Irrigation Runoff from Narrow Turf Areas for Sprinkler and Surface Flow Systems

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Abstract.
Landscape irrigation runoff may contribute to contamination of streams, lakes and oceans, and some municipalities' enforce runoff ordinances. The objectives of this study were to measure and analyze runoff from small turf plots on a slope with Surface Flow irrigation, and sprinklers with spray and rotary nozzles. Under the tests conditions Surface Flow had less runoff than sprinklers with spray nozzles. Approximately 1 - 7% of applied water from sprinklers with spray nozzles became runoff; nearly 75% of this runoff was caused by wind. Replacing spray nozzles with rotary nozzles reduces runoff caused by wind.
Keywords. Landscape irrigation, irrigation runoff, sprinkler wind drift

Introduction.

Prevention of runoff from irrigated landscapes is important to prevent pollution due to the runoff, decrease demand for water, minimize irrigation cost, and decrease damage to hardscapes.

Legislation and ordinances affect irrigation practices. California Assembly Bill 2717 has a recommendation for a model landscape ordinance to include "provisions to minimize landscape irrigation overspray and runoff." This provision would impact methods of irrigation and operation of irrigation systems that result in runoff.

One area of regulatory interest for runoff from landscapes is runoff during the dry weather irrigation season. These surface flows, generally labeled nuisance flows, occur during the March through November irrigation season in Southern California. The quantity of runoff in an ideal world should be zero. However, the norm for many urban communities with irrigated landscapes is that significant runoff does occur in the summer unto hardscapes, gutters and storm drains that may ultimately degrade rivers and coastal waters. With Southern California water supplies stressed, any runoff from landscape is considered a waste of this limited resource.

A recent study by Municipal Water District of Orange County (Anonymous. 2004) showed a 49% reduction results in watershed runoff with the installation of ET controllers on residential sites. The city of Tustin and the Irvine Ranch Water District (Anonymous. 2004) installed a WICK irrigation system on a large street median, which virtually eliminated runoff that had previously occurred at the same site with sprinkler irrigation.

A study (Vis, 2006) reported both surface runoff and runoff due to wind drift on turf plots with 8% slope irrigated by rotary sprinklers on 50 x 50 spacing, and sprinkler precipitation rate near one inch per hour. Approximately twice the required irrigation water requirement was applied for the runoff data for the study. Under these conditions up to 9.5% of the applied water became runoff at the lower end of the plot. Surface runoff, if the irrigation runtime had been correct, was estimated at less than 0.2% of applied water. However, runoff due to wind drift under correct irrigation scheduling and moderate wind conditions (less 5 mph) was a substantial volume of water. This study showed that for the given soil, slope, and wind conditions, up to 3.3% applied water could become wind spray runoff if the irrigation runtime had been correct.

Replacement of spray nozzles with rotary multi-stream nozzles on existing landscapes improved the distribution uniformity (Kissinger 2005). Before and after catch can tests showed a distribution uniformity improvement of 18 percentage points.

Surface Flow, also identified as WICK and other names, was developed as an alternate irrigation method for landscape sprinkler irrigation for certain applications. This method has emission points spaced to achieve 100% wetted area. Flow is controlled by 2 gph or higher flow emitters with a micro tube emission point between the soil surface and turf cut height. The author's observations and experience with surface flow (WICK) systems suggest that with attention to detail in system design, site preparation, and installation, that good turf quality can be achieved. Potential advantages of surface flow irrigation are more uniform distribution of water, more control of water around landscape boundaries and curbs, and no wind drift. These factors could result in high irrigation efficiency, and the potential of reduced or no runoff from urban irrigation sites where wind is a major factor in runoff.

This study was initiated to measure runoff from turf plots irrigated by conventional popup with spray heads, conventional popup with rotary multi-stream nozzles, and Surface Flow irrigation. Each set of tests will be described in the following sections.

Conventional spray nozzles and Surface Flow

Methods and Procedures

There were eight turf plots for this project, four plots with sprinklers spray heads and four plots with surface flow irrigation. Plot dimensions were 20 feet by 5 feet. Native soil from the field was used to construct plots on 10% slope. Soil texture was sandy clay loam (58% sand, 18.4% silt, 23.6% silt). The 20 foot dimension of the plots was approximately 45 degrees from North. Runoff was collected from all plots during four irrigations in June 2007.

Jardinier Planter Systems Inc., manufacturer of some Surface Flow components, assisted with the design of emitter spacing and emitter flow rates for the plots. Emitters were installed on triangular spacing, 3 feet on the lateral and 3 feet between laterals with the lower lateral 1.5 feet from the lower edge of the plots. Emitters on this lower lateral had a flow rate of 3 gph. The top lateral was 0.5 feet from the top edge of the turf with emitter flow rates of 5 gph; this lateral had one additional emitter at each end. Average precipitation rate with this design was 0.98 inches per hour.

The sprinkler irrigated plots were designed and installed using traditional 6 inch popup spray heads with 5 foot nozzles (5^{o} trajectory) on 5 foot by 5 foot spacing operated at 30 psi. Manufacturer rated precipitation rate for the sprinkler nozzles in this design was 1.58 inches per hour. The lower row of sprinkler heads was installed approximately 4 inches up the slope from the lower edge of the turf. Sprinklers at each corner of the rectangular plots had 90^{o} arc nozzles, and 3 sprinklers at 5 foot intervals along the 20 foot side had 180^{o} arc nozzles. A-G Elite sod from A-G Sod Farms, Inc was installed.

Figure 1. Left photo shows runoff collection system for surface runoff and wind drift. Right photo shows 5 by 20 foot plots and wind drift collection barrier.

The irrigation runtimes were based on available water of 2 inches per foot of soil and targeted irrigation near 40% depletion of available water. For a rooting depth of 4 inches and an assumed 75% irrigation efficiency which resulted in a 14 minute runtime for the sprinkler plot. The same volume of water was applied to the Surface Flow plots in a 22 minute runtime.

The actual runtimes and volume of applied water are shown in Table 1. The volumetric moisture content was measured with a TDR with 4.8 inch probes as means to maintain surface moisture condition similar for all plots. The moisture contents in Table 1 are based on 3 reading per plot , one reading 0.5 feet up from the lower end of the slope, the second was 2.5 feet up the slope, and the last one 4.5 feet (0.5 feet from the top of the slope) up the slope. The TDR reading in the Surface Flow plots were sensitive to distance from an emitter where a reading was taken.

Table 1. Test dates, irrigation information, and volumetric soil moisture.

	Irrigation Runtime		Water Applied		Volumetric Soil Moisture*	
Date	minutes		gallons		%	
	S.F#.	spray@	S.F.	spray	S.F.	spray
June 1, 2007	22	14	22	22	51	48
June 5, 2007	22	14	22	22	44	39
June 8, 2007	22	14	22	22	38	41
June 12, 2007	22	14	22	22	36	40

Note: S.F. is Surface Flow
* Volumetric soil moisture measured with TDR before irrigation
# Surface Flow method of irrigation as described above
@ Six inch popup sprinklers with 30 psi PRS stems and 5 foot nozzles

Runoff from the sprinkler plots was collected in two components, surface runoff and wind drift runoff. All runoff was collected at the lower end of the plots only (Figure 1)
The plastic barrier directed any wind drift into one collection trough. Surface runoff from each plot was collected in a second trough at the lower edge of the plot. Both troughs drained into containers for runoff volume measurements. Turf was mowed one day before irrigation events.

Results and Discussion

Runoff collected after each irrigation event is shown in Table 2 for both irrigation treatments on four dates. The collected runoff was 100% surface flow for the Surface Flow method and a combination of surface flow and wind drift for the sprinkler plots. Sprinkler plots had some overspray on the sides and top of the rectangular plots; overspray was collected only from one side in this experiment. Likewise some Surface Flow irrigated plots had minor surface flow off the plot sides and some subsurface flow near the lower end. The total collected runoff was only the water collected at the lower end of each plot, and it should be consider the minimum potential runoff.

Significant differences were shown for mean collected runoff for Surface Flow and mean collected runoff sprinkler plots for each date (Table 2).

There was no overspray, as defined for this study, with Surface Flow method since water from the 3 and 5 gph emitters is not projected into the air. There was no measured runoff for the Surface Flow plots, but there was some subsurface water flow that will be discussed later.

Table 2. Surface runoff and overspray collected from plots.

	Mean of 4 plots per treatment			
	Surface Flow Emitters	Sprinkler Spray Nozzles		
Date	Collected Surface Runoff, Liters	Surface Runoff, Liters	Overspray Runoff, Liters	Total Collected Runoff, Liters
6/1/2007	0.0a	0.8	2.6	3.4b
6/5/2007	0.0a	0.9	2.9	3.8b
6/8/2007	0.0a	0.6	2.7	3.3b
6/12/2007	0.0a	0.6	3.0	3.6b

Mean values in rows followed by different letters are statistically different at the 95 % level by Duncan's Multiple Range Test.

Runoff as a percentage of applied water is important for using test data and projecting potential runoff from a larger site with irrigation systems operated under similar conditions. Runoff from the sprinkler plots ranged from 3.9 – 4-5% of the applied water (Table 3).

Average hourly wind speed was obtained from a CIMIS weather station (height 2 meters) approximately 0.25 mile from the site. Average hourly wind speeds ranged from 2.9 to 6.5 mph with a mean of 4.6 mph. Instantaneous wind speed measured at the site with an anemometer approximately 1 foot above grade had mean values of 2.2 mph. Wind direction was generally 45 degrees toward the runoff collection device at the lower end of the plots.

The sprinklers for the sprinkler irrigated plots were new, head to head spacing, new nozzles, and no turf interfering with nozzle spray. Therefore, volume of runoff is probably the minimum expected for these general irrigation conditions.

Table 4 reports the sprinkler runoff in two components of surface runoff and overspray. The mean wind speeds of 2.2 mph were moderate, but accounted for 76 – 83% of total runoff for experiment. Surface runoff was 17 – 24% of total collected runoff; this runoff potentially could be reduced or eliminated by cycle and soak irrigation scheduling or extending the irrigation interval. Runoff due to wind may be more difficult to reduce since the time of the irrigation event with respect to wind is normally not controlled.

Table 3. Runoff as percentage of applied water.

	Mean of 4 plots per treatment, % of Applied Water			
	Surface Flow Emitters	Sprinkler Spray Nozzles		
Date	Collected Surface Runoff	Surface Runoff	Overspray Runoff	Total Collected Runoff
6/1/2007	0.0	0.9	3.1	4.0
6/5/2007	0.0	1.1	3.4	4.5
6/8/2007	0.0	0.7	3.2	3.9
6/12/2007	0.0	0.7	3.5	4.2

Table 4. Surface runoff and overspray components of runoff from sprinkler plots.

	Sprinkler Spray Nozzles		
Date	Surface Runoff, %	Overspray Runoff,%	Total Collected Runoff,%
6/1/2007	23.6	76.4	100.0
6/5/2007	24.3	75.7	100.0
6/8/2007	18.0	82.0	100.0
6/12/2007	17.4	82.6	100.0

As discussed earlier in this report, the water measured in the runoff collection should be considered the minimum runoff expected. The pit at the end each plot where the buckets were installed collected some subsurface flow. These flows were not considered in the above data since we were primarily interested in runoff from the irrigated plots. In a commercial site, subsurface flows may become surface runoff down slope from the site, or it may become deep percolation.

We conducted one test with a 32 minute runtime to create measurable surface runoff from the Surface Flow plots. Surface runoff was measured and the subsurface flow into the collection pit was also estimated. This total runoff was compared to total runoff from the sprinkler plots.

Under these irrigation conditions, there was substantial variation in the volume of runoff, but the Surface Flow had less runoff in each pair of plots (Figure 2).

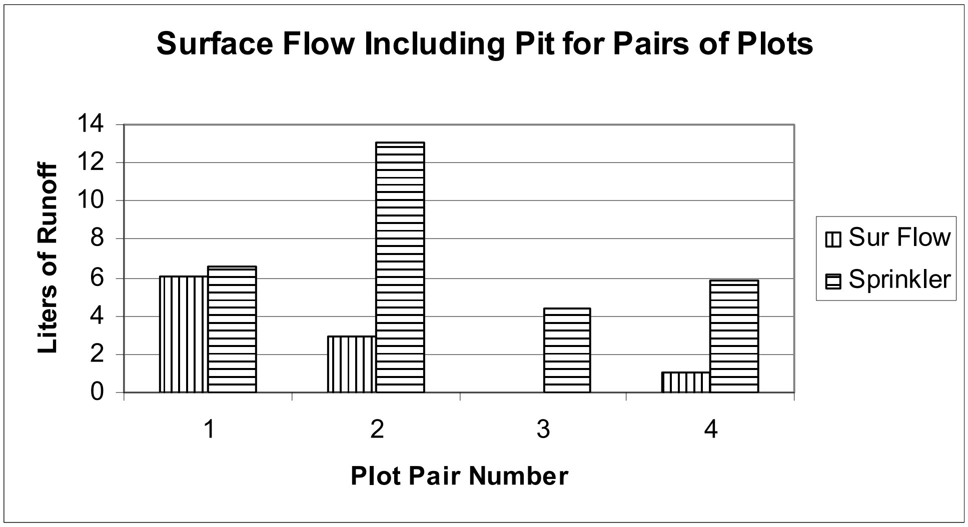

Figure 2. Comparison of potential runoff off perimeter of plots from Surface Flow and sprinkler irrigated plots.

Runoff with Cycle Soak Irrigation and Two Nozzles Types

Surface Runoff with Cycle and Soak Schedules for Sprinklers with Spray Nozzles

There is the question whether surface runoff for sprinklers with spray nozzles can be reduced with cycle and soak programming of the irrigation runtime. Cycle and soak is commonly recommended for irrigation on soils with low infiltration rates. The results of one test run of each sprinkler plot had surface runoff for the irrigation with one cycle more than twice the runoff than any of three cycle and soak irrigation schedules.

The water collected in this test was surface runoff from the 10% slope and any overspray that landed in the 5 inch wide trough at the lower end of the plots.

Surface Runoff Comparisons Between Spray and Rotary Nozzles

The same four plots were used in this study. Six inch popup sprinklers in two plots had spray nozzles and two plots had sprinklers with rotary multi-stream nozzles, all on 30 psi PRS heads. Catch can tests were conducted to determine the distribution uniformity and precipitation rate. Irrigation runtimes were calculated for the soil type, 4 inch root zone, 40% management allowable depletion, and DU_{lh} which determined runtimes of 20 minutes for the spray heads and 27 minutes for rotary nozzles. Runoff was collected in a 5 inch trough at the lower end on the 10% slope. Runoff was measured for10 irrigations over approximately 2 months was determined to be 0.27% of applied water for spray nozzles and 0.29% for rotary nozzles.

Comparisons Wind Drift between Spray and Rotary Nozzles

The same turf plots and sprinklers were used as for the previous study. Wood frame panels with plastic covers were installed around the plot to collect water due to wind drift on all four sides of each plot. The width of the collection panels ranged from 3 to 5 feet to fit the available space. The systems were run early morning, late morning, and early afternoon times; early morning had lower wind speeds.
Overspray accounted for 2.4 to 7.9% of the applied water for the spray nozzles, and 0.8 to 2.7% for the rotary, multi-stream nozzles.

Comparison of Potential Runoff with Spray and Rotary Nozzles after Arc and Radii Adjustment.

This part of the study was conducted to determine if overspray could be decreased by further adjustment of the arc and radius of the sprinkler nozzles. Rotary nozzles had adjustable arcs and radii while the spray nozzles had fixed arcs and adjustable radii. After adjustments there was some overspray visible but it was best that could be done under these field conditions. There were two plots for each type of nozzle.

Wind drift was collected by plastic covered panels surrounding the 10 by 20 foot plots. Surface runoff was also collected at the lower end of each sloped plot. Catch can tests performed on each plot showed DU_{lq} decreased from 38 to 35%for the spray nozzles and 68% to 60% for the rotary nozzles. DU_{lh} was used for scheduling purposes.
Total runoff was 6.3% of applied water for plots with spray nozzles and 1.0% for the rotary nozzles

Summary

A summary of the results are as follows:

- Surface Flow method of irrigation had less runoff than sprinklers with spray nozzles and was not affected by moderate wind conditions.
- Sprinklers with spray nozzles had 3.9 to 4.5% of applied water became runoff surface runoff. Seventeen to twenty four percent of the runoff was surface runoff which can be minimized by proper irrigation scheduling.
- Sprinklers with spray nozzles had 76 – 83 % of the total runoff due to wind drift. It is difficult to reduce with current spray nozzles and controller technologies.
- Sprinklers with spray nozzles had wind drift that ranged from 2.4 to 7.9% of applied water when wind drift is collected from all four sides of plot, and wind in the 0 – 5 mph range.
- Sprinklers with spray nozzles had wind drift that ranged from 0.8 to 2.7% of applied water when wind drift is collected from all four sides of plot, and wind in the 0 – 5 mph range.

General Conclusions

Irrigation systems such as Surface Flow and subsurface drip may have application in narrow turf areas where wind causes runoff, and where design of sprinkler systems in curved areas that

border hardscapes may be difficult. It was possible to control surface runoff from sprinkler irrigated turf on 10% slope with proper runtimes sprinkler.
Wind was an uncontrolled variable in these tests, and wind speed ranged of 0 – 5 mph. Under these conditions total runoff ranged from 1 – 7% of applied water. Runoff due to wind drift was in the range of 70-98% of the total runoff even with wind speeds of 5 mph or less.

Increased use of ET controllers, soil moisture sensors, and good irrigation scheduling practices may minimize surface runoff with sprinkler system near curbs and hardscapes. But to minimize total runoff, the system management must take into account wind speed and direction. The other alternative is to consider methods of irrigation such as Surface Flow and subsurface drip for landscapes near curbs and hardscapes that are affected by wind.

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