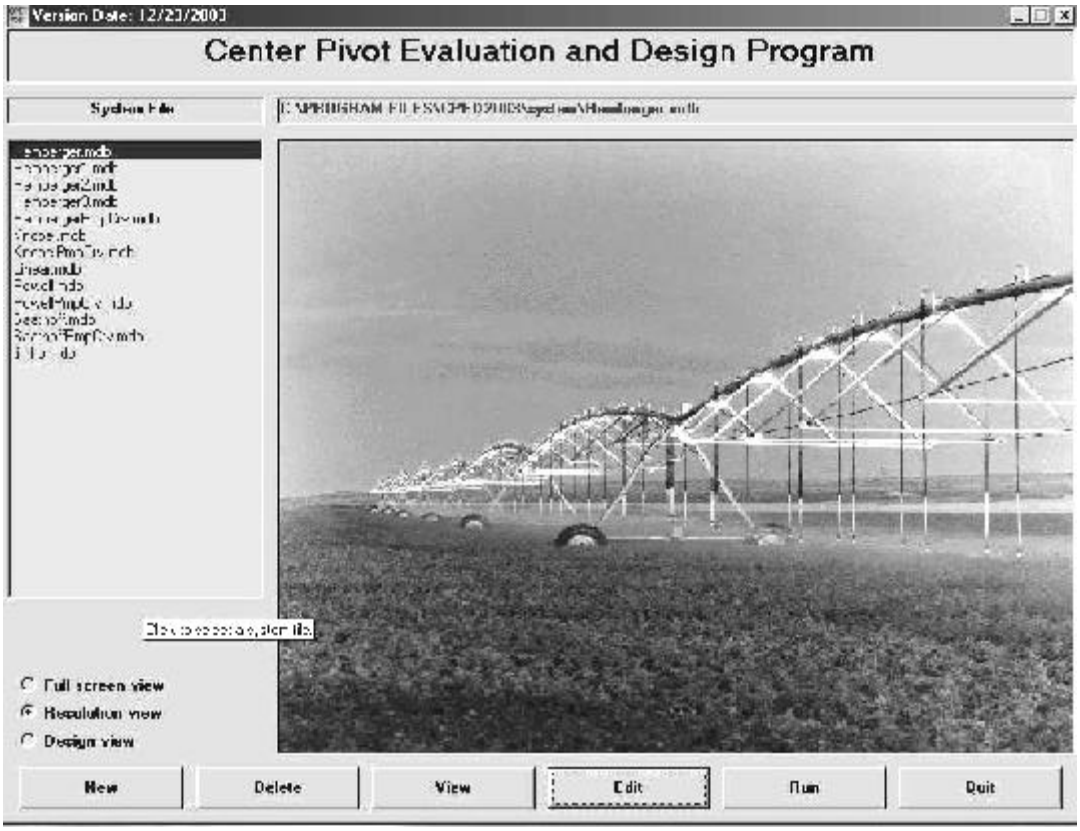
The selection or development of an evaluation standard and procedures should focus on the need for the evaluation. The USDA, Environmental Quality Incentive Program (EQIP) administered by the Natural Resource Conservation Service (NRCS) currently can provide cost sharing on the installation and upgrading of irrigation systems for improving water quality or conservation under irrigation. Center pivots are frequently the system of choice. There is a need to assure that installed systems will provide the desired improvement in irrigation performance. A similar need exists for any user of center pivot systems to assure that an installed or modified system will perform as designed. It must be recognized that the scheduling of irrigations is most important for the beneficial use of water. Efficient scheduling of irrigation systems requires knowing the amount of water applied per irrigation. The CPED program has been streamlined and simplified for use in evaluating center pivot systems for cost sharing on new and upgraded systems. The CPEDLite program is similar to the one being used in this workshop. The primary difference is the simulations are for 1 foot intervals beginning and ending at fixed distances. This assures that any simulation will provide the same results. The uniformity is output in 5% bands.

CPED PROGRAM OPERATION

The following pages will present the various windows that are presented to the user for controlling the input and operation of the program. The program illustrated is the full version of CPED. The CPEDLite program has the same look at the window level but requires less input with some of the options being fixed so that similar results will be obtained independent of the operator.

The program is available on request but the user is cautioned that there is always the possibility of program errors when different systems present conditions that have not been experienced prior to this time. The program is therefore limited in its release to minimize the problems of users that are not familiar with center pivot operation and terminology.

MAIN PROGRAM WINDOW



The options available are to **select** or create a **new** system file, **view** output from previous simulations, and **quit** the program. Once a system file is **selected** or created, the options to **run, edit, or delete** the system file are enabled. In all cases throughout the program “click” means click the left mouse button.

A system file can be **Selected** by clicking one of the systems listed in the list box labeled *System File List.* The name of the selected system file will be displayed in the label box labeled *Name of Selected System File.*
The **New** button allows the user to create a new system file. There are two ways to create a new system. The first way is to enter a name and click the OK button. You are then transferred into the Edit window that is discussed below. The second option is to create a system from an existing file. You then select the existing file; name the new system; click the OK button and you will be in the Edit window where only changes need to be entered.

The **Delete** button will delete the selected system file from the user's hard drive. The user will be asked for confirmation before deleting a system file.

The **View** button allows examining previous simulation results. The *View previous output* button will bring up the data files that have been saved from previous simulations. Selecting one of these files will plot to the screen the simulated depth versus distance data.

The *Analyze catch can data* button allows you to enter catch can data for uniformity evaluation. A simulation output data set can be input to the catch can data file and allow the uniformity analysis for different distances along the lateral.
The procedure to save simulation data is presented latter with running the program.

The **Edit** button allows editing of the selected system file. More detail is below.

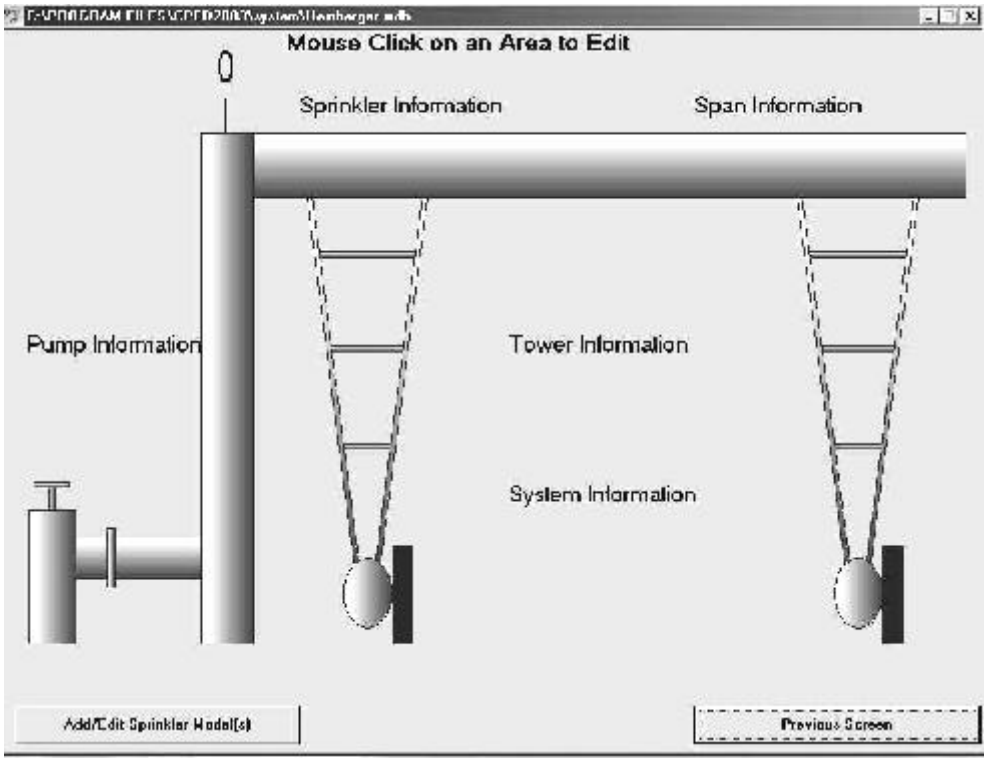
The **Run** button moves to the screen for entering the parameters to run the simulation. More detail is given below.

The **Quit** button exits the program. Pressing CTRL +Q anytime during the simulation will have the same effect.

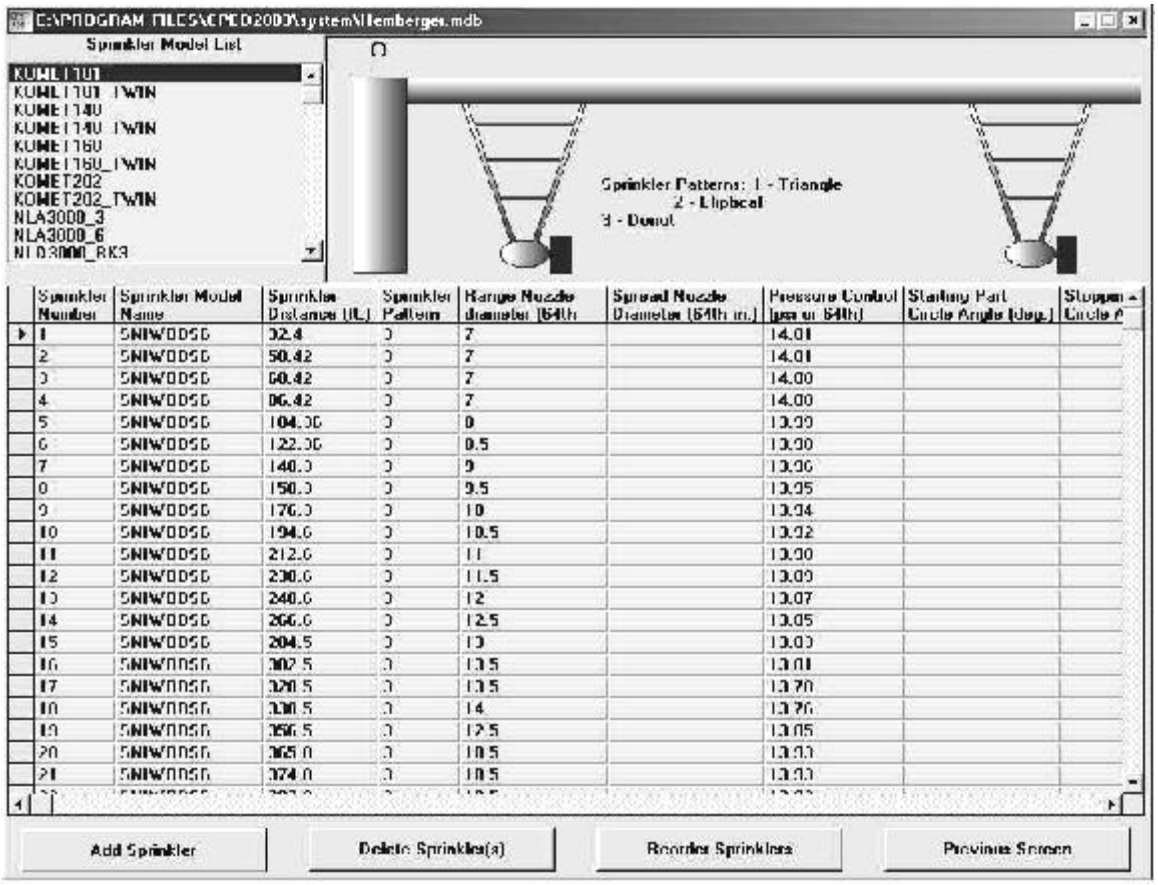
EDIT SYSTEM FILE WINDOW

The different information groups of data can be entered or edited by moving the mouse pointer over the image of the sprinkler system. The labels *Pump Information, Tower Information, Sprinkler Information, Span Information, and System Information* can be selected by clicking on the text to open its edit window.

The *Add/Edit Sprinkler Model* button opens a window for adding or editing sprinkler models. This is password protected and normally is not needed by the user. Those supporting the program will do this editing. The *Previous Window* button saves the changes and returns to the main program window.



SPRINKLER EDIT WINDOW



A new sprinkler can be added by clicking the *Add Sprinkler* button. If no sprinklers are present by pressing the *Add Sprinkler* button a sprinkler with zero distance will default and you can begin by entering the other information for the first sprinkler. The sprinkler model is selected by clicking on the model listed in the box labeled *Sprinkler Model List*. Sprinklers can be added in any order. If one sprinkler is missed you can merely add it at any time. By clicking the *Reorder Sprinklers* button the sprinklers will be ordered from the pivot to the outer end based on their individual distances from the pivot. You do not enter the sprinkler number as this is done automatically. If sprinklers are present the information from the previous record will be used and the distance will automatically be incremented. Edit the information for the newly added sprinkler. Many systems will have the same sprinkler models and these will need no editing. If the sprinkler spacing is uniform this will also require minimal editing. Even the nozzle sizes may be the same for several sprinklers minimizing the editing required.

The nozzle size is the diameter in 1/64 inches. For example a nozzle diameter of 9.5 is equal to 9.5/64 or 19/128 inch. There are columns for a range and spread nozzle which was typical for high pressure heads. Enter the diameter for single nozzle sprinklers in the range column. The pressure control column is the outlet pressure of the pressure regulator if this is selected in the *System file screen.* When the constant orifice is the selected pressure control, the orifice size in 64th inch is entered. When this column is left blank, it is an indication there is no flow control on that sprinkler even if the system has pressure regulation selected.

The start and stop angles are viewed from the pivot toward a part circle sprinkler. Check if the sprinkler starts on the right or left. Then using the pipe as the zero reference point, measure the angle back toward the pivot. Use the same technique for the stop angle. All angles are positive and between 0 and 180 degrees (Figure 3).

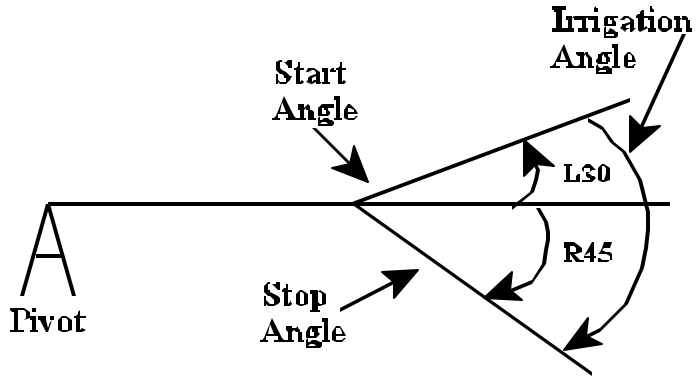


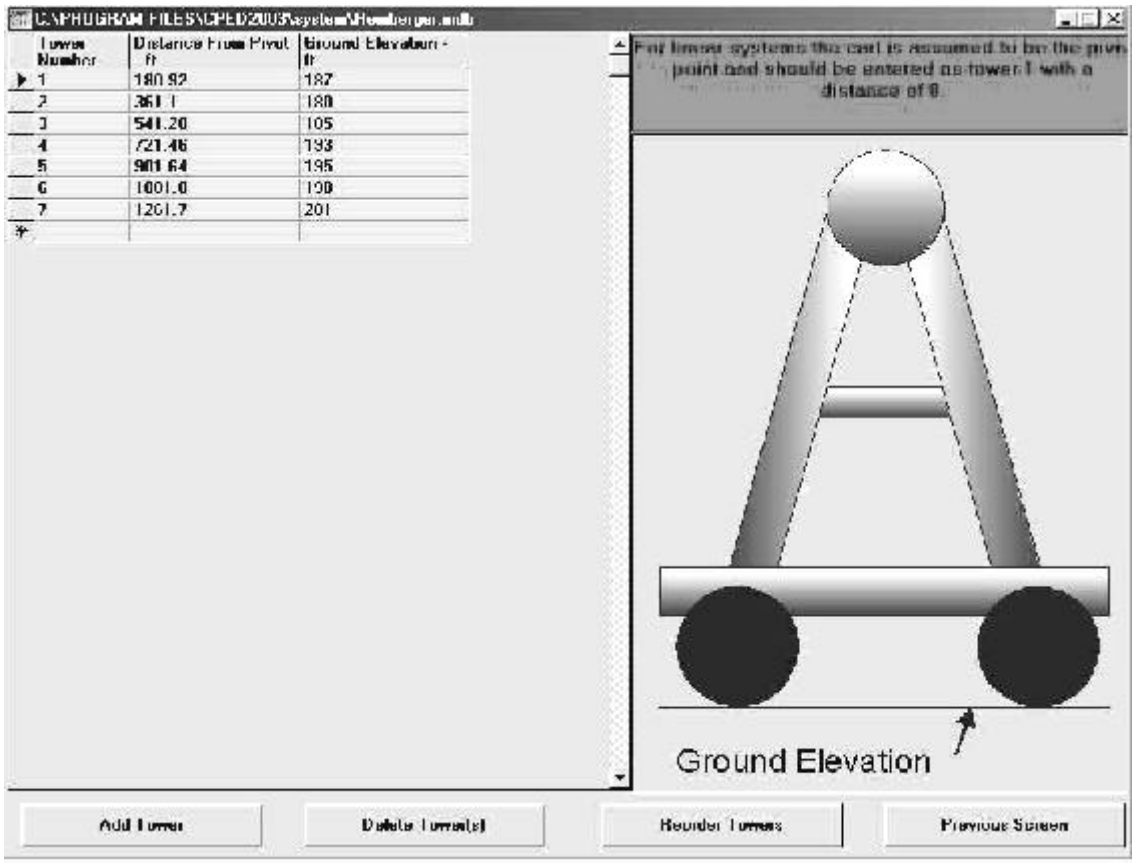
Figure 3. Part circle sprinklers angles. Angles are between 0 -180 degrees with an L or R prefix.

Alternatively you can move to the bottom row marked with an '*' and enter the new sprinkler information manually. A sprinkler can be deleted by selecting any column in the row for the sprinkler and click the *Delete* button.

The *Reorder* button will sort and number the sprinklers by sprinkler distance from the pivot.

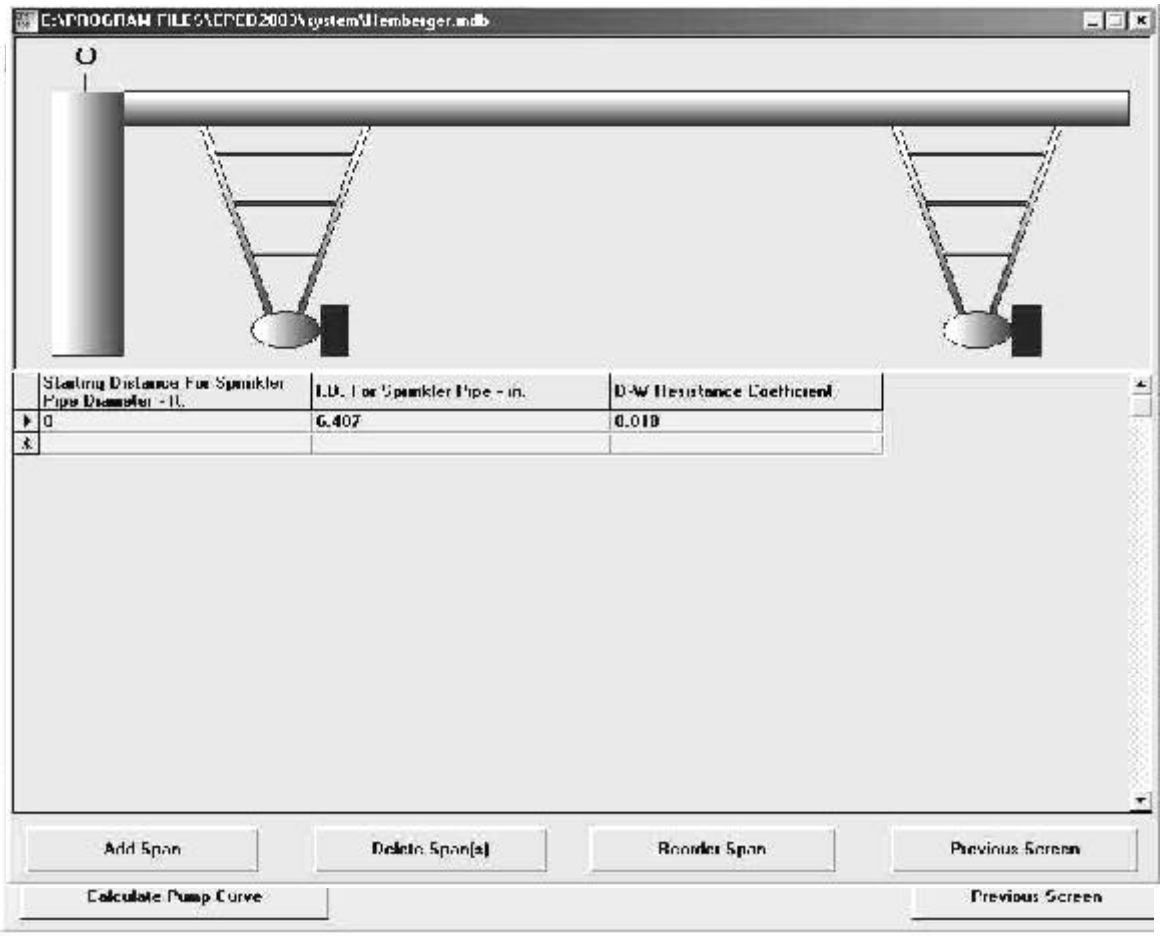
The *Previous Screen* button returns to the **Edit system file window**.

TOWER EDIT WINDOW



Towers are added by clicking on the *Add Tower* button and editing the distance from the pivot and its elevation. It is often assumed that the pivot and all towers are at an elevation of 100 feet if no field information is available. For the linear system, the first cart is assumed to be the pivot with a distance of 0. As the *Add Tower* button is clicked, the towers are added with the spacing of the previous two towers and the same elevation as the previous tower. The *Reorder Towers* will sort the towers by distance from the pivot if there happen to be entered in the wrong sequence. Select a tower and click the *Delete Tower* button if a tower needs to be deleted. The *Previous Screen* returns to the *Edit system file window.*

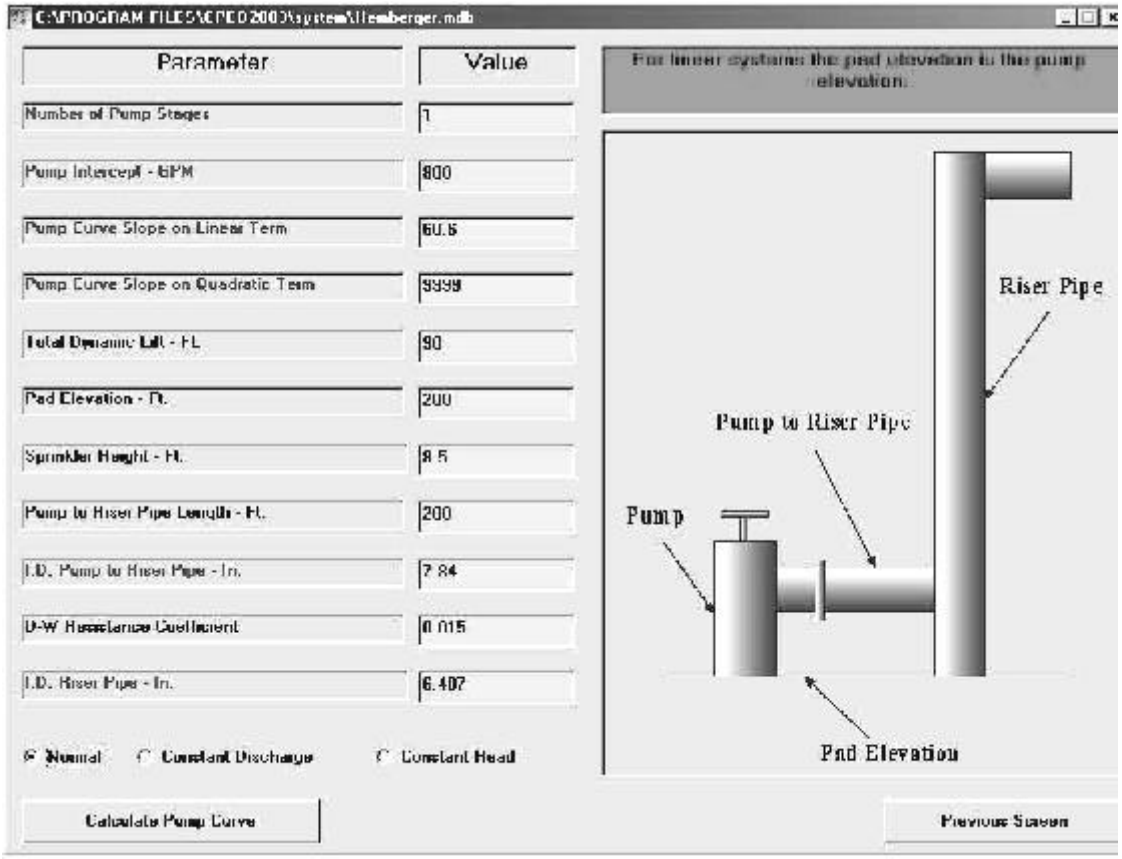
SPAN INFORMATION WINDOW



Clicking the *Add Span* button inserts a starting distance of 0 and the Pipe I.D. and the Darcy-Weisbach resistance coefficient must be entered. A typical value of the D-W coefficient is 0.xxx to 0.xxx for center pivots. Multiple pipe sizes can be added by clicking the *Add Span* button and entering the starting distance from the pivot and its resistance coefficient. The spans are assumed to go from the starting distance to the next span or end of the pivot for the last span. Spans can be deleted (*Delete Span)* and reordered (*Reorder spans)* by clicking the appropriate button. Never delete the span with starting distance of 0. The *Previous Screen* button returns to the *Edit system file window.*

PUMP INFORMATION WINDOW

The piping to the pivot, pump curve, and pivot elevation are entered in this window. If the pump curve information is not available, either a constant discharge or constant pressure can be selected.



Selecting the *Normal* option requires the quadratic equation for the pump curve. The curve of the total head vs discharge for the pump is needed to develop the regression equation that describes the pump. This relationship can be determined externally from this program or there is an option that will fit the pump curve equation with points from a pump curve or field measured data. At least 4 points that span the operating range are needed, however 8-10 will give a better fit. Problems have occurred where the operating point is beyond the pump curve data. **Use caution.** The form of the equation for the pump curve is:

$$Q = B_0 + B_1H + B_2H^2$$

where:

Q - discharge - gpm
H - head/stage - psi
B_0 - intercept
B_1 - linear slope coefficient on head
B_2 - quadratic slope coefficient on head

The number of stages for the pump must be entered when the manufacturers pump curve is for a single stage. However, if the pump curve comes from field measurements, set the number of stages equal to one. The *Calculate Pump Curve* button can be selected for

calculating the coefficients when data are available from either the manufacturers pump curve or field measured data. The paired data of discharge in gpm and head in feet can be entered and the three coefficients calculated.

The total dynamic lift in feet must also be entered. It is the elevation difference (feet) between the center pivot pad elevation and the depth to the water table including the drawdown while pumping. The pad elevation is the elevation for the center pivot at from an assumed or measured datum elevation. The sprinkler height is the distance above the pad height for the sprinklers as if they were on a level field. The inside diameter (I.D.) of the pipe size and length of pipe from the pump to the pivot and the I.D. of the riser pipe must be entered. Include the Darcy-Weisbach coefficient for both pipes.

The *Constant Head* option is where the pivot pressure (psi) is specified. This is the most stable option where the pump curve is not known. Estimate the discharge in gpm and set the number of stages equal to one. The estimate discharge is only to shorten the calculation time and the actual value is not critical.

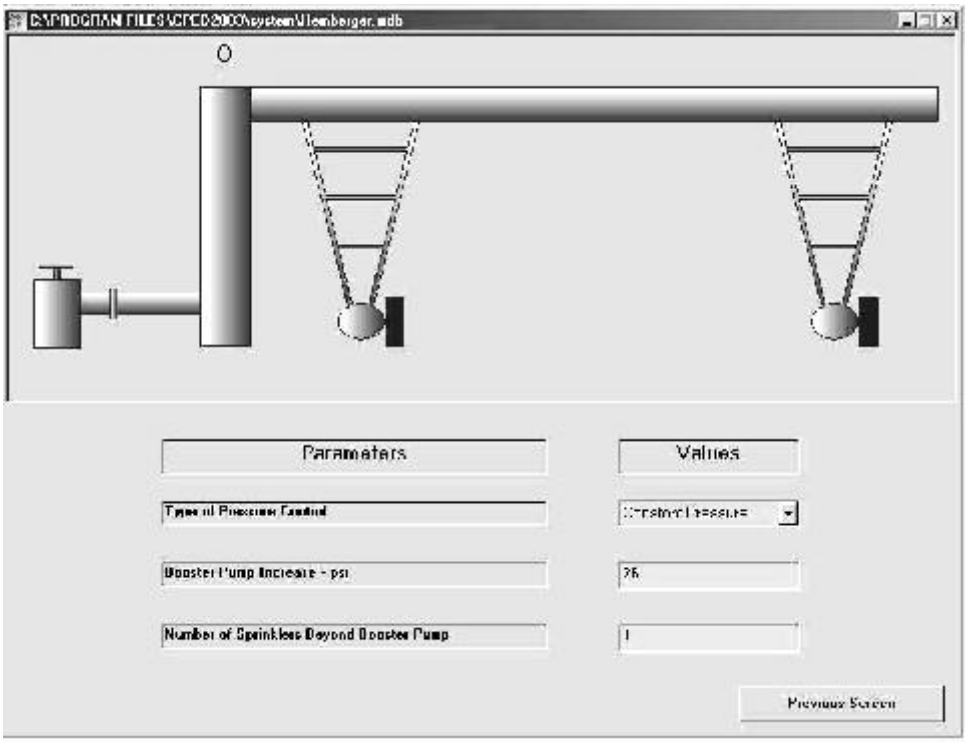
The *Constant Discharge* in gpm can also be specified. The potential problem with constant discharge is when all sprinklers are regulated. If the discharge does not match the calculated discharge with the regulated pressure an error will occur when attempting to have the calculated discharge on the system match that specified. Again set the number of stages equal to one.

The constant head and constant discharge does not require pump to riser pipe and riser pipe sizes or resistance coefficient since the pressure or discharge is assumed to be at the pivot and no head loss is calculated for these sections. The *Previous Screen* button returns to the *Edit system file window.*

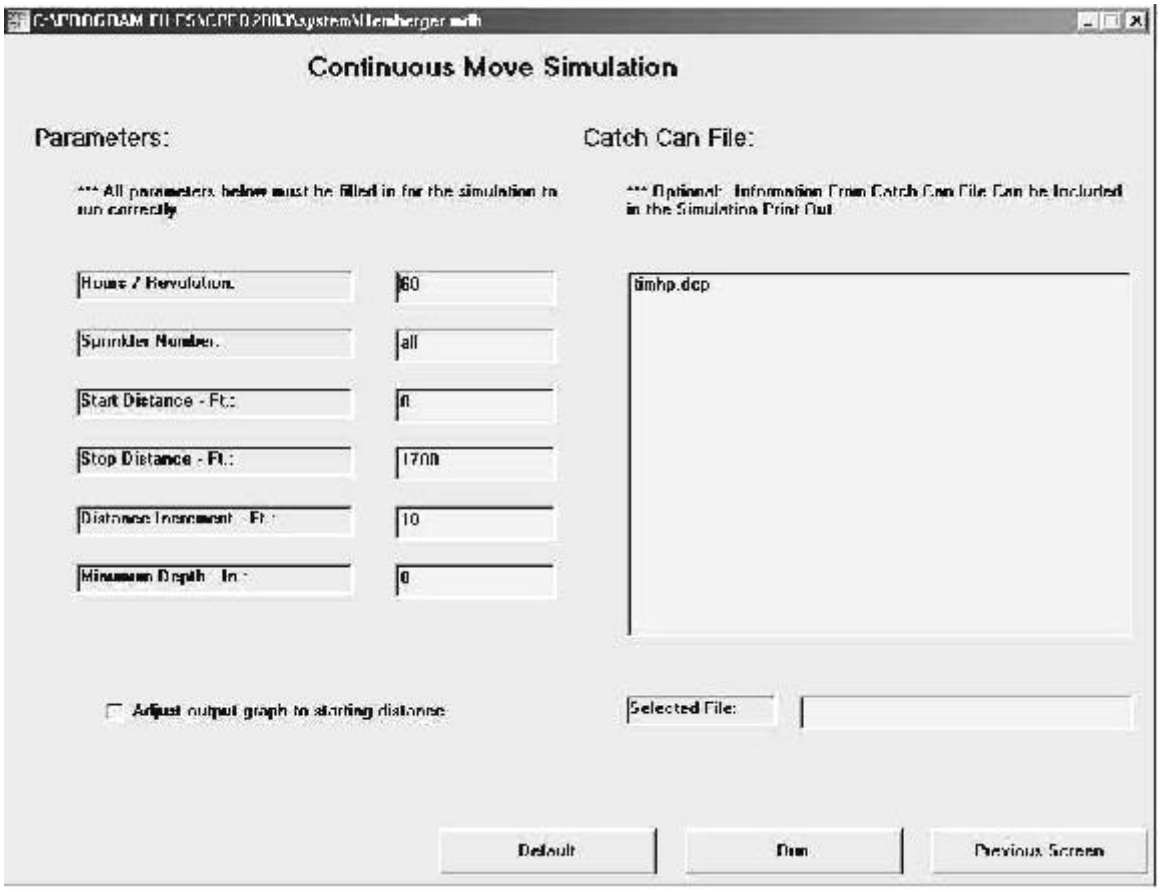
SYSTEM INFORMATION SCREEN

Three options for the *Type of Pressure Control* can be select from the drop down box. They are none, pressure regulated, or constant orifice. Systems with booster pumps for the big gun at the end of a center pivot system are simply estimated with a pressure increase in psi just prior to the big gun or guns. The number of sprinklers beyond the booster pump is specified. The actual pressure is dependent on the center pivot system and the inlet pressure, discharge or pump curve.

The *Previous Screen* button returns the *Edit system file window.*


Parameters
Values
Number of Sprinklers Beyond Booster Pump
Previous Screen

RUN WINDOW


Continuous Move Simulation
Parameters:
Catch Can File:
Hours / Revolution:
60
Sprinkler Number:
all
Start Distance - Ft.:
0
Stop Distance - Ft.:
1700
10
0
timhp.dcp
Adjust output graph to starting distance
Selected File:
Default
Run
Previous Screen

This is the screen that you will enter when you click *RUN* and all of the system files with the necessary data have been entered. Minimal input is required on this screen before the simulation is run. The *Default* button will restore the default values that were used on the previous simulation run for this system. The hours/revolution are entered to obtain the depth for this condition. Normally the sprinkler number is set to “all” for including all the sprinklers to be simulated. However, you can select one sprinkler by entering its number to see the contribution to the depths from the specified sprinkler.

The start, stop distances and distance increment specifies the location for simulation depths. For example you can start at 10 feet and go to 500 feet with 5 foot increments. The minimum depth specifies that only locations with depths greater than that will be included in the uniformity calculations. This is often desirable when not including the small depths at the outer boundary where there is not sufficient overlap with other sprinklers. The CPEDLite program fixes these four parameters and only the speed in hours/revolution can be changed.

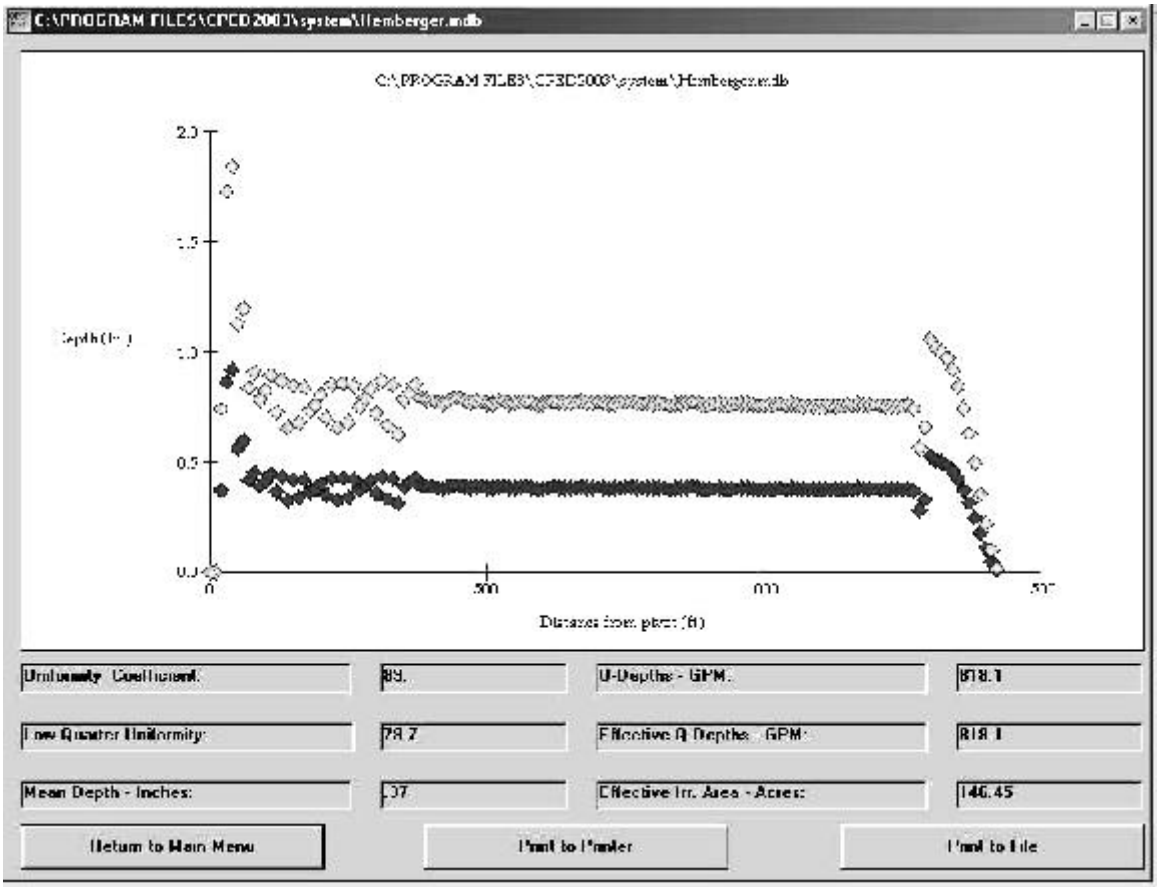
Clicking the *RUN* button will start the simulation. You will automatically be moved to another window that will plot the simulated depth versus distance data on the monitor. Prior to pressing *RUN* you can select a catch can data set or data saved from a previous run to be displayed on the monitor after the simulation is completed. This provides a visual comparison of the current simulation with other data. The data for comparison can be selected from the files listed in the Catch Can File Window. The *Previous Screen* button will return to the Main Window.

You will note a possible selection to Adjust output graph to starting distance. This is normally not needed when simulating the entire system. Clicking this selection is beneficial if you are not simulating from near the pivot and want the plot to begin at the starting distance instead of 0.

SIMULATION OUTPUT WINDOW

The output window plots the simulated depth versus distance from the pivot for the parameters set in the run window. The Coefficient of Uniformity, the Distribution Uniformity, and mean application depth are printed. The Q-Depths, gpm, is the discharge calculated from all simulated depths while the Effective Q-Depths, gpm, is calculated from the depths that are above the specified minimum depth used in the Uniformity and mean depth calculations. The effective area is the simulated area for those areas receiving more than the minimum depth between the starting and stop distances. The window below is an example of plotting catch can data from a previous simulation run.

Additional data can be printed either to the printer or to a file. The *Return to Main Menu* button will return to the main menu screen. The *Print to File* button will ask for the file name



for storing the information. You will then be prompted for saving the individual sprinkler and tower data followed for a prompt to save the simulated
depth data and the name for its file. The saved simulated depth data are then available for comparison with future simulations for the same center pivot system.

The following information can be printed to the printer after the simulation run.

1. The head per stage of the pump - gpm
2. The pivot pressure - psi
3. The system discharge based on the pump curve - gpm
4. The system discharge based on all the integrated depths - gpm
5. The system discharge based on all depths above the minimum depth - gpm
6. The effective irrigated area, which is the area receiving water above the minimum depth - acres
7. The mean depth - in. (of all depths above the minimum)
8. Christiansen's uniformity coefficient (of all depths above the minimum)
9. Mean low quarter uniformity (of all depths above the minimum)
10. Plot of depth vs distance

The information that is available for each sprinkler is the line pressure - psi, the nozzle pressure - psi, the discharge - gpm, and the pattern radius - ft.

The application depths are the final piece of information provided. They are listed by distance.

The *Previous Window* button saves the changes to the system file and returns to the main program window.The *Previous Window* button saves the changes to the system file and returns to the main program window.

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