Irrigation Training Toolbox
Irrigation System Design

CPNOZZLE Program

CPNOZZLE PROGRAM

USER INSTRUCTIONS

Problem Description :

      The agricultural specialist dealing with sprinkler irrigation needs a quick, easy way to analyze the potential for runoff under center pivots and the economic impact of that runoff. This need arises mainly because of the increased adoption of lower operating pressures on center pivots and changing sprinkler packages which concentrate water application in smaller areas. These changes take advantage of lower inputs for fuel but do not take into account the potential for runoff. Runoff decreases the system efficiency and may actually lead to increased operating costs. This computer program was developed to quickly and easily determine potential runoff and its economic impact which requires minimal user inputs.

User Documentation :

      The program runs on IBM-PC or compatible computers with a color graphics adapter. A math co-processor chip and a color monitor are suggested, but not required. The program disk is inserted in drive A and drive A should be made the default disk drive. To initiate the program, the user types 'CPNOZZLE' and presses return. User provided inputs are entered in response to questions posed by the program. Where necessary, help screens are provided to assist in determining the appropriate inputs. The initial screen is the title screen. To continue, the user presses any key.

      The output and input values can have either SI or English units associated with them and can be specified separately. In this way, the user can enter English as the input units and SI units as the output, or vice versa. Specifying SI or English units is accomplished by answering with a Y or N for yes or no to the first 2 questions.

      Ex. :   Output in Metric units (Y/N) => Y
                   Input in Metric units (Y/N) => N

      The user then has an option to choose the Energy Savings Analysis, Potential Runoff Analysis, or Quit the program. Entering the appropriate number will choose the option desired.

      Ex. :   1. Energy Savings Analysis
                   2. Potential Runoff Analysis
                   3. End Program

             Enter your choice => 2

      The first question identifies the center pivot system length. This information is used to determine water application patterns, acres irrigated and length increments for field slope estimate inputs.

      Ex. :   System Length (meters)?   408

IRRIGATION DESIGN

A field slope estimate must be entered to establish the soil surface storage amount within the program, or the surface storage can be entered directly. Surface storage estimates were taken from Dillon, et al., 1972.

The program allows the user to enter a constant slope (C) for the entire system length or vary the slope (V) along the system length.

Depending on whether C or V was selected the program requests the estimate of field slope.

Constant slope (C):

Ex: 0 feet to 1340 feet

```
        SLOPE : 0-1% => 1 = 12.7 mm (0.50 in)
        SLOPE : 1-3% => 2 =  7.6 mm (0.30 in)
        SLOPE : 3-5% => 3 =  2.5 mm (0.10 in)
        SLOPE : > 5% => 4 =  0.0 mm (0.00 in)
                       5

                   =>?3
```

Variable Slope (V): A field slope estimate must be entered for 10 locations along the system length.

Ex: 0 feet to 134 feet

```
              SLOPE : 0-1% => 1 = 12.7 mm (0.50 in)
              SLOPE : 1-3% => 2 =  7.6 mm (0.30 in)
              SLOPE : 3-5% => 3 =  2.5 mm (0.10 in)
              SLOPE : > 5% => 4 =  0.0 mm (0.00 in)
  Enter your own storage amount => 5 = ?.?? mm (?.?? in)
                       =>?3
```

Additional responses requested for 9 remaining length increments:

```
        134 feet to   268 feet
        268 feet to   402 feet
        402 feet to   536 feet
        536 feet to   670 feet
        670 feet to   804 feet
        804 feet to   938 feet
        938 feet to  1072 feet
       1072 feet to  1206 feet
       1206 feet to  1340 feet
```

Although slope differences are seldom if ever in concentric circles, the ability to vary the slope input is valuable when trying to show the impact of position on the center pivot and field slope on potential runoff estimates. Different positions of the field can be evaluated separately by simply entering a new set of field slope estimates.

The radius of throw of the sprinkler package at the end of the pivot is requested next. With the exception of the constant spaced high pressure inpact sprinklers, all wetted radii are assumed to be constant for the entire system length. This will describe the sprinkler water application pattern on the center pivot. If a high pressure impact sprinkler package with constant spacing is used, an 'H' may be entered. An equation will then be used to calculate the sprinkler radius of throw dependent upon the position along the pivot. A table of sprinkler packages and suggested radius of throw of that package is presented to assist the user in this entry.

Ex. :

Sprinkler Package	Suggested Radius of Throw
High Pressure Impact (Constant Spacing)	'H'
High Pressure Impact (Variable Spacing)	12 - 15 m (40 - 50 ft)
Medium Pressure Impact (Variable Spacing)	10 - 14 m (35 - 45 ft)
Low Pressure Impact (Variable Spacing)	6 - 10 m (20 - 35 ft)
Low Pressure Impact (CDS)	6 - 10 m (20 - 35 ft)
Low Pressure Spray (360 degrees)	5 m (16 ft)
Low Pressure Spray (180 degrees)	2 - 3 m (8 - 10 ft)
Ultra Low Spray (LEPA)	1 - 2 m (1 - 3 ft)

Sprinkler radius of throw at end of pivot, feet
(or 'H' for high pressure system) => ? 20

The application amount and system output are requested next.

Ex. : Application amount, in => ? 1

System output, gpm => ? 800

The Soil Conservation Service (SCS) Soil Intake Family Curves have been converted to Kostiakov equations by drawing tangental lines to the SCS curves at an accumulated time of 60 minutes. The curve number can be selected from the available families listed. 'H' can be entered for help or 'I' can be entered to allow specific Kostiakov equation constants to be supplied by the user.

Ex. :
SCS Intake Family
Available Families - 1 => 0.1
                    2 => 0.3
                    3 => 0.5
                    4 => 1.0
                    5 => 1.5
                    6 => 2.0
                    7 => 3.0

Choose your family, 'H' for help or "I" for customized constants => H

Help screen for Intake Family Curve Input

SCS INTAKE FAMILY DESCRIPTION

0.1 -------- Clay, silty clay, silty clay loam, clay loam
-------- Slowly permeable subsoils
0.3 -------- Silt loam, loam, very fine sandy loam, clay loam,
-------- silty clay loam, sandy clay loam
-------- Slow to moderately slow permeable subsoils
0.5 -------- Silt loam, loam, very fine sandy loam
-------- Moderately slow permeable subsoils
1.0 -------- Fine sandy loam, loamy fine sand, silt loam,
-------- loam, very fine sandy loam, very fine sandy
-------- Moderate, moderately slow, moderately permeable,
-------- medium textured, moderately rapidly permeable
-------- subsoils underlain by bedrock or mixed sand & gravel
1.5 -------- Fine sandy loam, loam, sandy loam
-------- Moderately rapid, rapidly, moderate subsoils underlain
-------- by bedrock or mixed sand & gravel
2.0 -------- Loamy fine sand or loamy sand
-------- Moderately rapid to rapidly permeable subsoils
3.0 -------- Loamy sand, loamy fine sand, fine sandy loam, fine sand
-------- Rapidly permeable subsoils

Any key to continue.

SCS Intake Family
Available Families - **1** => 0.1
2 => 0.3
3 => 0.5
4 => 1.0
5 => 1.5
6 => 2.0
7 => 3.0

Choose your family, 'H' for help or 'I' for customized constants => 3

The user can have intermediate output sent to the screen or by-passed by responding with a Y or N.

Ex. : Would you like intermediate output to the screen (Y/N) Y

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If intermediate output is selected by pressing Y, 30 screens will be shown with a pause between each for the user to view the screen.

Ex. :

Q	=	44.16 l/sec	Q	=	44.16 l/sec	Q	=	44.16 l/sec
R	=	81.69 meters	R	=	81.69 meters	R	=	81.69 meters
r	=	4.88 meters	r	=	4.88 meters	r	=	4.88 meters
SCS	=	0.1	SCS	=	0.3	SCS	=	0.5
k	=	6.32 mm/hr	k	=	12.27 mm/hr	k	=	18.57 mm/hr
n	=	-0.62	n	=	-0.49	n	=	-0.44
I(Ts)	=	10.15 mm/hr	I(Ts)	=	12.94 mm/hr			
AR(Ts)	=	19.16 mm/hr	AR(Ts)	=	19.47 mm/hr			
Im(Ts)	=	19.17 mm/hr	Im(Ts)	=	19.46 mm/hr			
Tp	=	0.70 hr	Tp	=	0.70 hr	Tp	=	0.70 hr
Ts	=	0.46 hr	Ts	=	0.90 hr			
Delta t	=	0.30 hr	Delta t	=	0.51 hr			
Hp	=	20.33 mm/hr	Hp	=	20.33 mm/hr	Hp	=	20.33 mm/hr
Tf	=	1.36 hr	Tf	=	1.16 hr			
I(Tf)	=	5.24 mm/hr	I(Tf)	=	11.40 mm/hr			
Im(Tf)	=	6.10 mm/hr	Im(Tf)	=	15.09 mm/hr			
AR(Tf)	=	6.11 mm/hr	AR(Tf)	=	15.10 mm/hr			
SSA	=	2.50 mm	SSA	=	2.50 mm	SSA	=	2.50 mm
			No runoff			No runoff		
TA	=	22.22 mm	TA	=	22.22 mm	TA	=	22.22 mm
PR	=	4.52 mm						
or		20.34%						

Hit any key to continue or 'L' for a list of variable name explanations

The user can obtain a list of the variables and an explanation for each after each screen of data is presented by pressing 'L'.

Ex. :

Q	=	system discharge, l/sec (gpm)
R	=	system length, meters (feet)
r	=	sprinkler radius of throw, meters (feet)
SCS	=	SCS Soil Intake Family
k	=	empirical constant in the soil infiltration equation
n	=	empirical constant in the soil infiltration equation
AR(Ts)	=	application rate of the system at saturation, mm/hr (in/hr)
Im(Ts)	=	modified soil infiltration rate at saturation, mm/hr (in/hr)
I(Ts)	=	infiltration rate at saturation, mm/hr (in/hr)
Tp	=	time when the application rate is at its peak rate, hr
Ts	=	time to surface saturation, hr (first time when the system application rate is equal to the modified infiltration rate)
Delta t	=	time shift between the soil infiltration equation and the modified infiltration equation, hr
Hp	=	peak application rate, mm/hr (in/hr)
Tf	=	final time when the system application rate is equal to the modified infiltration rate, hr

I(Tf)	=	infiltration rate at time Tf, mm/hr (in/hr)			
Im(Tf)	=	modified infiltration rate at time Tf, mm/hr (in/hr)			
AR(Tf)	=	application rate of the system at time Tf, mm/hr (in/hr)			
SSA	=	allowable surface storage, mm (in)			
TA	=	total application of the system, mm (in)			
PR	=	potential runoff, mm (in)			

Any key to continue.

After all 30 screens are presented or, if no intermediate output was selected, three output tables are presented. Each of the three tables coincides with a different SCS Soil Intake Family. Each table presents three system outputs and ten distances from the pivot, with the sprinkler wetted radius and soil surface storage for that point. The percent potential runoff is given for each of these conditions. The weighted potential runoff for the system is presented at the base of the table. The application amount, and system length are presented with each screen along with the calculated hours per revolution of the center pivot. Pressing 'P' with any of these screens will print the screen to a printer, if attached.

Ex. :

PERCENT POTENTIAL RUNOFF
0.3 SCS Intake Family

System length meters	Wetted Radius meters	Surface Storage mm	44 l/sec	50 l/sec	56 l/sec
41	20	2.5	0.0%	0.0%	0.0%
82	20	2.5	0.0%	0.0%	0.0%
122	20	2.5	0.0%	0.0%	0.0%
163	20	2.5	0.0%	0.0%	0.0%
204	20	2.5	0.0%	0.0%	0.0%
245	20	2.5	0.0%	0.0%	0.0%
286	20	2.5	0.0%	0.0%	0.9%
326	20	2.5	0.0%	0.0%	5.2%
367	20	2.5	0.0%	0.4%	9.0%
408	20	2.5	0.0%	3.8%	12.4%
Weighted Average Potential Runoff			0.0%	0.2%	3.5%

25.4 mm application amount,   408 meters system length
 74 hours per revolution

PERCENT POTENTIAL RUNOFF
0.5 SCS Intake Family

System length meters	Wetted Radius meters	Surface Storage mm	44 l/sec	50 l/sec	56 l/sec
41	20	2.5	0.0%	0.0%	0.0%
82	20	2.5	0.0%	0.0%	0.0%
122	20	2.5	0.0%	0.0%	0.0%
163	20	2.5	0.0%	0.0%	0.0%
204	20	2.5	0.0%	0.0%	0.0%
245	20	2.5	0.0%	0.0%	0.0%
286	20	2.5	0.0%	0.0%	0.0%
326	20	2.5	0.0%	0.0%	0.0%
367	20	2.5	0.0%	0.0%	0.0%
408	20	2.5	0.0%	0.0%	0.0%
Weighted Average Potential Runoff			0.0%	0.0%	0.0%

25.4 mm application amount,   408 meters system length
74 hours per revolution

PERCENT POTENTIAL RUNOFF
1.0 SCS Intake Family

System length meters	Wetted Radius meters	Surface Storage mm	44 l/sec	50 l/sec	56 l/sec
41	20	2.5	0.0%	0.0%	0.0%
82	20	2.5	0.0%	0.0%	0.0%
122	20	2.5	0.0%	0.0%	0.0%
163	20	2.5	0.0%	0.0%	0.0%
204	20	2.5	0.0%	0.0%	0.0%
245	20	2.5	0.0%	0.0%	0.0%
286	20	2.5	0.0%	0.0%	0.0%
326	20	2.5	0.0%	0.0%	0.0%
367	20	2.5	0.0%	0.0%	0.0%
408	20	2.5	0.0%	0.0%	0.0%
Weighted Average Potential Runoff			0.0%	0.0%	0.0%

25.4 mm application amount,   408 meters system length
74 hours per revolution

The user can then graph the intake rate and application rate curves for any of three system outputs, three SCS Soil Intake Families, and ten distances from the pivot.

Ex. :

Enter output desired => 50 l/sec   (793 gpm)

1 => 44 l/sec   (693 gpm)
2 => 50 l/sec   (793 gpm)
3 => 56 l/sec   (893 gpm)

Enter system length desired => 408 meters   (1339 feet)

0 => 41 meters (134 feet)
1 => 82 meters (268 feet)
2 => 122 meters (402 feet)
3 => 163 meters (535 feet)
4 => 204 meters (669 feet)
5 => 245 meters (803 feet)
6 => 286 meters (937 feet)
7 => 326 meters (1071 feet)
8 => 367 meters (1205 feet)
9 => 408 meters (1339 feet)

Enter SCS Intake Family Number => 0.5

1 => SCS Intake Family 0.3
2 => SCS Intake Family 0.5
3 => SCS Intake Family 1.0

Hit any key to continue.

A graph will then be presented on the screen displaying the application rate and intake rate curves with potential runoff, using the conditions specified above. System criteria are presented below the graph including the system length, supply rate, soil surface storage, field slope and estimated runoff.

After the graph is drawn, it can be printed by pressing the shift-PrtSc key combination. Press any key to continue when done viewing the graph. Another set of values can be graphed if desired.

Ex. : Graph intake and application rate curves (Y/N) ?

Pressing 'N' will bring up an input table which allows any one of the data inputs to be changed. The table can be printed using the Shift-PrtSc key combination. To change an input value enter the selection number. Entering "9" will exit the program and return to DOS.

Ex.:

1. System length :   1320.0 feet
                                     402.3 meters

2. System output :   800.0 gpm
                                     50.5 l/sec

3. SCS Intake Family :   0.5

4. Sprinkler wetted   20.0 feet
   radius or throw :   6.1 meters

5. Application amount :   1.0 in
                                    25.4 mm

6. Surface storage :   0.1 in
                                    2.5 mm

7. Slope :   3-5%

8. RUN

9. Quit

ENERGY SAVINGS ANALYSIS -

Another option is the Energy Savings Analysis Option.

Ex. :   1. Energy Savings Analysis
         2. Potential Runoff Analysis
         3. End Program

         Enter your choice => 1

The user must then describe the high pressure system and the low pressure system by answering the specific questions for each system. The questions are the same as for the Potential Runoff Analysis.

System length, feet => ? 1340

SLOPE : 0-1% => **1** = 12.70 mm (0.50 in)
SLOPE : 1-3% => **2** = 7.60 mm (0.30 in)
SLOPE : 3-5% => **3** = 2.50 mm (0.10 in)
SLOPE : > 5% => **4** = 0.00 mm (0.00 in)
Enter your own storage amount => **5** = ?.?? mm (?.?? in)

=> ? 4

Sprinkler Package	Suggested Radius of Throw
High Pressure Impact (Constant Spacing)	'H'
High Pressure Impact (Variable Spacing)	12 - 15 m (40 - 50 ft)
Medium Pressure Impact (Variable Spacing)	10 - 14 m (35 - 45 ft)
Low Pressure Impact (Variable Spacing)	6 - 10 m (20 - 35 ft)
Low Pressure Impact (CDS)	6 - 10 m (20 - 35 ft)
Low Pressure Spray (360 degrees)	5 m (16 ft)
Low Pressure Spray (180 degrees)	2 - 3 m (8 - 10 ft)
Ultra Low Spray (LEPA)	1 - 2 m (1 - 3 ft)

Sprinkler radius of throw at end of pivot, feet
(or 'H' for high pressure system) => ? H

Application amount, in => ? 1

System output, gpm => ? 800

SCS Intake Family
Available Families - **1** => 0.1
                    2 => 0.3
                    3 => 0.5
                    4 => 1.0
                    5 => 1.5
                    6 => 2.0
                    7 => 3.0

Choose your family or 'H' for help => 3

Would you like intermediate output to the screen (Y/N) N

Lowered Pressure System Description

System length, feet => ? 1340

SLOPE : 0-1% => **1** = 12.70 mm (0.50 in)
SLOPE : 1-3% => **2** = 7.60 mm (0.30 in)
SLOPE : 3-5% => **3** = 2.50 mm (0.10 in)
SLOPE : > 5% => **4** = 0.00 mm (0.00 in)
Enter your own storage amount => **5** = ?.?? mm (?.?? in)

=> ? 1

Sprinkler Package	Suggested Radius of Throw
High Pressure Impact (Constant Spacing)	'H'
High Pressure Impact (Variable Spacing)	12 - 15 m (40 - 50 ft)
Medium Pressure Impact (Variable Spacing)	10 - 14 m (35 - 45 ft)
Low Pressure Impact (Variable Spacing)	6 - 10 m (20 - 35 ft)
Low Pressure Impact (CDS)	6 - 10 m (20 - 35 ft)
Low Pressure Spray (360 degrees)	5 m (16 ft)
Low Pressure Spray (180 degrees)	2 - 3 m (8 - 10 ft)
Ultra Low Spray (LEPA)	1 - 2 m (1 - 3 ft)

Sprinkler radius of throw at end of pivot, feet
(or 'H' for high pressure system) => ? 16

Application amount, in => ? 1

System output, gpm => ? 800

SCS Intake Family
Available Families - **1** => 0.1
                     2 => 0.3
                     3 => 0.5
                     4 => 1.0
                     5 => 1.5
                     6 => 2.0
                     7 => 3.0

Choose your family or 'H' for help => 3

Would you like intermediate output to the screen (Y/N) N

More descriptions of the high and low pressure systems must be entered. These include pumping lift, pivot operating pressure, and system efficiency.

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Ex. :

Enter depth of lift plus column and distribution pipe friction losses before adjustments, meters => ? 100

Enter depth of lift plus column & distribution pipe friction losses after adjustments, meters => ? 100

Enter pivot pressure before adjustments, kPa => ? 517

Enter pivot pressure after adjustments, kPa => ? 345

Potential runoff before adjustments =   0.0%
Maximum system efficiency = 90.0%
Enter actual efficiency (%) => ? 90

Potential runoff after adjustments =   16.5%
Maximum system efficiency = 73.5%
Enter actual efficiency (%) => ? 70

Energy source :
                    1 - Diesel
                    2 - Gasoline
                    3 - Propane
                    4 - Natural gas
                    5 - Electricity

Enter the energy source (1 - 5) =>

Enter the cost per liter of diesel?   0.22

Enter annual time of operation (hours) ? 750

Two output tables are then generated showing the possible savings (%) under various operating conditions and the system setup before and after changes to the center pivot.

Ex. :

Pressure kPa	Lift meters	Expected Savings	Actual Savings		Before	After
				Pressure	448.2 kPa	206.8 kPa
137.9	53.3	31.9 %	36.2 %	Length	408.4 meters	408.4 meters
137.9	68.6	27.7 %	32.2 %	Flow Rate	50.5 l/sec	50.5 l/sec
137.9	83.8	24.4 %	29.2 %	Lift	68.6 meters	68.6 meters
206.8	53.3	24.8 %	29.5 %	Radius	21.8 meters	4.9 meters
206.8	**68.6**	**21.5 %**	**26.4 %**	Storage	0.0 mm	12.7 mm
206.8	83.8	19.0 %	24.1 %	Application	25.4 mm	25.4 mm
275.8	53.3	17.7 %	22.9 %	Efficiency	75.0 %	80.0 %
275.8	68.6	15.4 %	20.7 %	SCS Intake	0.3	0.3
275.8	83.8	13.6 %	19.0 %	Runoff	11.1 %	3.6 %

Highlighted line indicates conditions specified.

Pressing 'P' will print the tables to the printer. Any other key will allow the user to run the program again.

The expected savings would be the potential savings realized if the efficiency of the system did not change after installing a different sprinkler package and/or lowering the operating pressure. The actual savings calculation takes into account the difference in system efficiency due to an increase in potential runoff or other known factors. If the system efficiency does not change, the expected and actual savings will be identical.