All too often, problems with sprinkler coverage come to light when the turf is faced with drought conditions.

Irrigation Design, Rocket Science, and the *SPACE* Program

Selecting sprinklers and determining the spacing is not rocket science. Not when using the SPACE program to model coverage and distribution.

by MIKE HUCK

IT DOESN'T TAKE a rocket scientist to determine that the effectiveness and efficiency of an irrigation system is more greatly influenced by the distribution uniformity of complementing sprinklers than the high-tech computer controlling the system. In this era of space-age technology, countless dollars and hours are spent evaluating and installing state-of-the-art irrigation control systems that turn water off and on with split-second accuracy. At the same time, however, very little time or effort is invested in evaluating the actual performance of sprinklers, spacings, and nozzle combinations. All too often problems with sprinkler coverage are not identified until it is too late, after they are buried in the field. With the price of new irrigation systems exceeding a million dollars, a very frustrating and embarrassing situation can arise if after a new irrigation system is installed the turf is still plagued with wet spots, dry spots, or, even worse yet, donuts.

Sprinkler performance has long been evaluated with statistical calculations such as Christiansen's Coefficient of Uniformity (CU) and Distribution Uniformity (DU). Both CU and DU are estimates of complementing sprinklers' application uniformity that were originally developed to evaluate agricultural irrigation. The ideal CU or DU is 100%; however, this is unattainable because even rainfall does not fall with 100% uniformity. A closer examination of CU and DU reveals why they alone do not guarantee success with regard to evaluating turfgrass irrigation. This is due to their methods of evaluating the under- and over-watered areas.

CU: Christiansen's Coefficient of Uniformity

The CU statistically analyzes the sprinkler pattern for uniformity based on an average of the entire area. It treats over-watered and under-watered areas in the same way. Since it is an average, it offers no indication of how poor the coverage may be in localized areas.

CU = 100 (1-D/M)

D = (1/N) 3 *Xi - M*

M = (1/N) 3 Xi

Where: CU = Christiansen's Coefficient of Uniformity (%)

D = Average Absolute Deviation

M = Mean Application

Xi = Individual Application Amounts

N = Number of Individual Application Amounts

3 = Symbol for summation

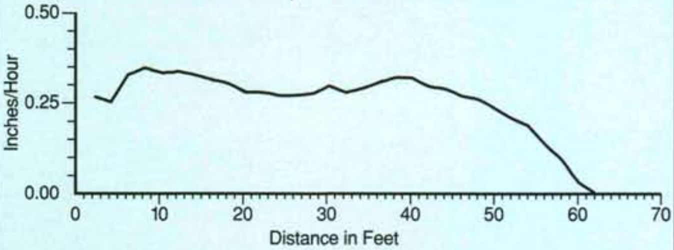
* * = Symbol for absolute value of quantity between the bars

Irrigation Efficiency Analysis
Poor Coverage Example

Sprinkler Name: Poor Coverage
Sprinkler Model: A3
Nozzle Size: A3
Flow Rate (gpm): 34.00
Date/Time of Test: 02/01/91 02:41
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 1.30
Record Number: 1003

Sprinkler Radius of Throw per ASAE Standard S398.1: 61 Feet



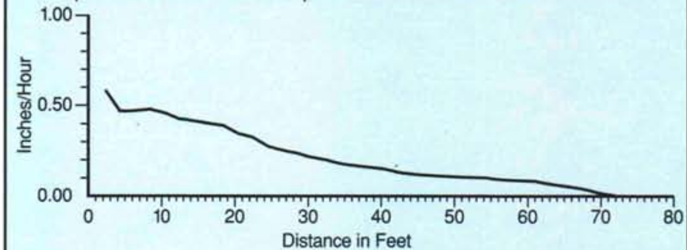
2.0' = 0.265	18.0' = 0.302	34.0' = 0.288	50.0' = 0.236
4.0' = 0.250	20.0' = 0.279	36.0' = 0.307	52.0' = 0.208
6.0' = 0.326	22.0' = 0.279	38.0' = 0.321	54.0' = 0.189
8.0' = 0.345	24.0' = 0.269	40.0' = 0.321	56.0' = 0.137
10.0' = 0.331	26.0' = 0.269	42.0' = 0.295	58.0' = 0.092
12.0' = 0.335	28.0' = 0.274	44.0' = 0.288	60.0' = 0.033
14.0' = 0.326	30.0' = 0.295	46.0' = 0.269	
16.0' = 0.312	32.0' = 0.279	48.0' = 0.260	

Irrigation Efficiency Analysis
Good Coverage Example

Sprinkler Name: Good Coverage
Sprinkler Model: A1
Nozzle Size: A1
Flow Rate (gpm): 25.00
Date/Time of Test: 02/01/91 12:47
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 3.00
Record Number: 1001

Sprinkler Radius of Throw per ASAE Standard S398.1: 71 Feet



2.0' = 0.585	22.0' = 0.327	42.0' = 0.132	62.0' = 0.076
4.0' = 0.468	24.0' = 0.278	44.0' = 0.122	64.0' = 0.061
6.0' = 0.468	26.0' = 0.254	46.0' = 0.117	66.0' = 0.049
8.0' = 0.478	28.0' = 0.239	48.0' = 0.112	68.0' = 0.034
10.0' = 0.459	30.0' = 0.215	50.0' = 0.107	70.0' = 0.015
12.0' = 0.424	32.0' = 0.200	52.0' = 0.107	
14.0' = 0.415	34.0' = 0.180	54.0' = 0.102	
16.0' = 0.400	36.0' = 0.171	56.0' = 0.093	
18.0' = 0.390	38.0' = 0.159	58.0' = 0.088	
20.0' = 0.346	40.0' = 0.151	60.0' = 0.088	

The Profile Report shows graphically and quantitatively the precipitation amounts and their relative distance from the sprinkler to the terminal point that the water is thrown.

Irrigation Efficiency Analysis
Uniformity Evaluation
Poor Coverage Example

Sprinkler Name: Poor Coverage
Sprinkler Model: A3
Nozzle Size: A3
Flow Rate (gpm): 34.00
Date/Time of Test: 02/01/91 02:41
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 1.30
Record Number: 1003

Distr. Uniformity: 76% CU (Christiansen): 88% Sched. Coeff. (5%): 2.2	Min. (In./Hr.): 0.253 Mean (In./Hr.): 0.762 0.895 (Theor.) Max. (In./Hr.): 0.952	Spacing Equilateral 65.0' × 56.3'

Data Grid in 0.001 Inches/Hour

265	257	283	416	468	555	602	635	708	738	754	786	807	834	843	852	831	831	852	843	834	807	786	754	738	708	635	602	555	468	416	283	257	265
257	253	311	473	541	605	647	675	702	718	725	748	800	826	834	843	819	819	843	834	826	800	748	725	718	702	675	647	605	541	473	311	253	257
286	364	413	522	576	643	687	716	745	752	755	770	778	800	806	814	783	783	814	806	800	778	770	755	752	745	716	687	643	576	522	413	364	286
446	438	463	547	616	683	718	734	756	764	775	791	801	828	839	840	811	811	840	839	828	801	791	775	764	756	734	718	683	616	547	463	438	446
540	528	493	583	643	690	727	748	771	781	796	811	820	851	867	859	838	838	859	867	851	820	811	796	781	771	748	727	690	643	583	493	528	540
608	610	594	591	648	696	740	761	777	799	807	819	830	855	883	868	856	856	868	883	855	830	819	807	799	777	761	740	696	648	591	594	610	608
685	664	645	665	686	698	750	759	776	802	811	828	846	874	901	887	882	882	887	901	874	846	828	811	802	776	759	750	698	686	665	645	664	685
721	710	689	668	726	729	731	754	783	807	822	836	856	883	900	902	904	904	902	900	883	856	836	822	807	783	754	731	729	726	668	689	710	721
743	745	735	706	741	749	722	764	780	803	829	847	882	900	911	930	940	940	930	911	900	882	847	829	803	780	764	722	749	741	706	735	745	743
770	764	752	731	753	778	784	757	781	815	846	868	893	893	906	938	952	952	938	906	893	893	868	846	815	781	757	784	778	753	731	752	764	770
787	776	765	762	777	792	807	822	790	814	845	874	867	880	894	924	945	945	924	894	880	867	874	845	814	790	822	807	792	777	762	765	776	787
806	802	793	775	766	818	832	840	834	805	837	842	846	861	884	901	927	927	901	884	861	846	842	837	805	834	840	832	818	766	775	793	802	806
816	820	809	803	797	827	844	842	852	827	796	812	834	852	877	893	904	904	893	877	852	834	812	796	827	852	842	844	827	797	803	809	820	816
838	831	840	836	817	796	850	852	840	822	773	801	838	865	885	902	895	895	902	885	865	838	801	773	822	840	852	850	796	817	836	840	831	838
859	863	867	862	841	815	824	833	823	833	824	815	841	862	867	863	859	859	863	867	862	841	815	824	833	823	833	824	815	841	862	867	863	859
895	902	885	865	838	801	773	822	840	852	850	796	817	836	840	831	838	838	831	840	836	817	796	850	852	840	822	773	801	838	865	885	902	895
904	893	877	852	834	812	796	827	852	842	844	827	797	803	809	820	816	816	820	809	803	797	827	844	842	852	827	796	812	834	852	877	893	904
927	901	884	861	846	842	837	805	834	840	832	818	766	775	793	802	806	806	802	793	775	766	818	832	840	834	805	837	842	846	861	884	901	927
945	924	894	880	867	874	845	814	790	822	807	792	777	762	765	776	787	787	776	765	762	777	792	807	822	790	814	845	874	867	880	894	924	945
952	938	906	893	893	868	846	815	781	757	784	778	753	731	752	764	770	770	764	752	731	753	778	784	757	781	815	846	868	893	893	906	938	952
940	930	911	900	882	847	829	803	780	764	722	749	741	706	735	745	743	743	745	735	706	741	749	722	764	780	803	829	847	882	900	911	930	940
904	902	900	883	856	836	822	807	783	754	731	729	726	668	689	710	721	721	710	689	668	726	729	731	754	783	807	822	836	856	883	900	902	904
882	887	901	874	846	828	811	802	776	759	750	698	686	665	645	664	685	685	664	645	665	686	698	750	759	776	802	811	828	846	874	901	887	882
856	868	883	855	830	819	807	799	777	761	740	696	648	591	594	610	608	608	610	594	591	648	696	740	761	777	799	807	819	830	855	883	868	856
838	859	867	851	820	811	796	781	771	748	727	690	643	583	493	528	540	540	528	493	583	643	690	727	748	771	781	796	811	820	851	867	859	838
811	840	839	828	801	791	775	764	756	734	718	683	616	547	463	438	446	446	438	463	547	616	683	718	734	756	764	775	791	801	828	839	840	811
783	814	806	800	778	770	755	752	745	716	687	643	576	522	413	364	286	286	364	413	522	576	643	687	716	745	752	755	770	778	800	806	814	783
819	843	834	826	800	748	725	718	702	675	647	605	541	473	311	253	257	257	253	311	473	541	605	647	675	702	718	725	748	800	826	834	843	819
831	852	843	834	807	786	754	738	708	635	602	555	468	416	283	257	265	265	257	283	416	468	555	602	635	708	738	754	786	807	834	843	852	831

Critical 5% Window Size

Mean In./Hr.: 0.762
Min. Window In./Hr.: 0.343
Max. Window In./Hr.: 0.905

Sched. Coefficient: 2.2
Min. Window % of Mean: 45%
Max. Window % of Mean: 119%

Window Size 7 × 7: 179 ft²

Irrigation Efficiency Analysis
Uniformity Evaluation
Good Coverage Example

Sprinkler Name: Good Coverage
Sprinkler Model: A1
Nozzle Size: A1
Flow Rate (gpm): 25.00
Date/Time of Test: 02/01/91 12:47
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 3.00
Record Number: 1001

Distr. Uniformity: 84% CU (Christiansen): 89% Sched. Coeff. (5%): 1.2	Min. (In./Hr.): 0.477 Mean (In./Hr.): 0.613 0.658 (Theor.) Max. (In./Hr.): 0.915	Spacing Equilateral 65.0' × 56.3'

Data Grid in 0.001 Inches/Hour

915	854	787	768	751	717	699	695	686	679	644	634	602	593	589	578	574	574	578	589	593	602	634	644	679	686	695	699	717	751	768	787	854	915
851	792	780	755	748	727	706	686	681	675	646	636	606	599	594	582	578	578	582	594	599	606	636	646	675	681	686	706	727	748	755	780	792	851
786	770	766	756	744	720	710	695	673	660	637	621	595	591	586	575	571	571	575	586	591	595	621	637	660	673	695	710	720	744	756	766	770	786
754	769	752	745	728	715	712	697	682	637	619	595	574	573	566	558	553	553	558	566	573	574	595	619	637	682	697	712	715	728	745	752	769	754
751	748	725	725	709	707	703	691	670	630	602	569	555	559	550	544	538	538	544	550	559	555	569	602	630	670	691	703	707	709	725	725	748	751
732	725	702	702	692	681	685	680	645	622	591	544	536	541	532	528	522	522	528	532	541	536	544	591	622	645	680	685	681	692	702	702	725	732
715	707	693	696	690	681	676	647	615	594	550	536	514	514	511	508	501	501	508	511	514	514	536	550	594	615	647	676	681	690	696	693	707	715
708	698	682	686	683	684	661	636	616	578	547	525	492	484	488	481	479	479	481	488	484	492	525	547	578	616	636	661	684	683	686	682	698	708
693	684	677	682	671	653	645	635	602	568	551	538	516	487	491	487	488	488	487	491	487	516	538	551	568	602	635	645	653	671	682	677	684	693
669	650	654	653	644	636	631	615	595	576	563	546	523	504	481	487	486	486	487	481	504	523	546	563	576	595	615	631	636	644	653	654	650	669
628	616	627	635	638	617	603	603	596	583	563	544	530	510	477	485	487	487	485	477	510	530	544	563	583	596	603	603	617	638	635	627	616	628
601	592	596	603	604	603	595	591	594	584	563	549	533	514	499	478	486	486	478	499	514	533	549	563	584	594	591	595	603	604	603	596	592	601
540	553	564	579	595	597	590	587	584	581	568	551	537	528	515	500	490	490	500	515	528	537	551	568	581	584	587	590	597	595	579	564	553	540
519	536	555	569	581	591	587	576	574	578	576	561	550	541	527	512	485	485	512	527	541	550	561	576	578	574	576	587	591	581	569	555	536	519
506	529	546	554	563	574	579	575	575	575	579	574	563	554	546	529	506	506	529	546	554	563	574	579	575	575	575	579	574	563	554	546	529	506
485	512	527	541	550	561	576	578	574	576	587	591	581	569	555	536	519	519	536	555	569	581	591	587	576	574	578	576	561	550	541	527	512	485
490	500	515	528	537	551	568	581	584	587	590	597	595	579	564	553	540	540	553	564	579	595	597	590	587	584	581	568	551	537	528	515	500	490
486	478	499	514	533	549	563	584	594	591	595	603	604	603	596	592	601	601	592	596	603	604	603	595	591	594	584	563	549	533	514	499	478	486
487	485	477	510	530	544	563	583	596	603	603	617	638	635	627	616	628	628	616	627	635	638	617	603	603	596	583	563	544	530	510	477	485	487
486	487	481	504	523	546	563	576	595	615	631	636	644	653	654	650	669	669	650	654	653	644	636	631	615	595	576	563	546	523	504	481	487	486
488	487	491	487	516	538	551	568	602	635	645	653	671	682	677	684	693	693	684	677	682	671	653	645	635	602	568	551	538	516	487	491	487	488
479	481	488	484	492	525	547	578	616	636	661	684	683	686	682	698	708	708	698	682	686	683	684	661	636	616	578	547	525	492	484	488	481	479
501	508	511	514	514	536	550	594	615	647	676	681	690	696	693	707	715	715	707	693	696	690	681	676	647	615	594	550	536	514	514	511	508	501
522	528	532	541	536	544	591	622	645	680	685	681	692	702	702	725	732	732	725	702	702	692	681	685	680	645	622	591	544	536	541	532	528	522
538	544	550	559	555	569	602	630	670	691	703	707	709	725	725	748	751	751	748	725	725	709	707	703	691	670	630	602	569	555	559	550	544	538
553	558	566	573	574	595	619	637	682	697	712	715	728	745	752	769	754	754	769	752	745	728	715	712	697	682	637	619	595	574	573	566	558	553
571	575	586	591	595	621	637	660	673	695	710	720	744	756	766	770	786	786	770	766	756	744	720	710	695	673	660	637	621	595	591	586	575	571
578	582	594	599	606	636	646	675	681	686	706	727	748	755	780	792	851	851	792	780	755	748	727	706	686	681	675	646	636	606	599	594	582	578
574	578	589	593	602	634	644	679	686	695	699	717	751	768	787	854	915	915	854	787	768	751	717	699	695	686	679	644	634	602	593	589	578	574

Critical 5% Window Size

Mean In./Hr.: 0.613
Min. Window In./Hr.: 0.493
Max. Window In./Hr.: 0.797

Sched. Coefficient: 1.2
Min. Window % of Mean: 80%
Max. Window % of Mean: 130%

Window Size 7 × 7: 179 ft²

The Grid Listing Report analyzes the synthesized numeric coverage of a sprinkler overlap pattern.

DU: Distribution Uniformity

DU represents the average of the lowest 25% of the application rates in the sprinkler pattern divided by the average application rate of the entire pattern. This method sorts all values from the lowest to highest; the average of the lowest 25% of catchments is then divided by the mean value of the entire area. This method, however, does not take into account the location of the individual values or any benefit that may be derived from values immediately adjacent to the low values. In other words, the lowest 25% of catchments could be dispersed throughout the pattern and not necessarily be in the same localized area. Therefore, a benefit may be derived from an over-watered area immediately adjacent to an under-watered location.

$$DU = 100(1-[LQ/M])$$

Where:

DU = Distribution Uniformity (%)

LQ = Average of the Lowest ¼ of the Irrigation Amounts

M = Average of the Irrigation Amounts

Golf course irrigation designers recognize that sprinklers with high CU or DU ratings could still develop significant wet or dry areas when irrigating turf. This, in turn, required many designers to rely upon past field experience when selecting sprinklers and appropriate spacings. Now, however, the advent of the personal computer has created another method. Sprinklers now can be evaluated before they are installed in the field with the SPACE program. No, this has nothing to do with rocket science; SPACE is an acronym for *Sprinkler Profile And Coverage Evaluation.* The SPACE program is personal computer software developed by the Center for Irrigation Technology (CIT), at the California State University, Fresno, California.

Capabilities of SPACE

Using the SPACE program, one can evaluate the distribution and uniformity of sprinklers either at one's own site or, for a small fee, in the CIT laboratory. This is accomplished through a combined analysis of statistical, numerical, and graphic data, all based on the actual application of water collected from one sprinkler. This can be accomplished before installing the equipment in the field.

The SPACE program is capable of evaluating two distinctly different types of data. The first type of evaluation is known as a single-leg profile analysis, while the second is a grid analysis. The single-leg profile analysis is used when a sprinkler is being selected either for a new system design or for a retrofit or upgrade of an existing system. The single-leg profile data are then used to create overlaps and reports that simulate how one can expect the sprinkler to perform in the field. The grid analysis is used to field audit the efficiency of existing systems or examine wind effects on a single sprinkler. By following a step-by-step procedure, a great deal can be learned about an existing or proposed system.

Single-Leg Profile, Overlaps, Multiple Spacing Analysis, and Associated Reports

Creating a Single-Leg Profile: To create a single-leg profile, raw data from a single sprinkler are collected from a single row of catchments placed in a straight line on 1-foot or 2-foot intervals from the sprinkler outward. The sprinkler is operated at a specified pressure for a period of time sufficient to collect a representative amount of water in each catchment. The water in each catchment is measured to the nearest hundredth of an inch and entered into the computer. The time the sprinkler is allowed to run (in minutes), along with other data such as sprinkler make, model, nozzle size, operating pressure, flow rate (gpm), arc (degrees of rotation), test date, and minutes per revolution, are collected to become part of the test record.

Overlaps: Once a profile has been developed, overlaps can be generated with SPACE. Overlaps simulate performance and coverage using the single-leg profile data, based on spacings and configurations determined by the computer operator. Spacings of up to 100 feet can be selected, with available configurations including square, rectangular, triangular, equilateral triangles, offset rows, single row, and single head.

Reports: Once an overlap is generated, a variety of information can be viewed from the monitor or printed as individual one-page reports. Profile, Grid Listing, Densogram, Histogram, Sliding Window, and Multiple Spacing reports are available.

Profile Report: The profile report represents both graphically and numerically the water collected in the single row of catchments. The graphic portion represents the accumulation of water plotted on an X- and Y-axis. By studying this graphic, areas of low and high precipitation can be observed as to their relative positioning from the sprinkler to the terminal point that water is thrown. Quantitative data for each catchment are also represented in inches per hour and reported numerically with a reference for the location of each catchment in the row. The most ideal profile for turfgrass irrigation is wedge shaped, as this will deliver the most uniform distribution when overlapped at a proper spacing. The wedge-shaped pattern is also the most forgiving and maintains more uniform coverage where slight spacing adjustments are required around greens, bunkers, and trees.

Grid Listing Report: Numeric data representing the overlapped pattern are termed a grid listing. A table of numbers represents each calculated value of the simulated catchments within the overlap matrix. Each number depicts the amount of water applied within that area when the sprinklers are spaced at the selected distance and configuration. All data are represented in inches per hour.

Histogram Report: The histogram report is a bar graph depicting the application rates of each data point from the overlap, categorizing them from 100% below the mean to 100% above the mean in 5% increments. This report represents graphically both the percent variation from the mean and the number of simulated catchments falling into each range. The most ideal results are represented by the least variance from the mean application in both categories.

Densogram Reports: The densogram report is a two-dimensional dot matrix graphic of the grid listing showing the relative wet and dry areas within the pattern. Darker areas represent wetter portions, and lighter areas represent drier portions of the overlap. Perfect uniformity would be represented by a uniformly shaded printout.

Sliding Windows Report: The sliding window examines a 1%, 5%, and 10% area of the overlap pattern in both its wettest and driest locations. Values for mean inches per hour, minimum window inches per hour, minimum window percent of mean, maximum window inches per hour, maximum window percent of mean, and scheduling coefficient are calculated for each size window.

Mean Inches Per Hour: This value is the average application rate of the entire pattern. Each catchment in the entire pattern is added together and divided by the total number of catchments.

Minimum Window Inches Per Hour: This value represents the area of the pattern that receives the lowest application rate. The value listed is the lowest average of catchments found in the selected window size.

Minimum Window Percent of Mean: This value is the percentage of the mean application rate of the entire pattern that the average application rate of the catchments in the window size receive in the area receiving the lowest application rate.

Maximum Window Inches Per Hour: This value represents the area of the pattern that gets the highest application rate. The value listed is the highest average of catchments found in the selected window size.

Maximum Window Percent of Mean: This value is the percentage of the mean application rate of the entire pattern that the average application rate of the catchments in the window size receive in the area receiving the highest application rate.

Scheduling Coefficient: This value is the mean application rate of the pattern area, divided by the average application rate found in the driest window area. The scheduling coefficient is used as a run time multiplier as it relates to the driest portion of the entire pattern. This is based on the value 1.0 being perfection. (A 1.0 is impossible to obtain, as even rain does not fall this uniformly!)

Multiple Spacings Analysis: The SPACE program has other capabilities, including that it can (1) evaluate a given sprinkler over a range of spacings, (2) examine which spacing is most efficient, and (3) determine how performance will suffer where adjustments in spacing must be made. A series of values are calculated by the computer based upon the range of spacings selected by the computer operator. The result is a graph that plots continuous values for the Scheduling Coefficient (SC), Coefficient of Uniformity (CU), and Distribution Uniformity (DU) and can be displayed or printed as a report. Numerical data listing the spacings, CU, DU, SC (based on a 5% window), minimum inches per hour, mean inches per hour, theoretical inches per hour (based on gpm of sprinkler, configuration, and spacing), and maximum inches per hour are also provided. The program selects the best spacing based upon the lowest SC.

Grid Analysis and Associated Reports

A grid analysis is a combination of graphic and data reports based upon a conventional catch-can test. Grid analysis can be performed for two different evaluations. The first is to performance test or audit an existing irrigation system. This test determines the system's overall efficiency. The second is where a single sprinkler is tested to use this data in generating overlaps. (This can demonstrate the effects of wind on the pattern of a single sprinkler.) The overlaps that follow this test are similar to those of the single-leg profiles discussed earlier, with the exception that raw data are gathered from the entire area influenced by the sprinkler as opposed to a profile.

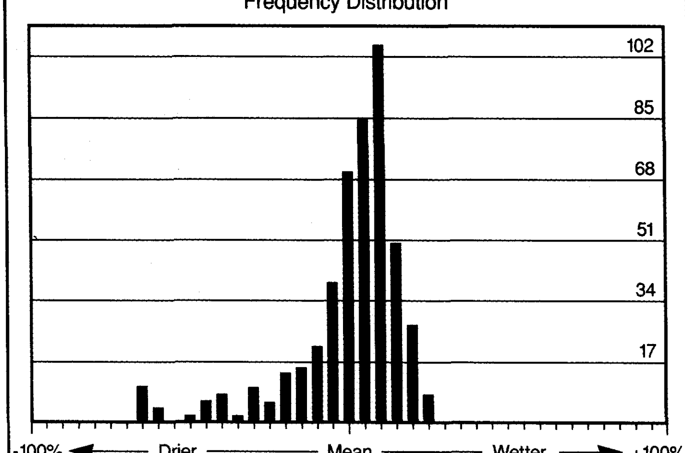
Grid Analysis of an Existing System: Data collection for grid analysis of an existing system begins with the layout of catchments between two rows of sprinklers. The catchments are laid out in square arrangements, at a predetermined distance, uniformly spaced throughout the area influenced by the

Irrigation Efficiency Analysis
Uniformity Evaluation
Poor Coverage Example

Sprinkler Name: Poor Coverage — Base Pressure (psi): 80.0
Sprinkler Model: A3 — Riser Height (inches): 0.0
Nozzle Size: A3 — Set Screw Setting: 0
Flow Rate (gpm): 34.00 — Degree of Arc: 360
Date/Time of Test: 02/01/91 02:41 — Minutes/Revolution: 1.30
Testing Facility: User Created — Record Number: 1003
Comment:

Distr. Uniformity: 76% CU (Christiansen): 88% Sched. Coeff. (5%): 2.2	Min. (In./Hr.): 0.253 Mean (In./Hr.): 0.762 0.895 (Theor.) Max. (In./Hr.): 0.952	Spacing Equilateral 65.0' × 56.3'

Frequency Distribution

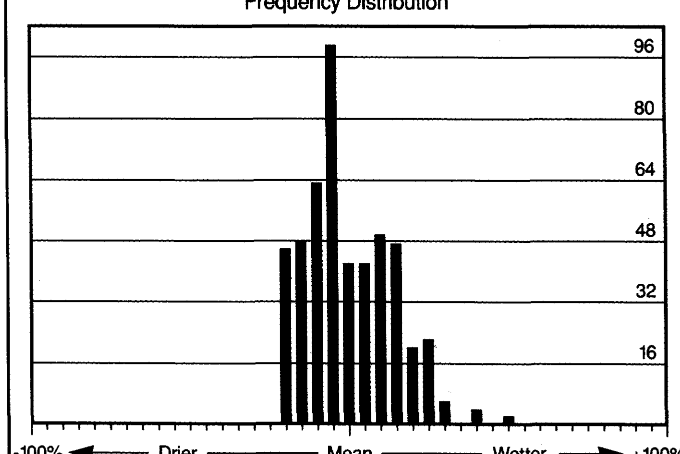


Irrigation Efficiency Analysis
Uniformity Evaluation
Good Coverage Example

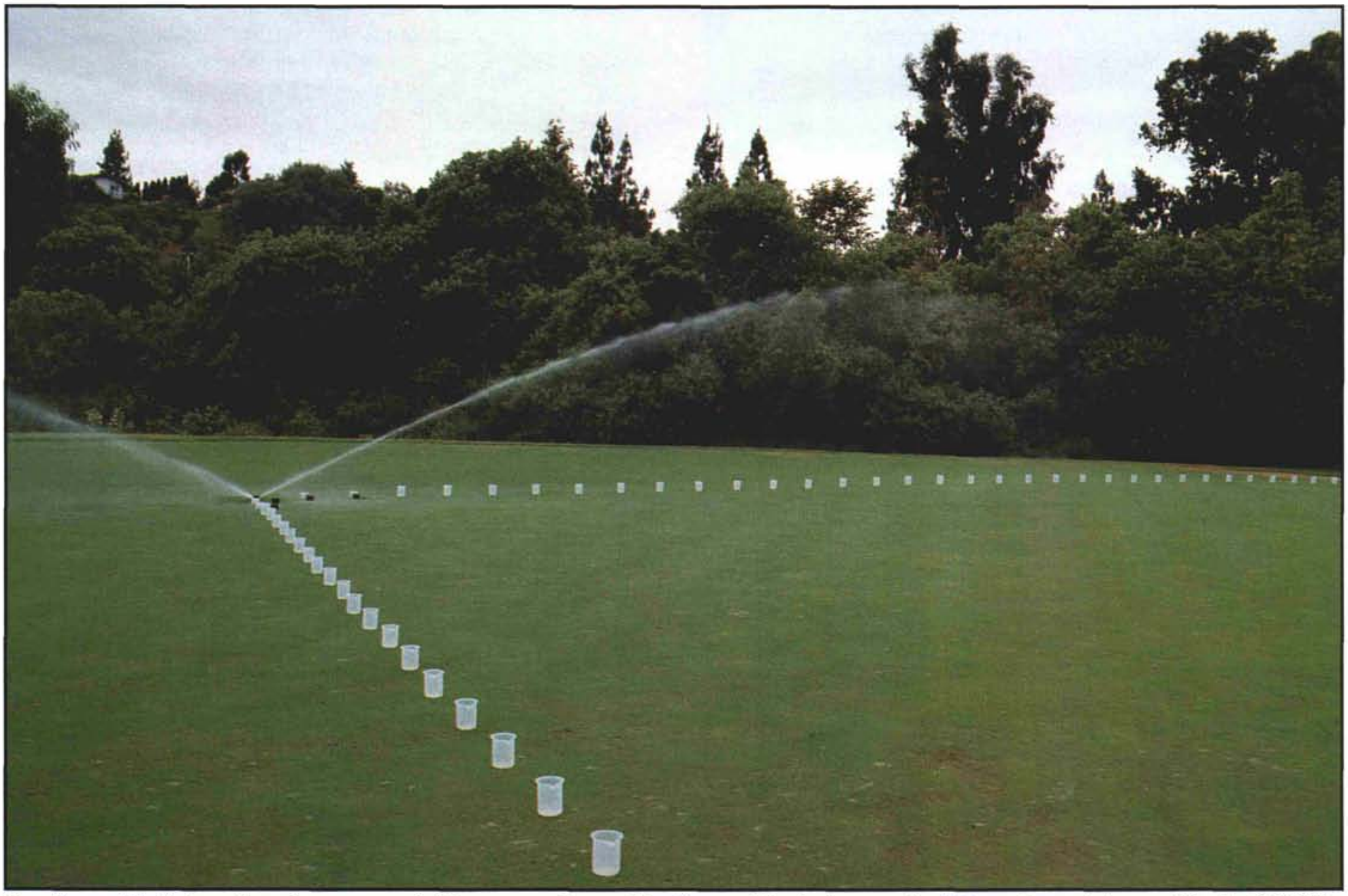
Sprinkler Name: Good Coverage — Base Pressure (psi): 80.0
Sprinkler Model: A1 — Riser Height (inches): 0.0
Nozzle Size: A1 — Set Screw Setting: 0
Flow Rate (gpm): 25.00 — Degree of Arc: 360
Date/Time of Test: 02/01/91 12:47 — Minutes/Revolution: 3.30
Testing Facility: User Created — Record Number: 1001
Comment:

Distr. Uniformity: 84% CU (Christiansen): 89% Sched. Coeff. (5%): 1.2	Min. (In./Hr.): 0.477 Mean (In./Hr.): 0.613 0.658 (Theor.) Max. (In./Hr.): 0.915	Spacing Equilateral 65.0' × 56.3'

Frequency Distribution



Histograms are used to represent the irrigation distribution in 5% increments. The frequency of each synthesized catchment occurs in the Grid Listing Report.



On-site profile data gathered on new sprinklers or nozzle combinations with single row of catchments are later used in the SPACE Program evaluation process.

overlap of the sprinklers. Any number can be used, with a maximum of 60 rows by 60 columns for a possible total of 3600 catchments. The more catchments used, the more precise the analysis. (It is suggested by irrigation texts that the maximum spacing for catchments be 5 feet by 5 feet if sprinkler spacing is less than 60 feet, and 10 feet by 10 feet if sprinklers are spaced over 60 feet.)

The area selected for testing should be representative of the entire system and conducted in wind conditions typical of those found during normal irrigation. An ideal way to perform this test is to set up the catchments the evening before and allow the sprinkler system to operate automatically. A minimum of 15 minutes run time is suggested to obtain an adequate amount of water in the catchments. For the sake of the test, run times of all stations influencing the catchments must be set to operate for the exact same amount of time while collecting data.

The water collected in the catchments is then measured to the nearest hundredth of an inch and entered into the computer. Data such as sprinkler run time in minutes, sprinkler make, model, nozzle size, operating pressure, flow rate (gpm), arc (degrees of rotation), test date, and minutes per revolution are recorded. These data become part of the permanent test record.

Single Sprinkler Grid: Grid data of a single sprinkler are collected much the same way as for an existing system, but the capability of operating only one sprinkler must be available. To arrange the catchments for collecting data, the radius of the sprinkler coverage must be known. After obtaining this information, the catchments are laid out in a square arrangement with the sprinkler located in the center and catchments positioned uniformly throughout as far as water is thrown.

Data are then collected and entered into the computer in the same manner as with an existing system. The difference is that these data can be overlapped, similar to a single-leg analysis, to examine different spacings and configurations. The data can then be viewed or printed as a grid listing, densogram, histogram, or sliding windows report for either the single head or a selected overlap.

Interpretation of Data and Summary

Interpretation of the final data and reports requires some time, and all the data must be taken into consideration. The final sprinkler selection should not be based on any one numerical or graphic representation alone. A good place to start, however, is with the profile. The more wedge-shaped the profile, the more uniform the coverage can be expected. Looking beyond the profile, one needs to examine the wettest and driest areas through the minimum and maximum values presented on the sliding windows report, determine how significant these might become, look for the lowest Scheduling Coefficient in combination with the highest CU and DU, most uniform Densogram, narrowest range of variation on the Histogram, and, finally, compare how well the sprinkler performs across a range of spacings. The

Irrigation Efficiency Analysis
Uniformity Evaluation
Poor Coverage Example

Sprinkler Name: Poor Coverage
Sprinkler Model: A3
Nozzle Size: A3
Flow Rate (gpm): 34.00
Date/Time of Test: 02/01/91 02:41
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 1.30
Record Number: 1003

Distr. Uniformity: 76%	Min. (In./Hr.): 0.253	Spacing
CU (Christiansen): 88%	Mean (In./Hr.): 0.762 0.895 (Theor.)	Equilateral
Sched. Coeff. (5%): 2.2	Max. (In./Hr.): 0.952	65.0' × 56.3'

Critical 1% Window Size

Mean In./Hr.: 0.762 — Sched. Coefficient: 2.9
Min. Window In./Hr.: 0.260 — Min. Window % of Mean: 34%
Max. Window In./Hr.: 0.941 — Max. Window % of Mean: 123%

Window Size 3 × 3: 33'²

Critical 5% Window Size

Mean In./Hr.: 0.762 — Sched. Coefficient: 2.2
Min. Window In./Hr.: 0.343 — Min. Window % of Mean: 45%
Max. Window In./Hr.: 0.905 — Max. Window % of Mean: 119%

Window Size 7 × 7: 179'²

Critical 10% Window Size

Mean In./Hr.: 0.762 — Sched. Coefficient: 1.7
Min. Window In./Hr.: 0.439 — Min. Window % of Mean: 58%
Max. Window In./Hr.: 0.885 — Max. Window % of Mean: 116%

Window Size 10 × 10: 365'²

Irrigation Efficiency Analysis
Uniformity Evaluation
Good Coverage Example

Sprinkler Name: Good Coverage
Sprinkler Model: A1
Nozzle Size: A1
Flow Rate (gpm): 25.00
Date/Time of Test: 02/01/91 12:47
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 3.00
Record Number: 1001

Distr. Uniformity: 84%	Min. (In./Hr.): 0.477	Spacing
CU (Christiansen): 89%	Mean (In./Hr.): 0.613 0.658 (Theor.)	Equilateral
Sched. Coeff. (5%): 1.2	Max. (In./Hr.): 0.915	65.0' × 56.3'

Critical 1% Window Size

Mean In./Hr.: 0.613 — Sched. Coefficient: 1.3
Min. Window In./Hr.: 0.485 — Min. Window % of Mean: 79%
Max. Window In./Hr.: 0.873 — Max. Window % of Mean: 142%

Window Size 3 × 3: 33'²

Critical 5% Window Size

Mean In./Hr.: 0.613 — Sched. Coefficient: 1.2
Min. Window In./Hr.: 0.493 — Min. Window % of Mean: 80%
Max. Window In./Hr.: 0.797 — Max. Window % of Mean: 130%

Window Size 7 × 7: 179'²

Critical 10% Window Size

Mean In./Hr.: 0.613 — Sched. Coefficient: 1.2
Min. Window In./Hr.: 0.509 — Min. Window % of Mean: 83%
Max. Window In./Hr.: 0.769 — Max. Window % of Mean: 125%

Window Size 10 × 10: 365'²

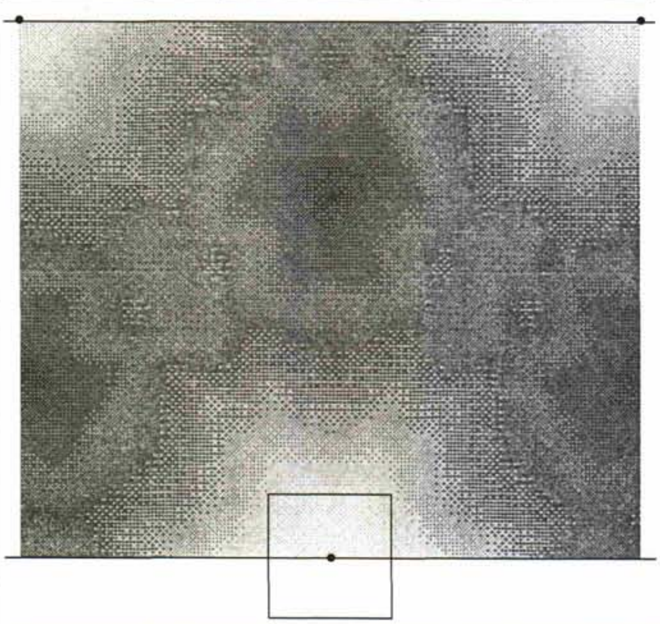
The Sliding Windows Report analyzes the most wet and dry 1, 5, and 10% areas of the overlap.

Irrigation Efficiency Analysis
Uniformity Evaluation
Poor Coverage Example

Sprinkler Name: Poor Coverage
Sprinkler Model: A3
Nozzle Size: A3
Flow Rate (gpm): 34.00
Date/Time of Test: 02/01/91 02:41
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 1.30
Record Number: 1003

Distr. Uniformity: 76%	Min. (In./Hr.): 0.253	Spacing
CU (Christiansen): 88%	Mean (In./Hr.): 0.762 0.895 (Theor.)	Equilateral
Sched. Coeff. (5%): 2.2	Max. (In./Hr.): 0.952	65.0' × 56.3'

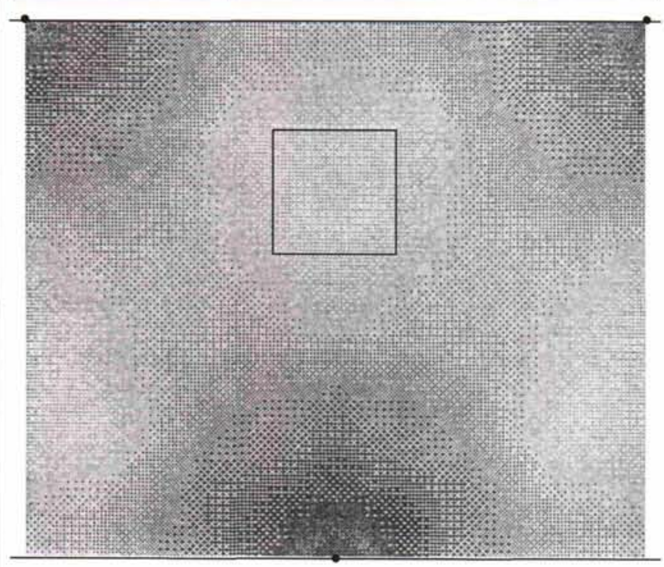


Irrigation Efficiency Analysis
Uniformity Evaluation
Good Coverage Example

Sprinkler Name: Good Coverage
Sprinkler Model: A1
Nozzle Size: A1
Flow Rate (gpm): 25.00
Date/Time of Test: 02/01/91 12:47
Testing Facility: User Created
Comment:

Base Pressure (psi): 80.0
Riser Height (inches): 0.0
Set Screw Setting: 0
Degree of Arc: 360
Minutes/Revolution: 3.00
Record Number: 1001

Distr. Uniformity: 84%	Min. (In./Hr.): 0.477	Spacing
CU (Christiansen): 89%	Mean (In./Hr.): 0.613 0.658 (Theor.)	Equilateral
Sched. Coeff. (5%): 1.2	Max. (In./Hr.): 0.915	65.0' × 56.3'



The Densogram graphically shows the synthesized coverage of overlap area. The lighter shaded areas indicate drier areas and the darker areas are more wet. The small square locates the critical dry area within the overlap pattern.

more consistent the results are at varying spacings, the more uniform the coverage will be where spacing adjustments are required.

In the case of new installations, it would be prudent to send one sprinkler for testing prior to the design phase to select the best spacing. During the system installation, sprinklers should be tested at the start of the project and then again one-third and two-thirds through completion of the project as a quality-control measure. Checking several sprinklers during the project will help insure that the manufacturer has not made any drastic change in the product or that problems with molding or machining nozzles have not occurred. This small investment could help avoid many headaches down the road.

There is a case to be made for performing on-site testing, especially at high elevations where thin air will affect the distribution pattern by how far water is thrown. You cannot expect information obtained at Fresno, California, at near sea level, to be completely valid in the Rocky Mountains at 10,000 feet elevation. Additionally, the effects of wind, temperature, relative humidity, and other unknown variables on sprinkler distribution are not yet completely known. However, the Center for Irrigation Technology is busy working with lasers to analyze actual droplet size in relationship to wind and drift. In the future, wind effects may become more predictable.

It must also be recognized that a nozzle one size larger or smaller can result in a drastic change in the shape of a profile. Some nozzles have also shown a great sensitivity in their performance with only slight variations in operating pressure. Evaluating sprinklers alone cannot guarantee success, but it may prevent certain failure. A system still needs to be properly designed hydraulically and then installed correctly. Laboratory evaluation of sprinklers is better than any other method of selection currently available, especially compared to the old-fashioned way of just sticking them in the ground and finding donuts upon completion. So don't let sprinkler selection be rocket science. Test before you invest, and put data from the SPACE program to work for you!

(SPACE is available for either DOS or Windows. For more information on SPACE or laboratory testing, contact the Center for Irrigation Technology, California State University — Fresno, 5370 North Chestnut Avenue, Fresno, California 93740-0018, or phone 209-278-2066.)

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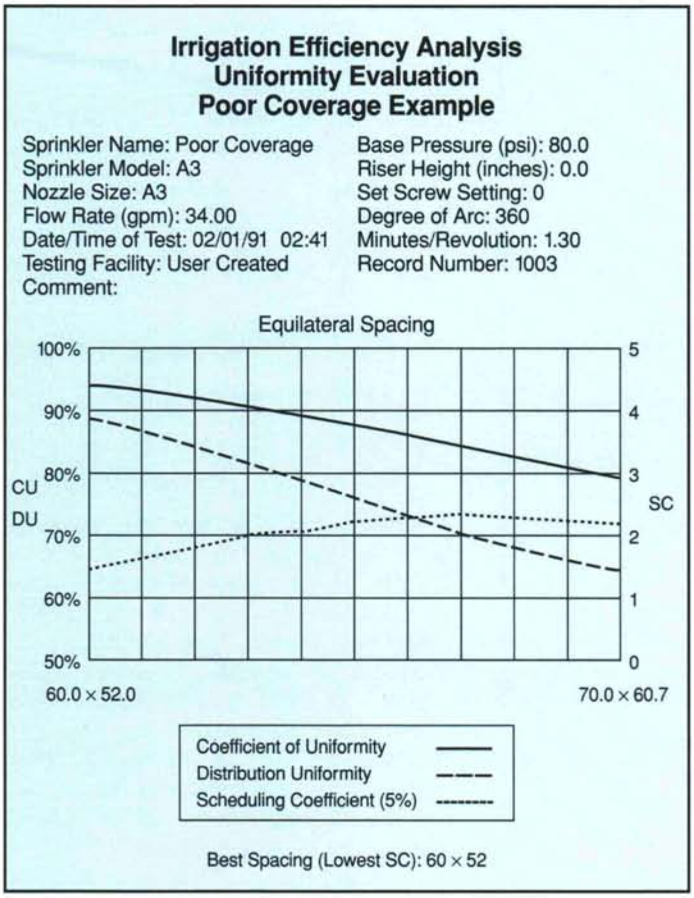
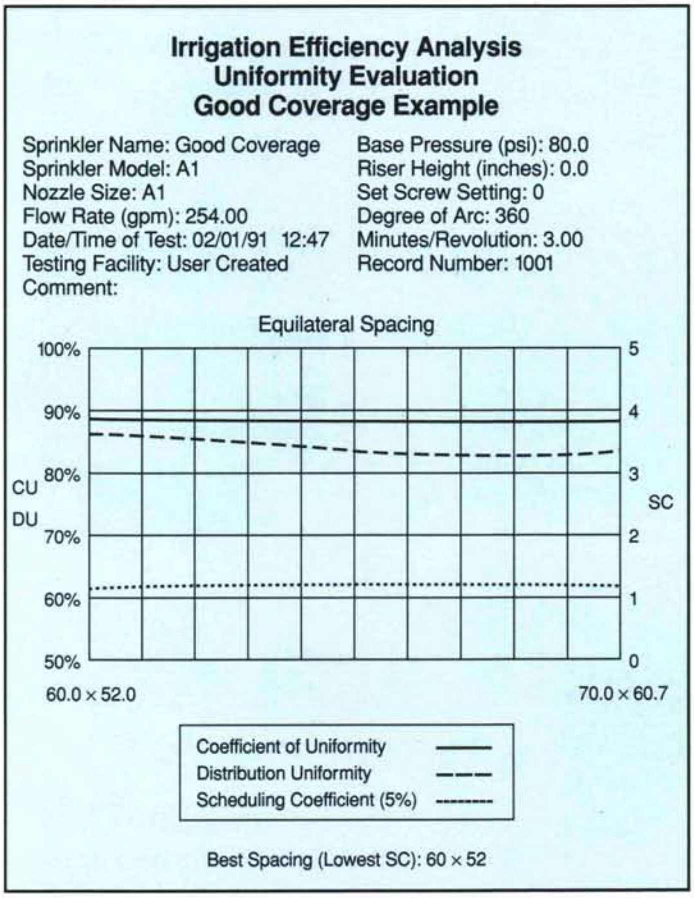
MIKE HUCK *is an agronomist in the Green Section's Western Region. He conducts TAS visits from the California coast to the peaks of the Rocky Mountains.*





Multiple Spacing Graphics display the consistency or lack of consistency of the Christiansen's Coefficient of Uniformity (CU), Distribution Uniformity (DU), and scheduling coefficient over a range of spacings.