OVERLAP — DEFINITION OF CU

Christiansen's Coefficient of Uniformity (CU) is based on a statistical analysis of sprinkler distribution pattern and calculated with the following formula:

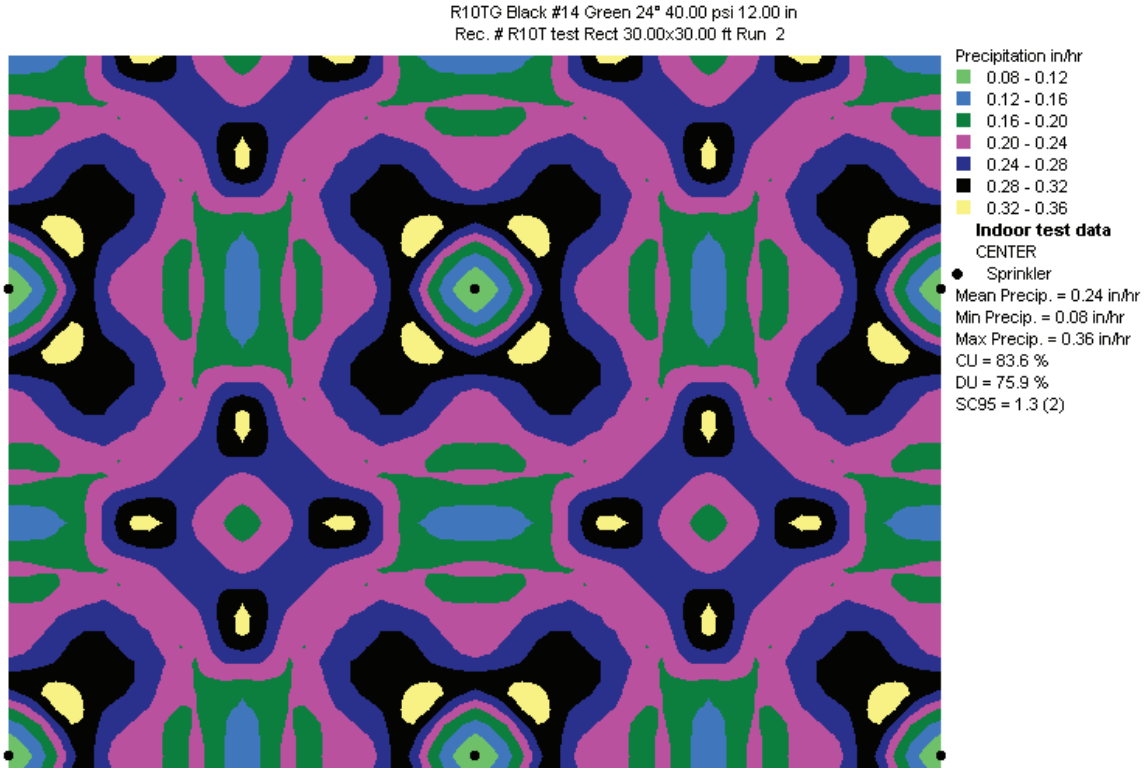
$$CU = 100\left(1 - \frac{D}{M}\right) \qquad D = \frac{1}{n}\sum |X_i - M| \qquad M = \frac{1}{n}\sum X_i$$

where:

CU	=	Christiansen's Coefficient of Uniformity (%)
D	=	Average Absolute Deviation from the Mean
M	=	Mean Application
X_i	=	Individual Application Amounts
n	=	Number of Individual Application Amounts

CU is a widely used measure of uniformity. A higher percentage indicates better uniformity. CU does not always account for the severity of over or under watered areas. The color contour below is a graph that illustrates this with a CU of 83.6% (which is good) however, there are small areas (blue colored) receiving a little more than 1/2 the mean application rate. In conditions in which wind, obstruction, and other environmental factors do not decrease uniformity, CU results from indoor testing can be characterized as follows:

91% +	Unusual and exceptionally high uniformity
84% to 90%	Excellent uniformity
77% to 83%	Good uniformity
70% to 76%	Acceptable for some low value crops
Below 69%	Poor and often not acceptable



OVERLAP — DEFINITION OF DU

Because DU is an indication of the severity of the driest areas, it has become for many the primary measure of uniformity for a sprinkler system. The following formula is used to calculate DU.

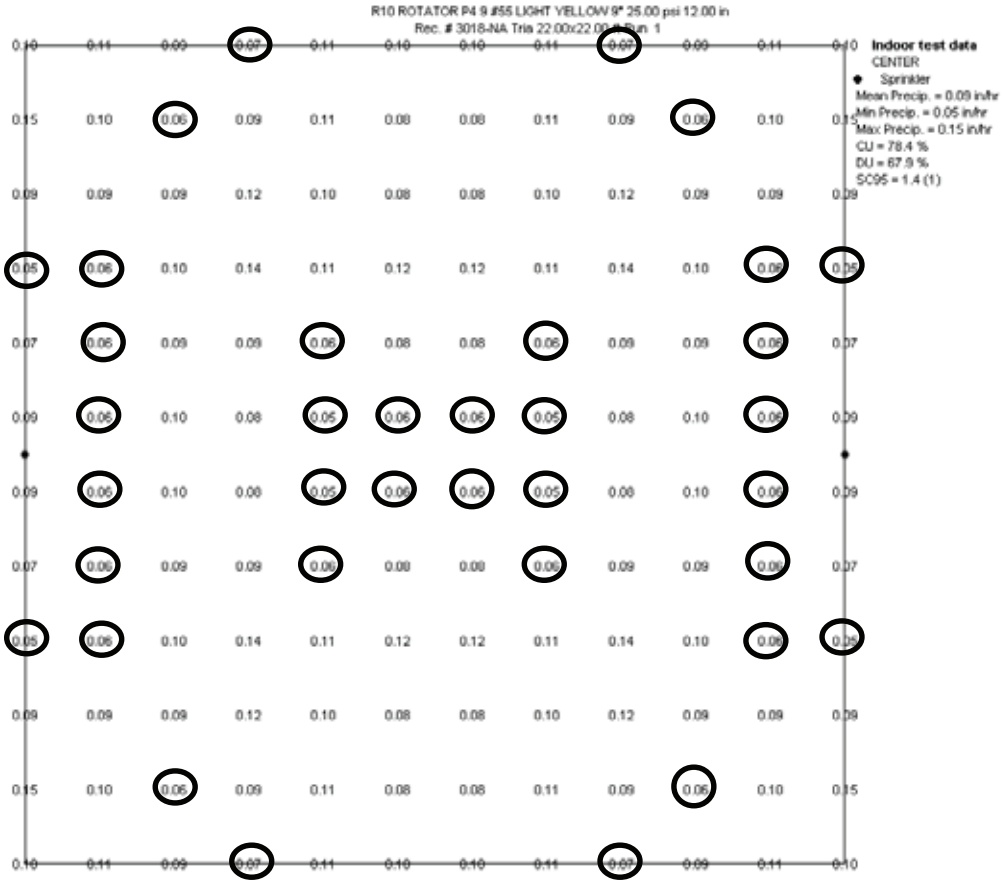
$$DU = 100\left(\frac{L}{M}\right) \qquad L = \frac{1}{n_d}\sum X_d \qquad M = \frac{1}{n}\sum X_i$$

where:

- DU = Distribution Uniformity
- M = Mean Application
- X_i = Individual Application Amounts
- n = Number of Individual Application Amounts
- n_d = n x .25
- X_d = are the n_d Individual Application Amounts in the grid with the lowest values
- L = Mean Application for X_d Application Amounts

A low DU may be misleading if the individual amounts are evenly spread throughout the grid. In the example below the lowest 36 individual amounts (all X_d) used to calculate the DU are circled. In conditions in which wind, obstruction, and other environmental factors do not decrease uniformity, the DU results from indoor testing can be characterized as follows:

86%+	Unusual and exceptionally high uniformity
78 to 85%	Excellent uniformity
70 to 77%	Good uniformity
64 to 69%	Acceptable for some low value crops
Below 65%	Poor



To determine scheduling Coefficient (SC) a sliding window of a specified size finds the lowest contiguous average application rate in the grid. The size of the window is specified by the user. The default is a 5% window which is inputted and indicated on the output as an SC95. For Overlap the user inputs the percentage of the grid not included in the window to specify a window size. (e.g. 90 = 10% window, or 95 = 5% window) The formula for calculating SC is as follows:

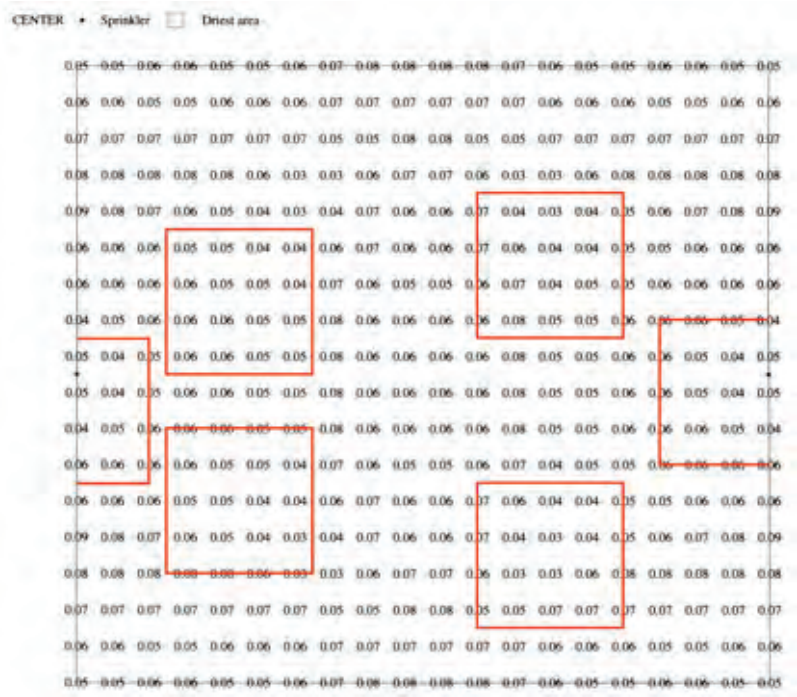
$$SC = \frac{M}{W} \qquad W = \frac{1}{n_w} \sum X_w \qquad M = \frac{1}{n} \sum X_i$$

Where:

- SC = Scheduling Coefficient
- M = Mean Application rate
- X_i = Individual Application Amounts
- n = Number of Individual Application Amounts
- S = Percentage of area of the grid not included in the scheduling coefficient window
- n_w = Number of Individual Application Amounts in the SC window or n(100-S)/100
- X_w = A total of n_w Individual Application Amounts that are contiguous in rectangular or square configuration which together have the lowest mean.
- W = Mean of all X_w

The red boxes in the figure below indicate the locations in the grid from which the SC has been calculated. In the example below the result is: SC95 1.2 (5) which means the Scheduling Coefficient is 1.2, the window size is 5% of the grid and the window can be located in 5 different locations each of which contain individual application amounts that together have the lowest possible mean. Use the SC to ensure that all areas of a field receive a certain quantity of water, by dividing that quantity by the mean application rate and then multiplying by the SC to determine the system run time.

Sprinkler:	R2000 Rotator
Model:	K2 9
Trajectory:	9
Nozzle:	#8.3 GRAY
Pressure:	45 PSI
Flow:	0.82 gpm
Riser Ht.:	12.00 inches
Mins/Rev:	1.23
Stream Ht.:	0.00 ft
Record #:	820-CA
Offset:	
Spacing:	38.00 x 34.00 ft
Layout:	Rect
Theor Precip:	0.06 in/hr
	27.6 gpm/acre
% Overlap	66%
Area/Sprinkler:	1292.00 ft2
CU:	84%
DU:	73.9%
SC (95):	1.2(5)
Mean Precip.:	0.06 in/hr
Min. Precip.:	0.03 in/hr
Max. Precip.:	0.09 in/hr



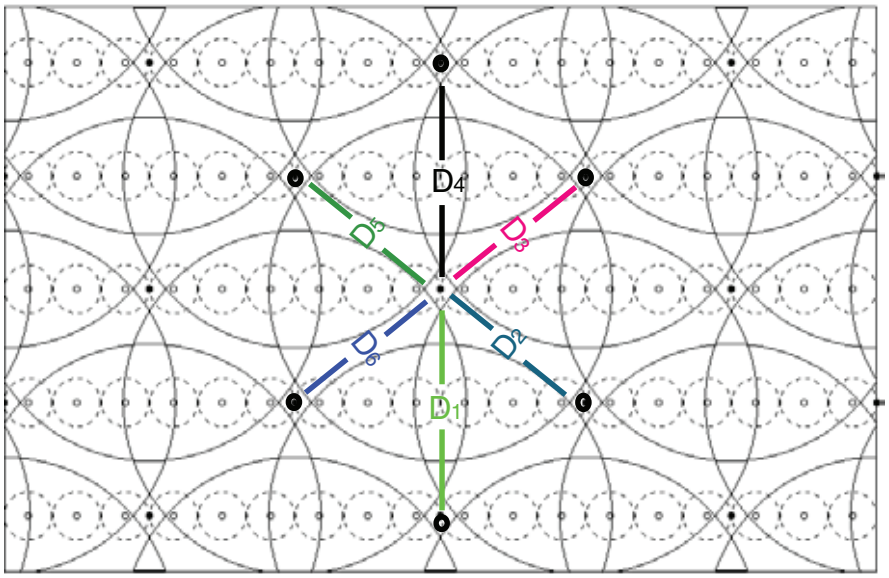
OVERLAP — DEFINITION OF % OVERLAP

% overlap indicates the amount of sprinkler to sprinkler overlap for a given spacing. The following formula is used to calculate % overlap

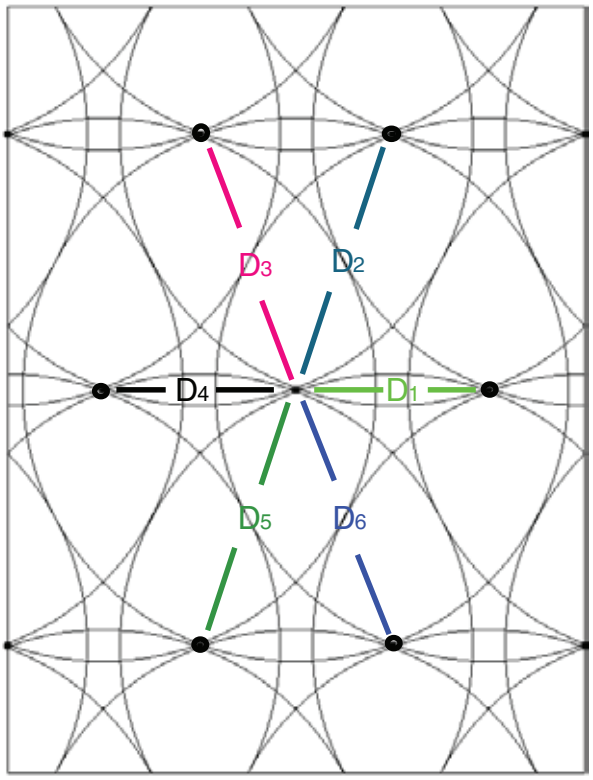
$$\% \text{ Overlap} = \frac{R}{D} \qquad D = \frac{1}{6} \sum D_i$$

Where:
- D = Mean distance of six closest sprinklers.
- R = Radius of Sprinkler
- Di = Distance to nearest sprinkler (always a total of 6 sprinklers)

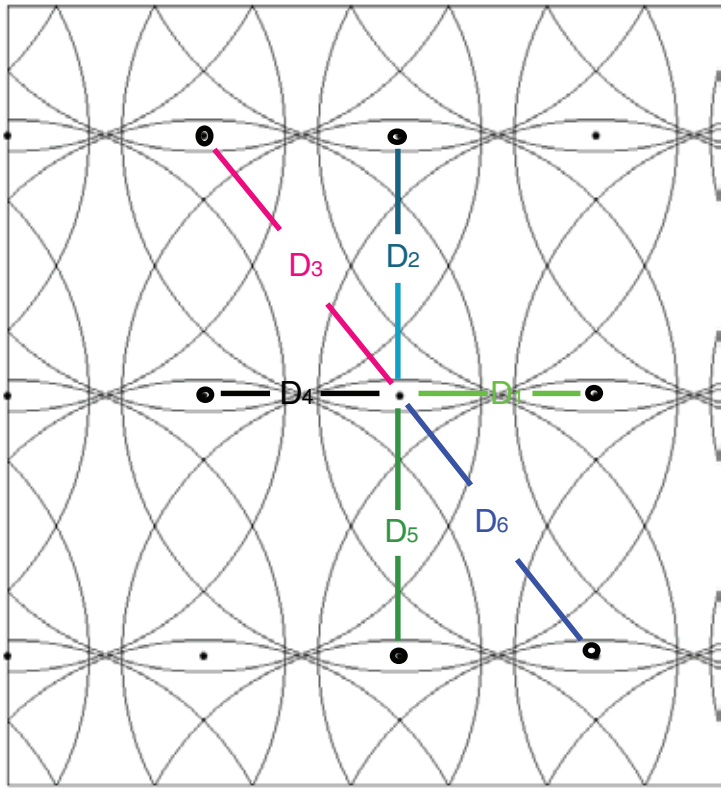
Example of 6 closest sprinklers for a 36 x 14 triangular pattern



Example of 6 closest sprinklers for a 30 x 40 triangular pattern



Example of 6 closest sprinklers for a 30 x 40 rectangular pattern



Why is % Overlap important?

Percent Overlap is especially useful when using overlaps created from indoor testing which can lull a designer into a false sense of security. Because of the influence of wind, obstruction, slope, vibration, tilted risers and other things, actual uniformity will be poor compared to that which is predicted by an overlap analysis if % Overlap is too low. Increasing the % Overlap is very often like buying a better insurance policy for the uniformity of a sprinkler system. For sprinkler irrigation of most agricultural crops the cost of poor uniformity is very high. The additional costs of designing a system such that it has 95 to 105% overlap will be recovered from better yield and quality in one to two years of production.

Here are some basic suggestions on the minimum % Overlap to use:

Crop types:	**(% Overlap from Indoor tests)**
Containerized ornamental crops	110%+
High density tree (600+ trees/acre) or high value vegetable crops	100%+
Medium density tree crops (150+ trees/acre) -- forage and grain crops	90 to 100%
Low density tree crops (less than 150 trees/acre)	85 to 95%
Special considerations:	
Wind above 8 miles per hour	100%+
Low angle sprinklers on slope above 5%	100%+
When using Flow Control nozzles in Rotators	100%+

Nelson Irrigation Corp. 848 Airport Rd. Walla Walla, WA 99362-2271 USA Tel: 509.525.7660 Fax: 509.525.7907 E-mail: info@nelsonirrigation.com Web site: www.nelsonirrigation.com

A few examples of the most commonly used Overlap outputs follow this page in the order they are listed below:

Color Contour

Densogram

Wetted Radius

Table

OVERLAP — COLOR CONTOURS

Contour diagrams are available for precipitation rate, depth applied in a given time and the time taken to apply a given depth of water.

These diagrams are the same as height (elevation) contours on a map. Each color shows a certain range of precipitation rate, depth or time. A key along the side or top of the diagram shows the range each color represents.

The colors and ranges to be used can be set up by choosing the **Options/Colors** part of the menu. Note that the top box under precipitation rate and depth reads 0.00, this cannot be edited. In the case of precipitation rate and depth, the value entered into a box gives the lower end of the range associated with the color in the box along side it.
The lower end of a range is the value shown in the box to the right of the particular color. The upper end of a range is the value contained in the box below and to the right of the color box.

Color Contours-Full Contours
In the case of time, the top box can be edited; the value in a box to the right shows the maximum time for the area in the color concerned, while that below shows the lower end of the time range associated with a certain color. Colors can be customized to your particular requirement; select colors in the **Options** menu of output in the **Display** menu.

Color contours provide quantitative information on the variation of precipitation rate within an area. This output is particularly valuable when used in conjunction with the display of tree root zones or target strips along the tree row. The variation from root zone to root zone can be determined, (refer to, “Using Trees & Strips”). Please note that the printed output provides numerical information on tree-to-tree variations and that associated with strips; this can be used in association with the visual presentations provided by Color Contours. Also, if you wish to obtain information relating to specific points in an area of interest, the grid data output should be viewed (refer to “Grid”).

The time option can be used to determine the variation in time requirements for applying a certain depth of irrigation water. This is just one of the Overlap outputs that can be used by a designer or manager to determine run times for the irrigation system.

Depth allows you to determine the variation in depth of water, applied over a given time. This allows you to see if areas of crop or individual trees are receiving sufficient water.

Another potential use, for this and some other outputs, concerns the placement of moisture measuring devices. It is possible, for example, to identify where mean rates are falling or, if required, where higher or lower rate areas are represented.