Water Distribution From a Sprinkler Lateral Moving Continuously in a Linear Direction

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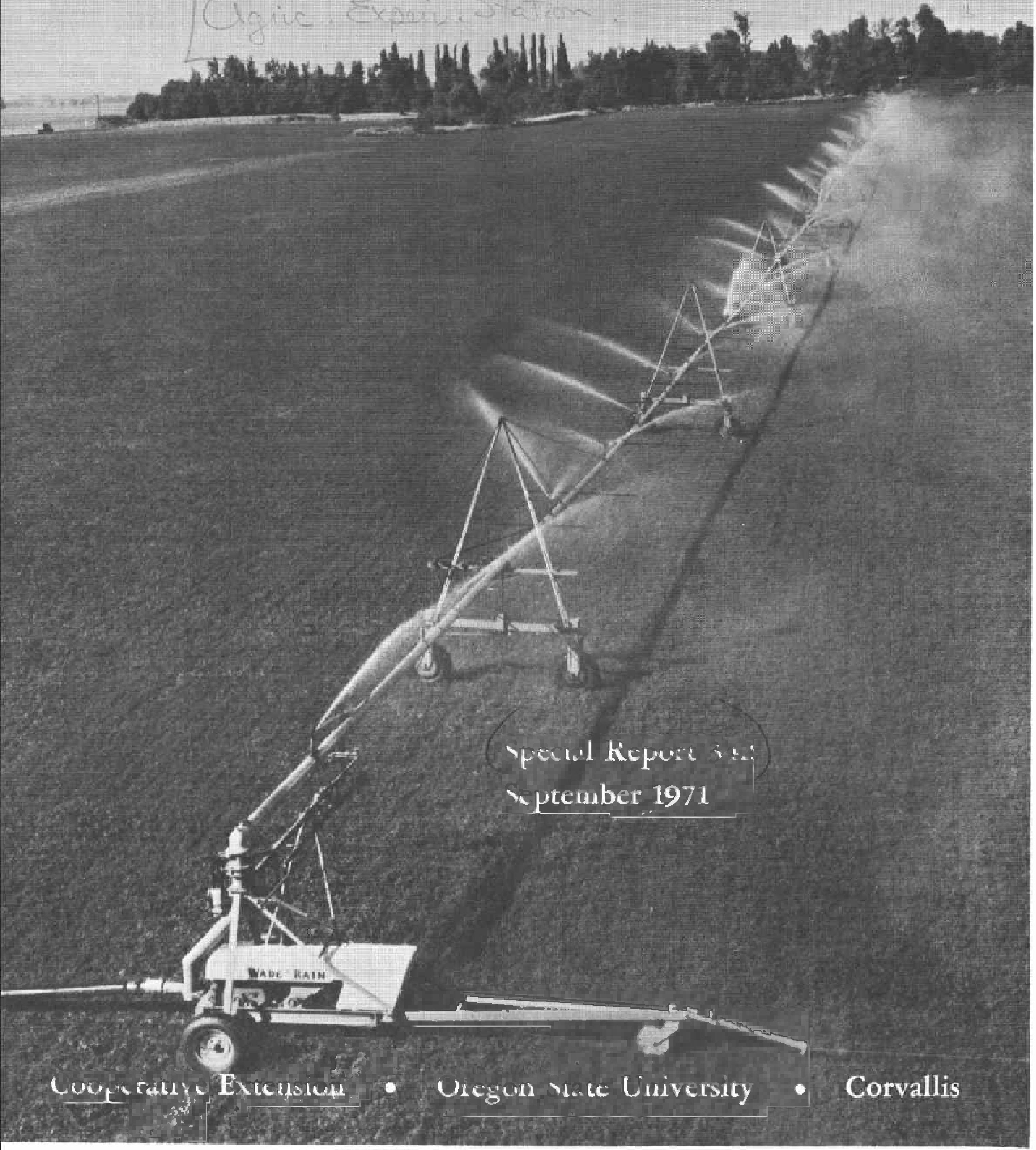

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References

(1) Shearer, M. N. "Continuous Move Laterals Apply Water Uniformity in High Winds", Irrigation Engineering and Maintenance, March, 1966, p. 20.

(2) Pair, C. H. Water Distribution Under Sprinkler Irrigation, ASAE Paper No. 67-709, December, 1967.

(3) Hart, W. E., Reynolds, W. N. Analytical Design of Sprinkler Systems, ASAE Paper No. 64-201, June, 1964.

(4) Christiansen, J. E. Irrigation by Sprinkling, Calif. Agr. Exp. Sta., Bul. 670, 1942.

For purposes of clarification, trade names have been used in this report. This is not to imply endorsement of products named or criticism of those not included.

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WATER DISTRIBUTION FROM A SPRINKLER LATERAL MOVING CONTINUOUSLY IN A LINEAR DIRECTION

by

Marvin N. Shearer
Extension Irrigation Specialist
Oregon State University

Introduction

Close spacing of sprinklers is necessary if uniform distribution of water is to be achieved with sprinkler systems operating under windy conditions. Moving laterals continuously during irrigation provides a means of obtaining close spacing. With such a system, sprinkler spacing is infinitely close in the direction of lateral move and can be adjusted along the lateral to meet the overlap requirements for uniform application.

Distribution from a continuously moving lateral was tested by Shearer (1) in 1965 and uniformities of 92 percent were observed in winds from 4 to 16 miles per hour.

Pair (2) reported tests on the same equipment in 1967 and observed uniformities of 90 to 95 percent under winds of 5 miles per hour.

A new continuous linear-move lateral marketed under the trade name *Squarematic*, was displayed by the R. M. Wade Company in 1970. Permission was granted to the author to test the distribution of water from this system during the final stages of the system's development.

Objective of tests

The main objectives of the tests were to make preliminary measurements of the uniformity and efficiency of water application and to determine the relative importance of factors affecting the uniformity of water application--particularly with respect to water motor discharge.

Description of equipment

The system was composed of a 6 inch aluminum lateral, 1/4 mile long, mounted 7 feet above ground level on 16 A-frames spaced 80 feet apart. Each A-frame was powered by a reaction type water motor. The head rig, which was attached to and controlled the lateral, contained a cable, winch, winch driving device (displacement water pump on the unit tested), and an alignment control mechanism. Water was fed to the head rig through 660 feet of 5 inch flexible reinforced hose from a mainline riser. Speed of the lateral could be varied from 6 to 24 inches per minute.

Water was discharged from the system through sprinklers spaced 20 feet apart on the lateral. A small amount was discharged through water motors on each A-frame and from the positive displacement pump driving the winch.

During operation, the head rig controlled the speed of the machine and the remainder of the equipment automatically aligned itself to it.

The water motors driving the A-frames were reaction type (Figure 1). Two nozzles (5/32" on the unit tested) spun verticle shafts as they discharged water. This motion was transferred to the wheels through a series of gears, a drive shaft, and a drive chain. Valves controlling the water motors were actuated by alignment devices. They opened individually, causing a motor to operate whenever an A-frame fell behind an adjacent one, and closed when it caught up. Motors operated roughly 10 to 15 percent of the time when the lateral traveled at a speed of 6 inches per minute. This resulted in excellent lateral alignment during the tests with motors starting and stopping 1 to 4 times per minute.

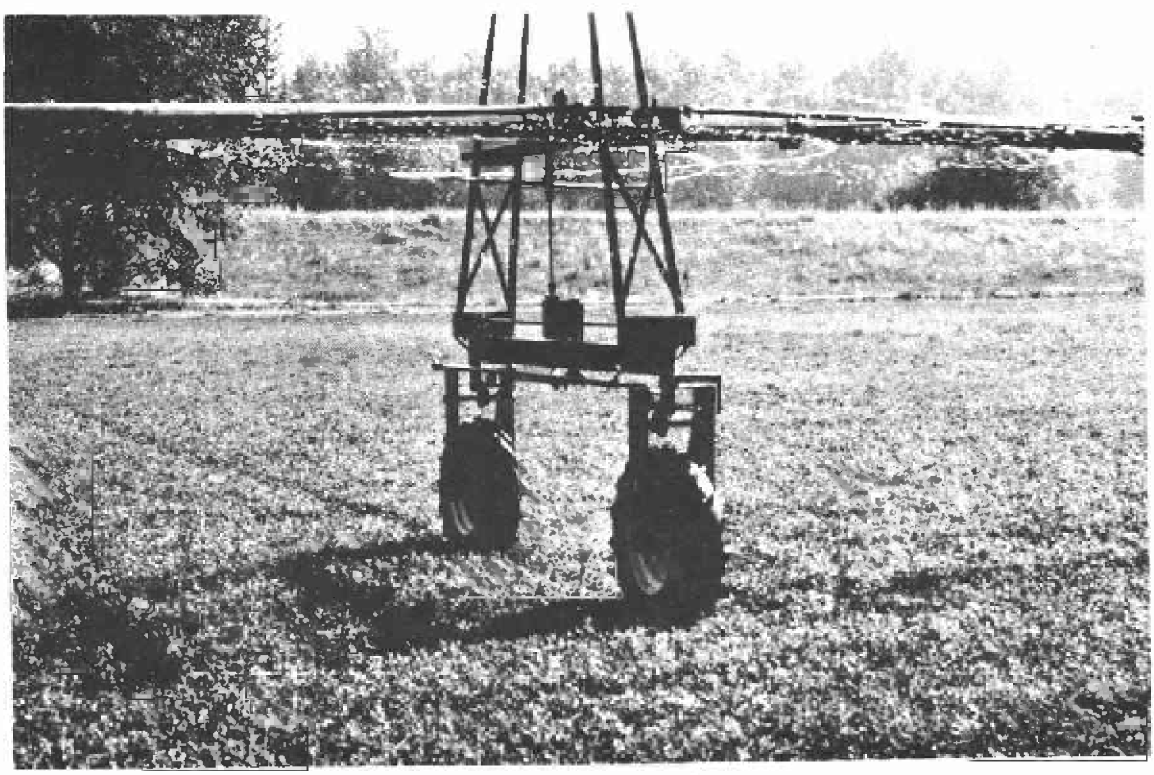

Figure 1. A-frame assembly with water motor operating. Revolving speed varied with opening and closing of alignment control valve giving a relatively flat distribution pattern from the water motor outward.

Method

A series of water distribution tests were made with selected sprinkler heads and nozzles with the lateral traveling at selected speeds. No tests were made of the distribution of water from the winch motor as it was concentrated in a relatively narrow band around the head rig.

Two rows of number one cans (3-1/16" dia. x 4-11/16" deep) were placed on a 10 foot spacing parallel to the lateral just outside the leading edge of the sprinkler pattern. The can rows were spaced five feet apart. A total of eighty cans were used which reached across five A-frame spaces. Each space between A-frames was considered a replication. They were not randomly selected but were side by side. They covered 1/3 the length of the lateral.

The lateral moved across the can rows applying irrigation water during the process. Wind velocity, wind direction, rate of travel, and individual can catchments in cubic centimeters was recorded.

Can catchments were plotted against sprinkler head location to identify where variations in water application occurred. Figure 2 shows two plots.

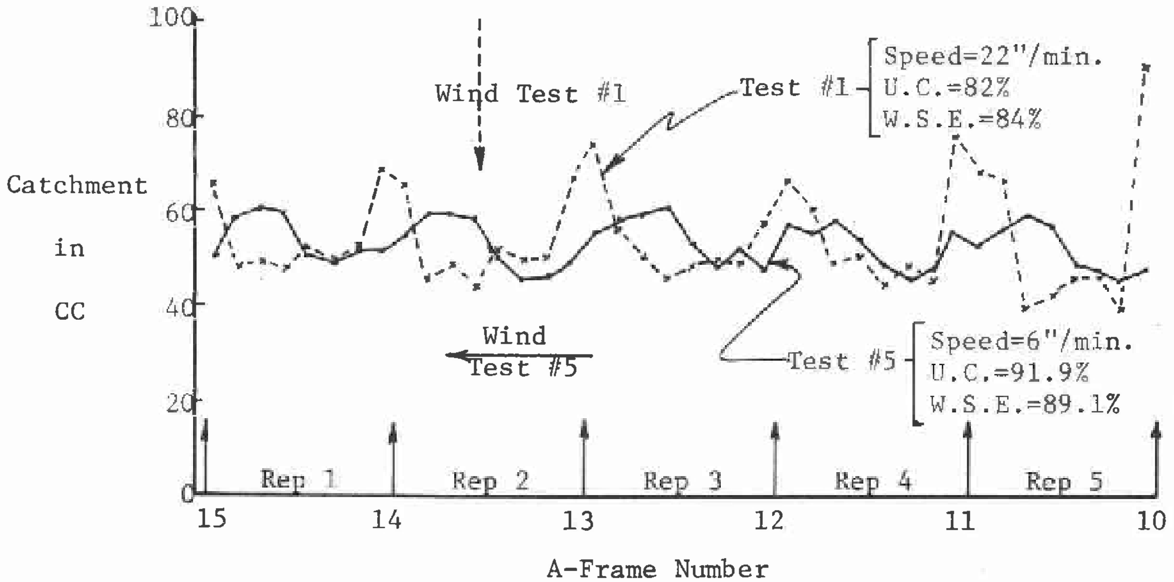

Figure 2. Water catchments along lateral. High water applications around A-frames in Test One were caused by low line pressure and high lateral speed without compensating adjustments in sprinkler nozzling. In Test Five, nozzle sizing over-compensated for water motor application at low speed. Pattern shifted 20 feet to left because of wind.

Water storage efficiency was calculated adapting a procedure described by Hart and Reynolds (3). It is the ratio of the amount of water applied which was stored and available for crop use to the total water applied to the soil surface. It assumes no run-off or lateral movement. In Figure 3, individual can water catchments are plotted as a histogram in decending order of quantity caught. Catchments are plotted downward instead of upward from a base line to graphically represent water penetrating into soil.

$$\text{Water storage efficiency} = \frac{\text{Area A}}{\text{Area A + B}} \times 100$$

$$= \frac{(73)(100)-(6)(12.5)}{(77)(100)} \times 100$$

$$= 94 \text{ percent}$$

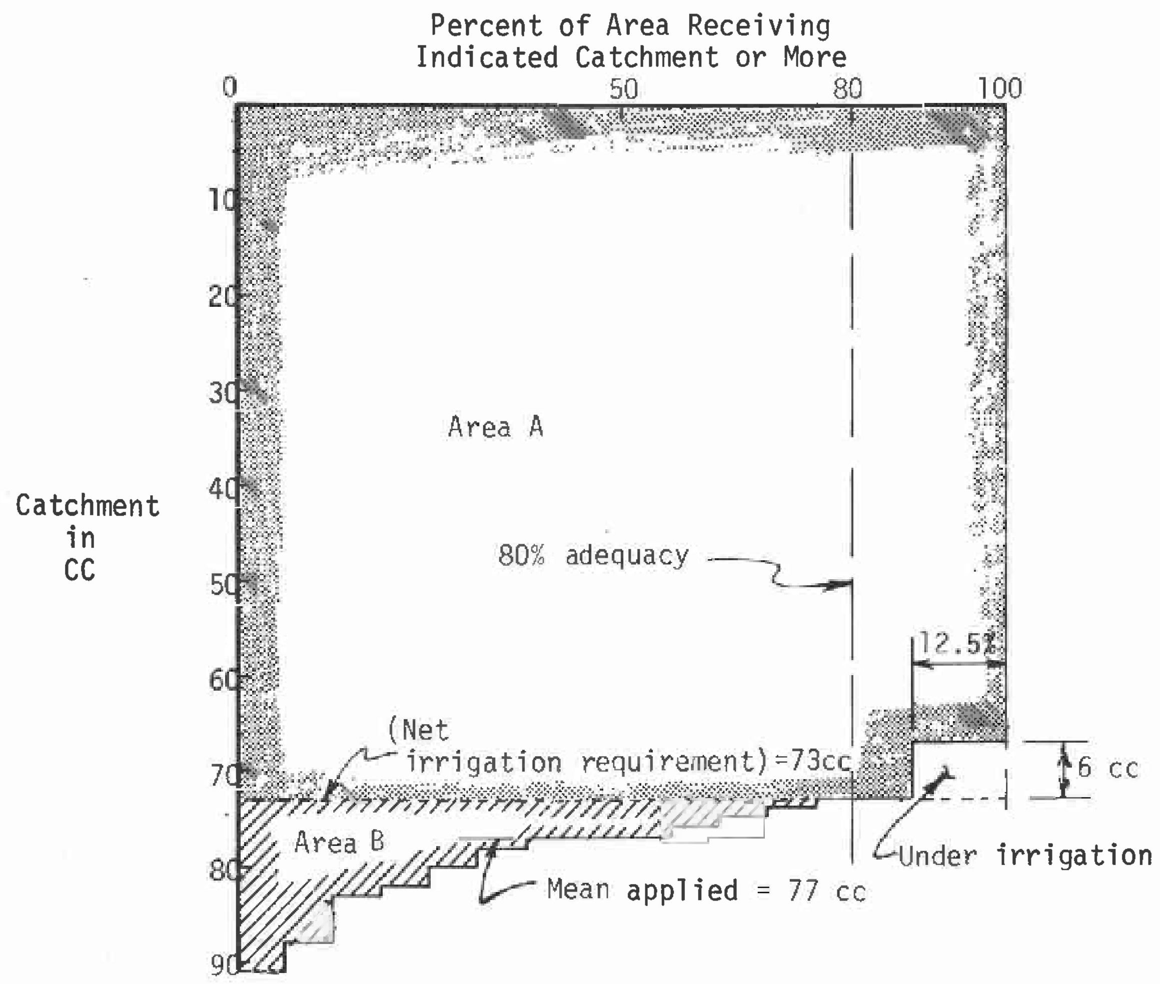

Figure 3. Graphic Presentation of Water Storage Efficiency for Test 4, Replication 5.

Eighty percent adequacy means that 80 percent of the area received an amount of water equal to or greater than required to refill the root zone (net irrigation requirement). Actual discharge from sprinklers must be increased above the mean indicated to compensate for water losses occurring between the sprinkler nozzle and the soil surface.

Uniformity of distribution was calculated using Christiansen's method (4) because of its common usage.

Tests were also run to determine the application rates under the sprinkler pattern.

Discussion

A summary of individual test results concerned with coefficient of uniformity and water storage efficiency is shown in Table 1.

Table 1. Results of Water Distribution Tests Run on Continuous-Move Lateral Line

Test no.	Reps.	Sprinkler	Nozzles	Pressure[a] line	Pressure[a] spr.	Wind ave. vel.	Wind direc.	Lateral speed	Coeff. of unif.[b]	Water stor. eff.[b] (80% adeq.)
				psi	psi	mph		in./min.		
1	5	RB 30E	13/64 x 1/8 7°	45	36	5.2		22	82.0 ± 5.5	83.7 ± 3.6
2	5	RB 30E	13/64 x 1/8 7°	65	57	6.5		6	92.3 ± 2.3	90.0 ± 2.1
3	5	RB 30E	13/64 x 1/8 7°	57	45	4.8		22	87.6 ± 2.7	86.3 ± 2.5
4	5	RB 30E	(13/64 x 1/8 7°) (13/64 x plug)	55	55	4.0		12	93.0 ± 0.7	92.2 ± 1.8
5	5	RB 30E & RB 14070	(13/64 x 1/8 7°) (13/64 x plug)	55	55	3.5		6	91.9 ± 0.8	89.1 ± 1.8

a. Dole flow control valves used in Tests 1, 2, and 3.

b. At 95% confidence level.

Pressure effects

The water motors driving the A-frames are reaction type. The amount of power generated by them is affected by both lateral line pressure and the quantity of water discharged.

A reduction in lateral pressure reduces the rate of water discharge with given jet diameters and lowers power output. This in turn requires a greater amount of water to be discharged per unit distance the lateral travels.

Discharge from the water motors fall within a 30 foot circle around each A-frame.

Tests 1 and 3 were compared to evaluate low pressure effects. Treatments were 36 psi and 45 psi under the sprinkler head. Minimum manufacturer's recommended operating pressure for the sprinkler used was 55 psi when used with a "set" type sprinkler system.

Table 2 shows the coefficient of uniformity and storage efficiency of these tests. Analysis failed to show any significant difference in coefficient of uniformity or water storage efficiency between the two pressure treatments at the 95 percent confidence level but the expected trend was apparent. Examination of can catchments revealed considerably more water caught around A-frames than between them. The excess water discharge required through the water motors due to low lateral pressure resulted in the lowest uniformity coefficients of any of the tests but they were still comparable to uniformities achieved under "set" type systems.

Table 2. Effect of Low Pressure on Uniformity Coefficient and Storage Efficiency

Test no.	Pressure at sprinkler	Unif. coeff. (Christiansen)	Water storage efficiency (80% adequacy)
		percent	percent
1	36	82.0	83.7
3	45	87.6	86.3

Rate of travel effects

At given pressures, the amount of water applied to an area through sprinklers during one pass is determined by the speed of the lateral. The amount of water applied through the water motors is relatively constant per lineal distance traveled by the lateral regardless of its speed. Higher lateral speeds therefore result in higher proportions of water applied through the water motors as compared to water applied through sprinklers, although these proportions may still be low in magnitude. Since discharge from the water motors fall in a band 15 feet wide each side of the A-frames, the real question is whether or not variation in this ratio for different speeds and the total amount discharged has a significant effect on uniformity of application.

Table 3 indicates a change in speed from 6 inches per minute to 22 inches per minute resulted in a significant decrease in uniformity coefficient at the 95 percent confidence level. It fails to show a significant change in storage efficiency at this confidence level but did at the 90 percent confidence level.

An examination of can catchments indicated higher water applications around A-frames than between them at 22 inches per minute lateral speed.

Table 3. Effect of Rate of Travel on Uniformity Coefficient and Storage Efficiency

Test no.	Speed	Uniformity coefficient	Water storage efficiency (80% adequacy)
	inches/minute	percent	percent
2	6	92.3	90.0
3	22	87.6	86.3
LSD 5% level		4.2	

Nozzles adjustments to compensate for water motor discharge

It appeared that total water application around the A-frames during high lateral speeds could be reduced substantially by plugging spreader nozzles on sprinklers around A-frames to compensate for the water discharged through the water motors. A comparison of Tests 3 and 6 indicate the effectiveness of this adjustment. The results were affected by two variables, low lateral speed and plugging selected sprinkler spreader nozzles, which both tended to increase uniformity of water distribution.

Test results shown in Table 4 indicate a highly significant effect from these treatments at the 99 percent level of confidence as indicated by both the coefficient of uniformity and the water storage efficiency.

Table 4. Effect of Plugging Selected Spreader Nozzles Around A-frames on Coefficient of Uniformity and Storage Efficiency

Test no.	Lateral speed	Nozzles	Coefficient of uniformity	Water storage efficiency (80% adequacy)
	inches/minute		percent	percent
3	22	13/64 x 1/8 7°	87.6	86.3
4	12	13/64 x 1/8 7° & 13/64 x plug	93.0	92.2
LSD 5% level			3.3	3.6
LSD 1% level			4.8	5.3

A comparison was made between Tests 2, 4, and 5 (Table 5) to determine the effect of plugging spreader nozzles around A-frames when the lateral was traveling at low speeds.

Table 5. Effect of Plugging Spreader Nozzles Around A-frames at Low Lateral Speeds.[a]

Test no.	Spreader nozzles plugged	Speed	Uniformity coefficient	Water storage efficiency (80% adequacy)
		inches/minute	percent	percent
2	no	6	92.3	90.0
4	yes	12	93.0	92.2
5	yes	6	91.9	89.1

a. All sprinklers were RB 30E except Test 5 which had a mixture of RB 30E and RB 14070. The mixture did not have a significant effect on uniformity of distribution or water storage efficiency.

There was no significant difference in uniformity coefficient or storage efficiency between Tests 2 and 5, and 4 and 5 at the 95 percent confidence level.

Examination of can catchments indicated that plugging the spreader nozzles at a lateral speed of 6 inches per minute resulted in a slight shortage of water around A-frames and at a speed of 12 inches per minute a slight excess. In both situations, however, uniformity of water distribution was very high, from 92 to 93 percent.

From these comparisons, it is concluded that with nozzle sizes used in the sprinklers and water motors in these tests, the contribution from the water motors was relatively insignificant at low lateral speeds.

Application rate under the sprinkler pattern

Tests were run on the RB 30E sprinkler and the RB 14070 sprinkler to determine application rate profiles perpendicular to the lateral. Results are plotted in Figures 4 and 5.

The catchment cans used in these tests were spaced 10 feet apart on the square. The lateral was made stationary and the water motors were allowed to rotate continuously for 33 percent of the total catchment time which corresponded to a speed of approximately 12 inches per minute. This procedure had drawbacks in that the amount of water that should be contributed by the water motor was estimated, the sprinkler pattern from the water motor was not uniform and when caught with the lateral stationary, water was concentrated in cans which happened to be under the "doughnut" type pattern. *The sprinkler pattern from the water motor would have been more uniform in normal operation due to frequent starting and stopping of the motor.* Can rows affected by water motor discharge, therefore, are not included in results shown in Table 6.

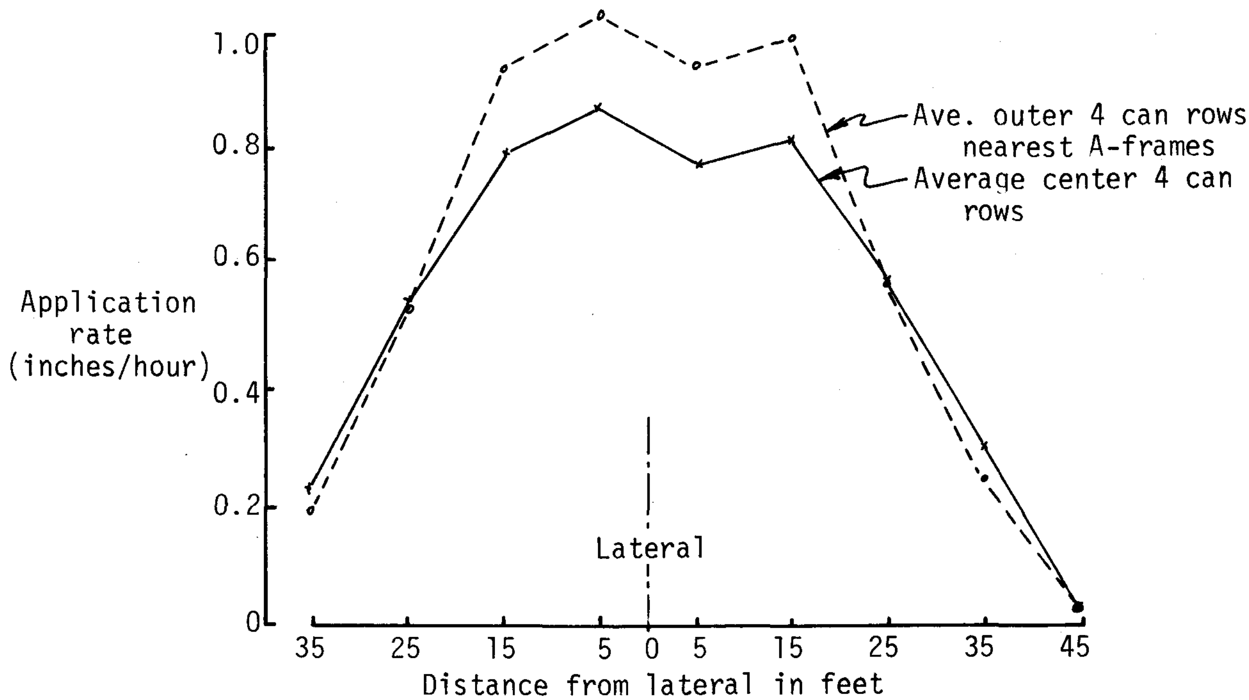

Figure 4. Profile of Water Application Perpendicular to Lateral From RB 30E Sprinklers with 13/64 x 1/8 7° Nozzles at 55 psi

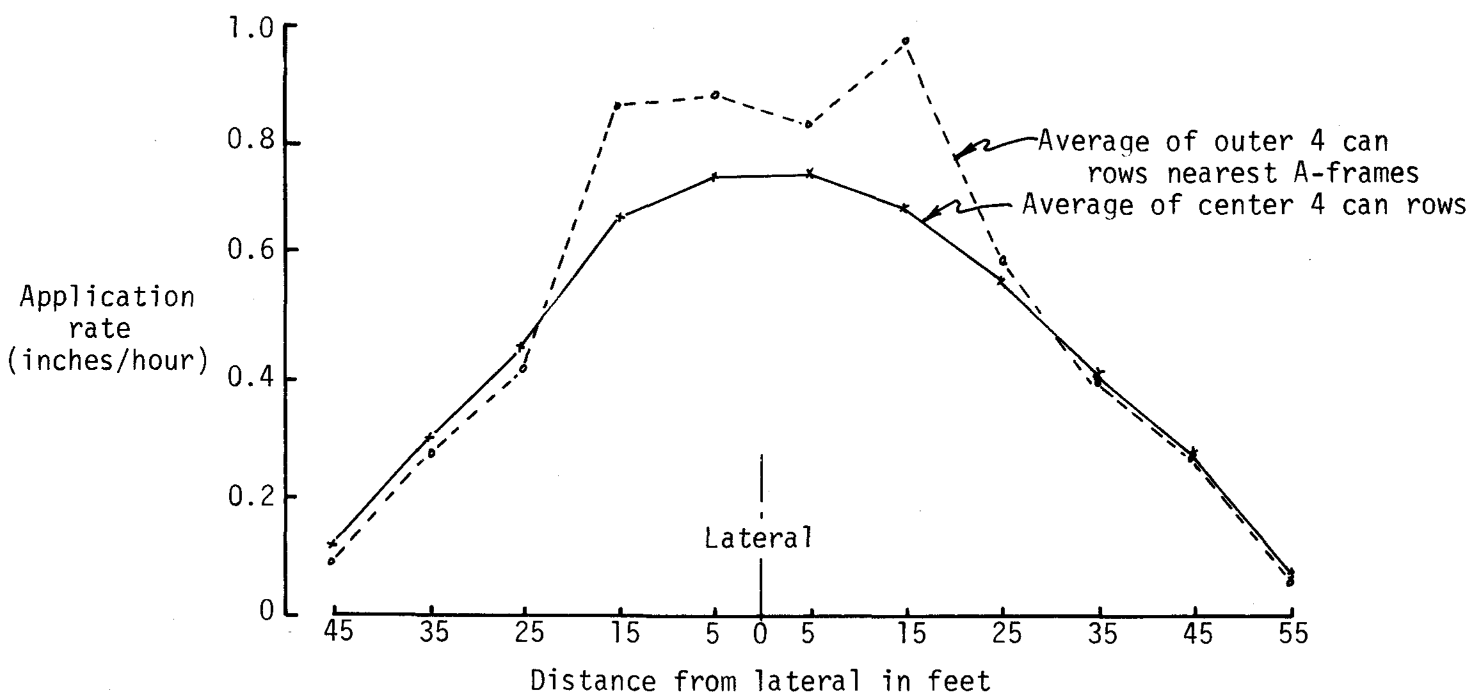

Figure 5. Profile of Water Application Perpendicular to Lateral From RB 14070 Sprinklers with 13/64 x 1/8 7° and 13/64 x plug Nozzles at 55 psi

The mean of the can catchments in the four center rows between A-frames and running perpendicular to the lateral were compared for both average and maximum application rates. These tests indicate that sprinkler selection and its corresponding application pattern had a highly significant effect upon maximum application rates.

Table 6. Application Rate Under the Sprinkler Pattern of a Continuously Moving Sprinkler Lateral.

Sprinkler	Pressure at sprinkler	Application rate average	Application rate maximum
	psi	inches/hour	inches/hour
RB 30E	55	.55	.83
RB 14070	55	.45	.71
LSD 5% level		.052	.086
LSD 1% level		.078	.130

Summary

A continuous-move lateral sprinkler system was tested to determine its water distribution characteristics with selected sprinklers and under selected operating conditions.

It was found that a high degree of uniformity (92 to 93 percent) could be achieved. These uniformities resulted in water storage efficiencies of 90 to 92 percent at 80 percent adequacy of irrigation.

Application rates within the sprinkler pattern averaged from .45 to .55 inches per hour with peaks of .71 to .83 inches per hour occurring in the 15 foot area each side of the lateral. Rate was affected by selection of sprinkler head models.

With the nozzle sizes used in the sprinklers and in the water motors, the contribution of the water motorswas insignificant at a lateral speed of 6 inches per minute, had an observable effect at 12 inches per minute, and should be considered in sprinkler nozzle selection if the lateral is to operate at speeds of 18 to 24 inches per minute during a significant portion of the irrigation season.