Pesticide Runoff Model for Turfgrass: Development, Testing and Application

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1999 Executive Summary

Goals

- *Adapt a previously developed pesticide runoff model to turfgrass conditions and test the accuracy of model predictions by comparisons with data from field experiments.*
- *Use the model to estimate pesticide runoff probabilities (return periods) for a range of chemicals and locations in the eastern U.S.*

Progress

The curve number approach for runoff prediction, as incorporated in the PESTRUN model, was tested using published plot runoff data from six states. The data set included 69 runoff events (30 exceeding 10 mm), three soil hydrologic groups and four turfgrass varieties. Runoff curve numbers were determined for different turf conditions as shown in Table 1.

Cover Condition	Soil Hydrologic Group A	B	C	D
Short grass (< 50 mm)	39	61	74	80
Tall grass (≥ 50 mm))	30	58	71	78
Heavily thatched short grass	35	55	67	72
Heavily thatched tall grass	27	52	64	70

Table 1. Curve Numbers for Turfgrass for Average Antecedent Moisture (CN2).

When data from all events are combined, the statistical comparisons in Table 2 indicate a high level of model performance for all events and also for the 30 largest. The curve number model, as incorporated in PESTRUN explains 77% of the variation in observed runoff at the sites. We conclude that the PESTRUN model is a reasonable approach for estimating runoff from turf.

	All 69 Events	Largest Observed Events ($Q_t \geq 10$ mm; 30 events)
Mean (mm)		
Model	13.1	23.8
Observed	13.1	24.7
Standard Deviation (mm)		
Model	15.0	16.5
Observed	14.7	15.9
Spearman R^2	0.77	0.69

Table 2. Statistical Comparison of PESTRUN Results and Observed Runoff.

GOALS

- *Adapt a previously developed pesticide runoff model to turfgrass conditions and test the accuracy of model predictions by comparisons with data from field experiments.*
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1999 PROGRESS

The dense vegetation of turfgrass and thatch minimizes possibilities for pesticide runoff. High water retention and infiltration constrain runoff opportunities and extensive pesticide adsorption by surface organic matter reduce chemical mobility. However, conditions such as thin stands, repeated irrigation applications and/or extreme hydrologic events can produce significant pesticide losses. Mathematical models can be used to simulate these conditions, and provided the simulations include sufficiently long weather records, return periods of pesticide runoff may be obtained. The approach is plausible only if a model can be shown to be a reasonable description of the pesticide runoff process, as confirmed by testing with field data. In this fashion, the model becomes a means of efficiently extrapolating the results of field experiments.

Research during the past year has continued an evaluation of the hydraulics portion of PRZM (Carsel *et al*., 1998) and PESTRUN(Haith, 1980,1985). Both models base runoff estimates on the U.S. Soil Conservation Service Curve Number equation, although the adaptations differ considerably. Both models require an average curve number as input datum. However, the actual curve number used in computing runoff for a particular event is determined by the current antecedent moisture. Antecedent moisture in PRZM is calculated as the actual moisture content of the top soil (and thatch) layers. PESTRUN uses the standard measure of 5-day antecedent precipitation, which is at best only an approximation of soil moisture content.

A central research question is whether either of these curve number based approaches are capable of representing runoff from turfgrass, and we are answering that question by determining if runoff measurements in field studies can be duplicated by model estimates. The initial testing was based on runoff measurements from turf plots at Penn State University (Linde *et al*.,1995; Linde & Watschke, 1997). Results from these tests were inconclusive, and neither model was particularly accurate.

Any single set of plots provides a very limited basis for model testing. However, in the last several years runoff data from a number of different sites have been published, including Georgia (Smith & Bridges, 1996; Hong & Smith,1997), Indiana (Moe *et al*., 1967, 1968), Kentucky (Evans *et al*., 1998), Maryland (Gross *et al*., 1991), and Oklahoma (Cole *et al*., 1997). When combined with the Pennsylvania experiments, these data provide a rich variety of information for model testing, including 69 runoff events in six states, three soil hydrologic groups, and four different turfgrasses (Bermudagrass, bentgrass, tall fescue and ryegrass). Unfortunately, most of these studies did not include sufficient plot and weather data for PRZM runs. However, information was sufficient for the much less data intensive PESTRUN model.

The basic runoff model in PESTRUN is based on the standard application of the curve number equation, with:

$$Q_t = \frac{(R_t - 0.2\, S_t)^2}{R_t + 0.8\, S_t} \quad \text{for } R_t \geq 0.2\, S_t \qquad (1)$$

where Q_t, R_t and S_t = runoff, rain and water detention, respectively on day t (mm), and S_t is related to a curve number, CN_t, by

$$S_t = \frac{25400}{CN_t} - 254 \qquad (2)$$

Curve number selection is determined by soil, cover and antecedent moisture conditions. Three different antecedent moisture levels are specified, 1,2, and 3 corresponding to very dry, average moisture and very wet conditions, with associated curve numbers CN1, CN2, and CN3. Current conditions are determined by A_t, the 5-day antecedent precipitation, or total rainfall in the 5 days preceding day t (mm).

Limiting curve number selection to only three distinct values is physically unrealistic, because of the resulting discontinuities in runoff calculations. Small changes in antecedent moisture produce implausibly large changes in curve number and hence runoff. Hence, in PESTRUN, these discontinuities are smoothed by making curve numbers continuous functions of antecedent precipitation, as indicated in Figure 1.

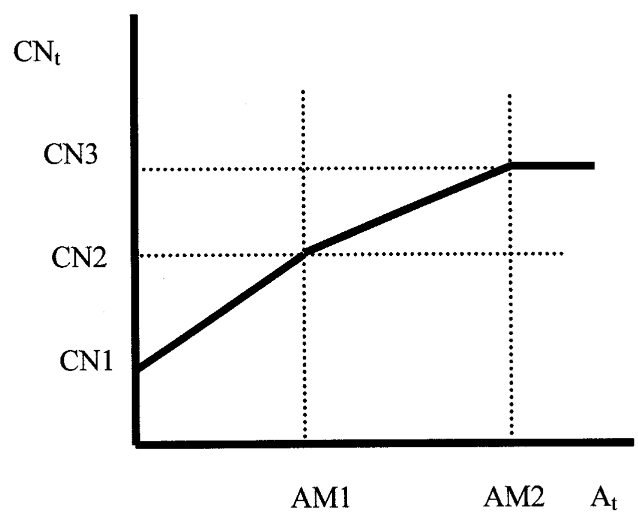

Figure 1. Curve Number Selection in PESTRUN as Function of 5-day Antecedent Precipitation.

The two A_t limits, AMC1 and AMC2 (mm) which are usually used are AMC1 = 13, 36 mm for dormant and growing seasons, respectively, and AMC2 = 28, 53 mm for dormant and growing seasons, respectively (Ralston, 1985). However, we obtained significantly better results with

AMC1 = 20 mm and AMC2 = 50 mm, and the results presented in this report are based on these values.

Since CN1 and CN3 can be computed from CN2 by equations given in Hawkins (1978), CN2 is the only parameter needed for the runoff model. However, selection of appropriate average curve numbers (CN2) for turfgrass is problematic. The numbers suggested in Soil Conservation Service (1986) for "open space" are actually pasture or range curve numbers (Ralston, 1985). The suggested curve numbers for "meadow" are also possible candidates for tall grasses. Neither set of curve numbers would seem to reflect the impacts of turf thatch. This thick mat of decaying vegetation in many established turfs increases moisture storage and infiltration (Taylor & Blake, 1982).

To determine appropriate curve numbers for heavily thatched conditions, we assumed that thatch has effects similar to those of plant residues left on the soil surface with conservation tillage. In their study of effects of conservation tillage on runoff from field crops, Rawls *et al.* (1980) determined that as surface coverage from residues increased to more than 60-70%, runoff curve numbers were reduced by approximately 10%. The curve numbers in Table 1 were obtained by using this 10% reduction, and assuming that the pasture and meadow curve numbers are appropriate. This produces four sets of curve numbers for short and tall grasses, with and without thatch.

	Soil Hydrologic Group			
Cover Condition	A	B	C	D
Short grass (lawns < 50 mm; fairways, tees, greens)[a]				
Poor condition (cover < 50%)	68	79	86	89
Fair condition (cover 50-75%)	49	69	79	84
Good condition (cover > 75%)	39	61	74	80
Tall, dense grass (roughs, lawns cut high (≥ 50 mm))[b]	30	58	71	78
Heavily thatched short grass[c]	35	55	67	72
Heavily thatched tall grass[c]	27	52	64	70

[a] Pasture and range curve numbers from Ralston (1985).
[b] Meadow curve numbers from Ralston (1985).
[c] Curve numbers reduced 10%, similar to conservation tillage (Rawls *et al.*, 1980).

Table 1. Curve Numbers for Turfgrass for Average Antecedent Moisture (CN2).

Site	Conditions	Runoff Events	Mean Runoff (mm)		Runoff for Largest Observed Event (mm)	
			Model	Observed	Model	Observed
GA	Bermudagrass soil C	13	10	13	24	36
IN	tall fescue soil C	9	26	25	33	48
KY	tall fescue soil B	3	5	9	10	13
MD	tall fescue partial cover soil B	12	11	12	22	23
OK	Bermudagrass soil D	8	35	32	56	63
PA	bentgrass soil C	12	6	3	21	8
	ryegrass soil C	12	4	5	35	14

Table 2. Comparison of PESTRUN Model Runoff Estimates with Observed Values at 6 Locations.

	All 69 Events	Largest Observed Events ($Q_t \geq 10$ mm; 30 events)
Mean (mm)		
Model	13.1	23.8
Observed	13.1	24.7
Standard Deviation (mm)		
Model	15.0	16.5
Observed	14.7	15.9
Spearman R^2	0.77	0.69

Table 3. Statistical Comparison of PESTRUN Results and Observed Runoff.

Comparisons of model results with observed runoff are given for each site in Table 2. Comparisons are made both for means and the largest event at each site. Such events are probably the most important in assessment of water pollution hazards. Although model accuracy differs from location to location, means are predicted fairly well at most sites. Maximum events are estimated more erratically, as might be expected for these single events. Except for the Pennsylvania site, the model appears to have a tendency to underestimate these extremes.

When data from all events are combined, the statistical comparisons in Table 3 indicate a high level of model performance for all events and also for the 30 largest events (those with observed runoff exceeding 10 mm). The curve number model, as incorporated in PESTRUN explains 77% of the variation in observed runoff at the sites.

We conclude that the curve number model, with curve numbers selected as indicated in Figure 1 and Table 1, is a reasonable approach for estimating runoff from turf.

RESEARCH PLANS FOR 2000

This year has concluded the testing of model hydraulics. The curve number approach for runoff estimation used in PESTRUN is clearly a suitable approach for runoff estimation. We will drop the PRZM model from further testing because sufficient site data are unavailable for parameter estimation.

We will continue testing of the PESTRUN model, focusing on its ability to predict pesticide levels in runoff. Testing will be based on plot data from the four turf runoff sites that also measured pesticide losses - Georgia, Kentucky and Oklahoma, and Pennsylvania.

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