EFFECT OF IRRIGATION SCHEDULING ON MOVEMENT OF PESTICIDES TO GROUND WATER IN COARSE SOILS:

MONTE CARLO ANALYSIS OF SIMULATION MODELING

By

F. Spurlock

January 2000

STATE OF CALIFORNIA
Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring and Pest Management Branch
Environmental Hazards Assessment Program
Sacramento, California 95814-3510
EH 00-01

ABSTRACT

Short-term field studies conducted over several weeks have shown that efficient irrigation scheduling in coarse soils reduces downward movement of pesticides through the soil profile. From a regulatory standpoint, further information over environmentally relevant time scales is required before specific efficient irrigation scheduling practices can be recommended as a mitigation measure to reduce pesticide movement to ground water in coarse soils. Longer-term field studies to obtain this information are difficult to design and conduct due to experimental difficulties and prohibitive cost. As an alternative, this report documents the results of computationally intensive computer simulation techniques that were used to evaluate the effect of duration of post-application irrigation restrictions on leaching of known California ground water contaminants in coarse soils. Similar to field data, the results indicate that irrigation scheduling based on evapotranspirative water demand is an effective approach for mitigating pesticide movement to ground water in coarse soils. Under the particular scenario and assumptions described herein, model outputs indicate that restriction of irrigation water applications to 133 percent of evapotranspirative demand for a period of six months following herbicide application will provide a greater than 95 per cent probability that currently known California pesticidal ground water contaminants listed in Title 3, California code of regulations, section 6800(a), will not be detected in ground water above current analytical reporting limits of 0.05 $\mu g\ L^{-1}$ (parts per billion, ppb). In contrast, model predictions for shorter duration irrigation restrictions following application indicate a greater likelihood of pesticides arriving in ground water at measureable concentrations. As indicated by a discussion of modeling limitations and uncertainties, these probabilities of contamination are best considered as estimates of actual possible outcomes under the different scenarios.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Mitigation of pesticide movement to California ground water will require a modification of agricultural management/pesticide use practices responsible for post-application off-site movement. Detections of pesticides in California ground water have been found in a variety of diverse climatic and soil conditions. One condition where pesticides have been found in California ground water is in semi-arid intensively irrigated coarse soil areas with shallow depth-to-ground water. Coarse soils are highly permeable so that dissolved substances move with percolating water - a process known as leaching. Efficient irrigation practices that minimize deep percolation will therefore minimize pesticide leaching. Field studies conducted in coarse Fresno County soils over 6 to 8 week time periods have demonstrated that irrigation scheduling based on evapotranspirative crop water demand can be effective for maintaining pesticide residues in the root zone and reduce their downward movement (Troiano et al., 1993). This report compares the effect of the duration of efficient post-application irrigation practices over longer time periods on the potential of 6800(a) pesticides to move to ground water. Included is a discussion of modeling assumptions, description of the modeling scenario, sources of input data, and potential uncertainties.

The purpose of this modeling project was to address the following question:

> *What is the effect of requiring efficient irrigation scheduling for different periods of time following application of a known ground water contaminant in coarse soils on the potential for the contaminant to be detected in ground?*

Monte Carlo analysis, a method of estimating the probability distribution of a model output variable given the distributions of input variables, was used in this study. The method involves repetitive model simulations in which each simulation is conducted using input variables randomly selected from their respective probability distributions. The aggregate output data is used to estimate the probability distribution of a selected output variable. The two input variables that were varied were field dissipation half-life data ($t_{1/2}$, days) and organic carbon normalized soil sorption coefficient data (K_{OC}) of known California ground water contaminants. The input data set for each simulation was obtained by generating random combinations of the possible 2964 ($t_{1/2}$, K_{OC}) data pairs by independent “resampling” (with replacement) from the half-life and K_{OC} data sets (n=52 and 57, respectively). A total of 969, 332, 310, and 673 simulations were conducted to estimate the distribution of expected ground water concentrations for the four cases of zero-, four-, five-, and six-month irrigation restrictions, respectively.

LEACHP (Hutson and Wagenet, 1992) was used for transport simulations because the model describes water flow using the Richard’s equation, the most theoretically rigorous modeling approach to describing water movement in soil. While other popular currently available models, such as PRZM 3.12, utilize a simpler “tipping bucket” approach to describing water movement (Carsel et al., 1998), preliminary results comparing the two models under coarse soil, irrigated California conditions indicate that LEACHP is superior to PRZM in describing solute movement under a range of irrigation practices (Spurlock, 1998). For the present simulations, the modeling scenario was based on climate and soil data representative of areas in Eastern Fresno County where there have been numerous detections of pesticides in ground water. The “representative” soil profile texture, bulk density, and organic carbon data were taken from the study of Troiano et al. (1993) that was conducted in a coarse Fresno County Delhi loamy sand (1993).

MODELING PROCEDURE AND SCENARIO

Program Execution

Individual computer simulations were conducted using a modified version of LEACHP, the pesticide component of the LEACHM model (Hutson and Wagenet, 1992). The SENSAN.EXE program, a component of PEST98 (Watermark Computing, 1998) was used to generate the Monte Carlo output results for each case of irrigation restriction by repeating the following steps:

1. read next Koc/field dissipation half-life data pair from random parameter file,
2. write data pair to appropriate location in LEACHP input file,

3. initiate LEACHP.EXE execution,
4. read output from the resultant LEACHP output file following model execution, and
5. write (append) those results to a SENSAN output file.
6. repeat.

Calculation of estimated ground water concentrations

Each individual model simulation was conducted over a three year period so that the output for the third year would reflect a near steady-state pesticide flux density of eluting from the soil profile (kg $[ha\ y]^{-1}$) from the annual applications. These third year outputs were used to calculate a distribution of estimated ground water concentrations for each case. Based on the within-aquifer depth gradient of chlorofluorocarbon estimated ground water recharge ages in Fresno and Tulare County and water balance calculations, the approximate annual ground water recharge in eastern Fresno County is approximately 0.5 meters (Spurlock et al., 2000). The annual eluted mass of pesticide was then combined with the annual recharge volume to yield estimated ground water concentrations. The resultant annual average eluant concentration was then assumed to undergo degradation for six years, where this period of time corresponds to the median chlorofluorocarbon estimated ground water recharge age in the area (Spurlock et al., 2000). The degradation half-life was taken as 365 days, the maximum half-live reported for the pesticides in Appendix 1.

Soil profile descritization and parameterization

Comparison of preliminary model simulations of bromide movement in the representative 3 meter coarse soil profile to measured field data indicated a high level of numerical dispersion. One contribution to numerical dispersion in LEACHM is related to the size of the depth node spacing, with numerical dispersion increasing with larger spacings (Hutson and Wagenet, 1992). The maximum number of nodes is defined by the parameter LL in the source code file PARMS.FOR; the value of LL in the original program is 28. To reduce numerical dispersion, the source code was modified to allow a maximum value of 120 for LL, and the program recompiled. The simulations were conducted using node spacings of 30.3 millimeters, corresponding to 101 nodes over the 3030 millimeter soil profile.

Soil texture and organic carbon content used in the simulations were based on the field data from Troiano et al. (1993). In that study measured soil bulk densities were relatively constant with depth (1.58 ± .05 g cm^{-3}); similarly, soil textures were relatively homogeneous while soil organic carbon content decreased markedly with depth (Fig. 1 & 2). Soil hydraulic parameters and dispersivity λ are correlated with texture and bulk density, and so were taken as constant with depth throughout the profile here. LEACHM uses the Campbell equation (Campbell, 1974) to describe the relationship between soil water matric potential h and water content Θ.

$$h = a\left(\frac{\Theta}{\Theta_S}\right)^{-b}$$

where Θ_S refers to saturated water content, and *a* and *b* are parameters. A similar expression containing *a* and *b* is used to relate hydraulic conductivity to water content (Hutson and Wagenet, 1992). Dispersivity λ describes mixing within and between soil pores that occurs due to local variations in water flow velocity. The profile-average λ and the hydraulic parameters *a* and *b* used to describe the soil water matric potential/water content/hydraulic conductivity relations were obtained from bromide tracer field data from a previous study in coarse Fresno County soil (Troiano et al., 1993) (Fig. 3). In that study, bromide tracer was applied to six different irrigation treatments (sprinkler low, medium, and high water applications, and border low, medium, and high water applications). Best-fit estimates for *a*, *b*, and λ were obtained using nonlinear optimization techniques by fitting LEACHM output to the measured data (Watermark Computing, 1998). Criterion for best-fit was the overall minimum sum of squared residuals (measured bromide - predicted bromide) across all six irrigation treatments, where residuals within each treatment were weighted inversely by the square root of total bromide recovery in that treatment. The actual values of *a, b*, and λ so obtained were -0.1644 kPa, 5.191 (unitless), and 48.8 mm, respectively.

FIGURE 1. Soil texture vs. depth
(Delhi loamy sand, Fresno County, CA.)

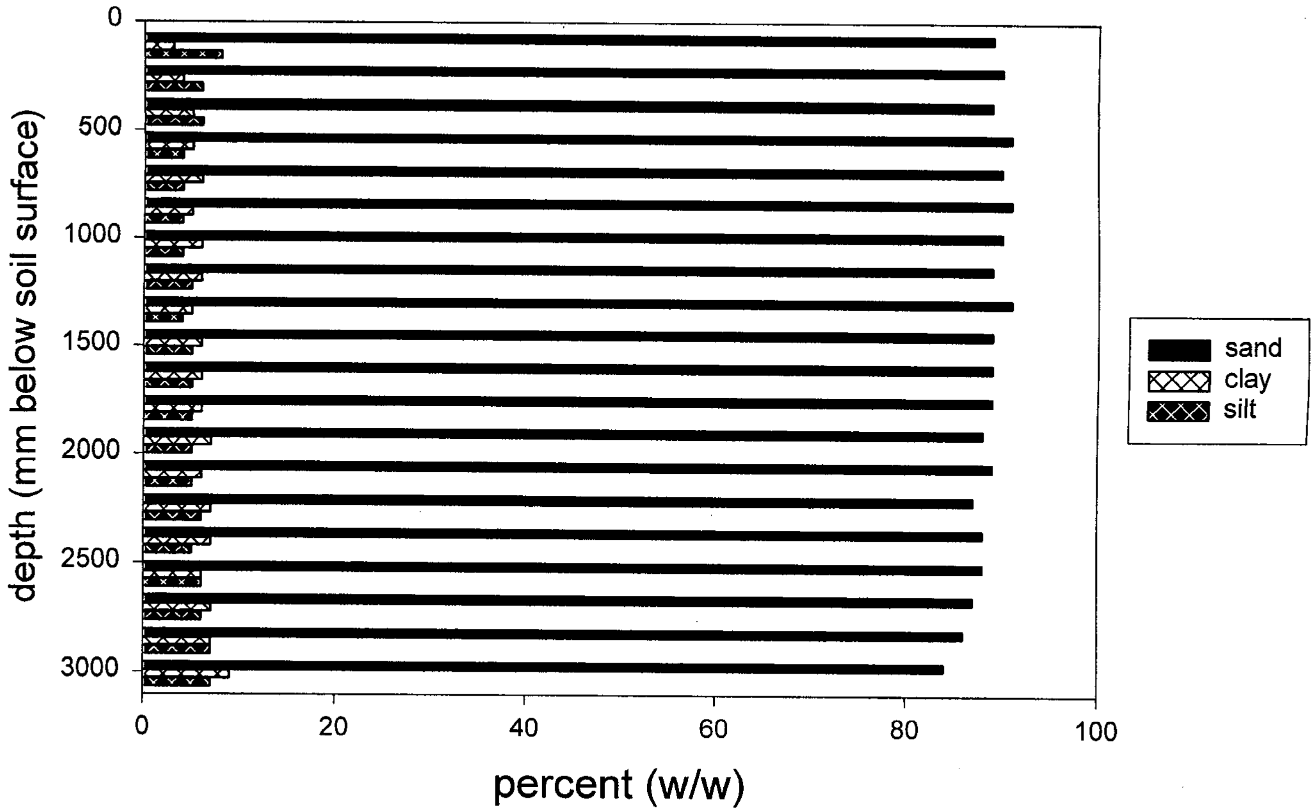
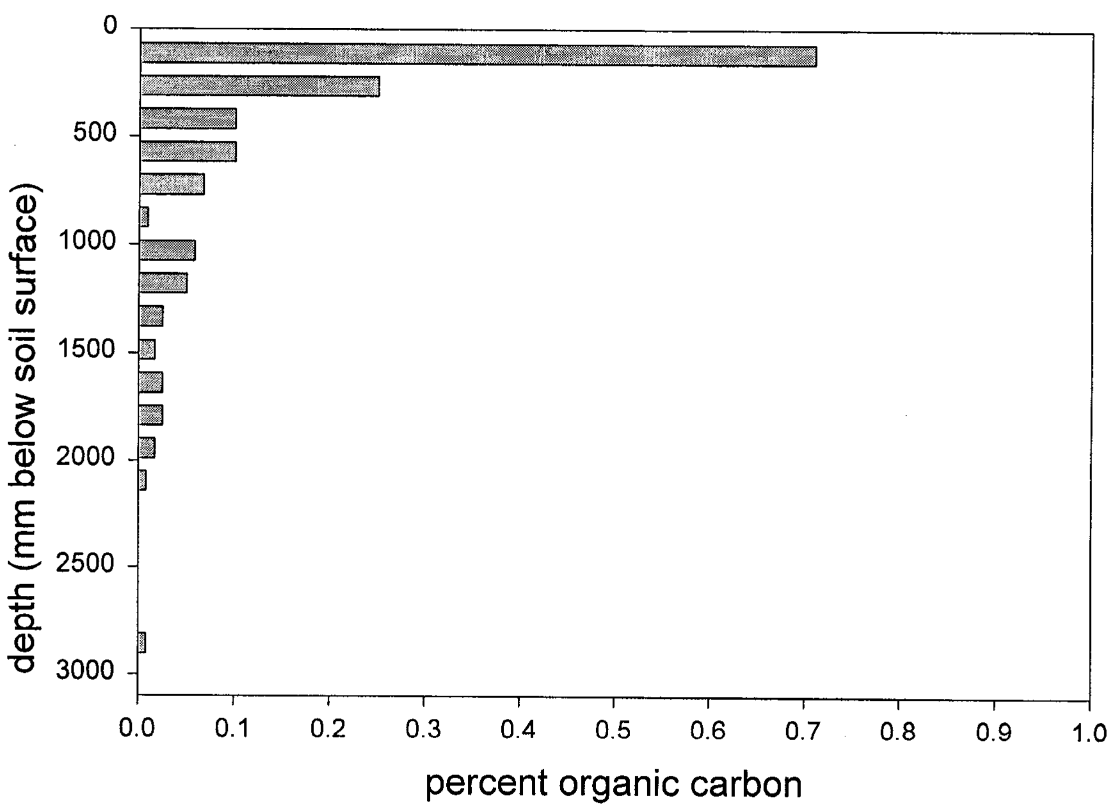


FIGURE 2. Organic carbon vs. depth



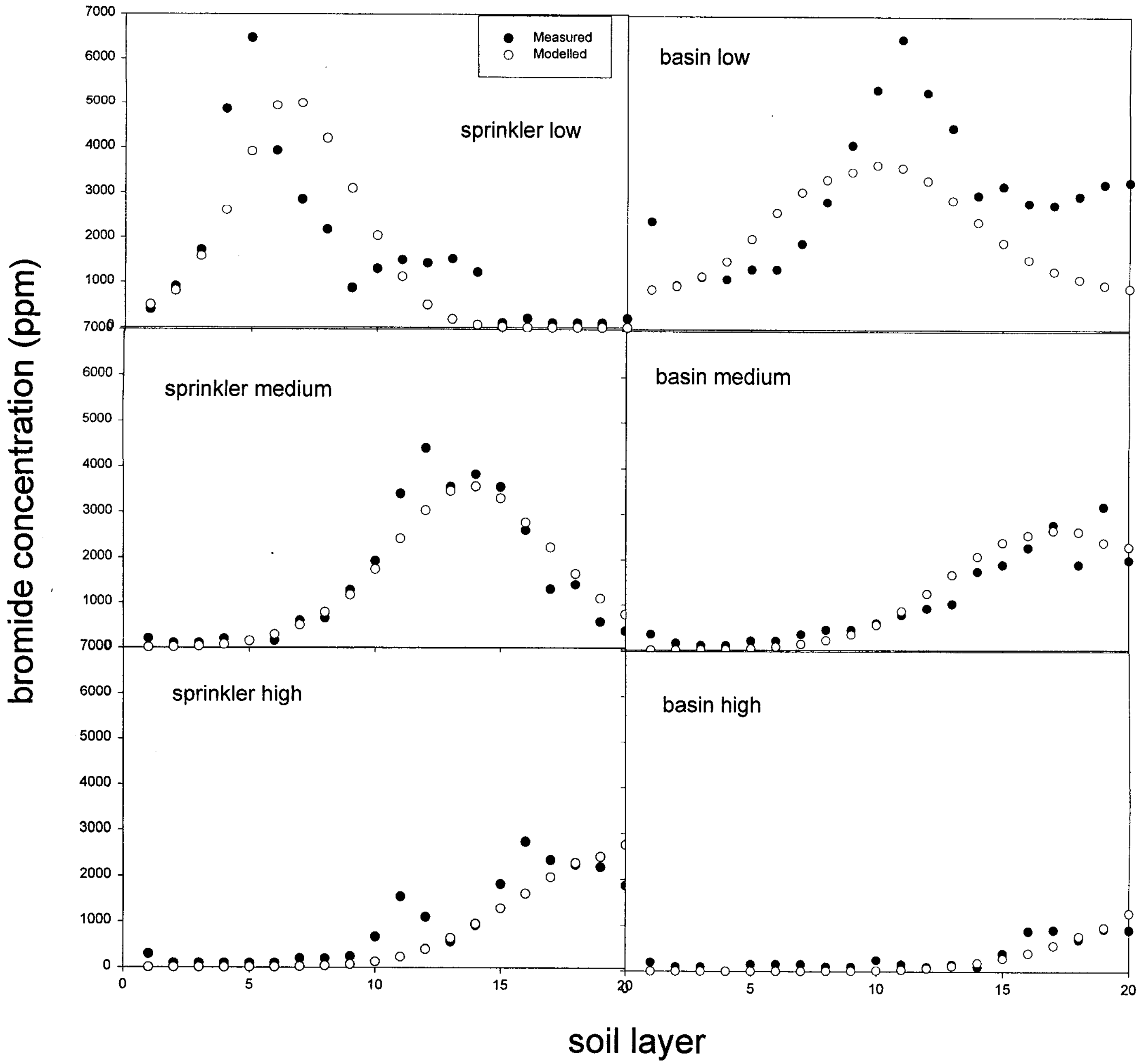


FIGURE 3. Measured and "best-fit" simulated bromide tracer data. Field data from Troiano et al. (1993). Best-fit data were obtained using nonlinear optimization techniques (Watermark Computing, 1998) to determine profile-average dispersivity and the 2 LEACHM soil hydraulic parameters used to describe the soil water matric potential/water content/hydraulic conductivity relations. Dispersivity (λ) describes mixing within and between soil pores that occurs due to local variations in water flow velocity. The two hydraulic parameters (*a,b*) are commonly known as the soil "air-entry value" and the Campbell equation exponent (Hutson and Wagenet, 1992, Campbell, 1974). Criterion for best-fit was the overall minimum sum of squared residuals (measured - predicted) across all six irrigation treatments, where residuals within each treatment were weighted inversely by the square root of total bromide recovery in that treatment.

Irrigation water applications

Surface irrigation methods are generally considered prone to low efficiencies (= [depth evapotranspirative crop water demand/depth required water applied]). However, under proper management, efficiencies approaching 75 percent are attainable for surface irrigation systems (California Agricultural Technology Institute, 1988; Snyder et al., 1986). Consequently, efficient irrigation was defined here from a practical standpoint as irrigation water applied to meet crop water need at 75 percent efficiency; this corresponds to water applications of 1/0.75 = 133% of evapotranspirative demand. Estimates of current irrigation efficiencies in California range from about 60 to 70 per cent (California Agricultural Technology Institute, 1988; Snyder et al., 1986), corresponding to irrigations of about 145 to 170 percent of crop water need. Based on this, irrigation applications of 160 percent of evapotranspirative demand were used in a "baseline" simulation analysis to approximately represent recent conditions, and for simulation of water inputs during the low efficiency irrigation scenarios

Climate/evapotranspiration data

Climatic rainfall averages were used as water inputs during the non-irrigation season (November - April). Precipitation occurred each time the accumulated long-term mean daily precipitation reached 1.2 cm (0.5 inches) since the previous water input. Mean long-term daily temperature, precipitation, and reference evapotranspiration (ET_o) data from the California Irrigation Management Information System weather station #80 at Fresno State University, Fresno, California were obtained from a public internet source (http://www.ipm.ucdavis.edu/WEATHER/weather1.html). Crop water evapotranspiration coefficients (Univ. of Calif., 1989) for San Joaquin Valley grape vineyards were applied to the ET_o data to determine crop water demand. An example LEACHP input file with these data is given in Appendix 2.

Pesticide data

Pesticide mobility and persistence data for the six California ground water contaminants atrazine, bromacil, diuron, hexazinone, norflurazon, and simazine were used in the Monte Carlo simulations (Kollman and Segewa, 1995; USDA-ARS, 1999). Cumulative frequency distributions of the aggregate $t_{1/2}$ and K_{OC} data are shown in Fig. 4 and 5 and the data are listed in Appendix 2. Other currently registered active ingredients that are known California ground water contaminants include bentazon and prometon. Prometon is not registered for crop use in California. California's bentazon detections are largely restricted to clay soils in rice-growing regions, where the specific transport mechanism has been the subject of controversy. Consequently, data for these pesticides were not included in the simulations. Degradation half-lives were assumed to apply to the bulk soil (i.e. adsorbed + solution phase pesticide); the first order rate constants were assumed constant over the soil profile depth of 3 m. The pesticide application of 2.2 kilograms per hectare was simulated to occur in early March, the approximate start of the irrigation season in California's Central Valley.

RESULTS

As previously mentioned, baseline simulations were conducted to compare modeled ground water concentrations using the above scheme to actual 6800(a) ground water monitoring results from a coarse soil area in Fresno County (Townships 14S-17S, Range 20E-23E). The simulation results compare favorably to the actual monitoring data. Over a range of concentrations spanning more than an order of magnitude simulated and actual monitoring data show similar maximum and median concentrations under the baseline scenario (Fig. 6).

The cumulative frequency distribution of expected ground water concentrations ($\mu g\ L^{-1}$, ppb) for the cases of four, five and six month irrigation restriction are shown in Figs. 7-9. Table 1 illustrates a marked effect of improved irrigation efficiency on estimated ground water concentrations predicted from the model output. The current analytical reporting limit (RL) used by DPR for simazine, atrazine, diuron, bromacil, hexazinone, and norflurazon is 0.05 ppb. The predicted results under the scenario of 6 months efficient irrigation are lower than the RL in more than ninety-five per cent of the simulations.

FIGURE 4. Atrazine, bromacil, diuron, hexazinone, norflurazon, simazine USDA-ARS and PESTCHEM field dissipation half-lives (n=52)

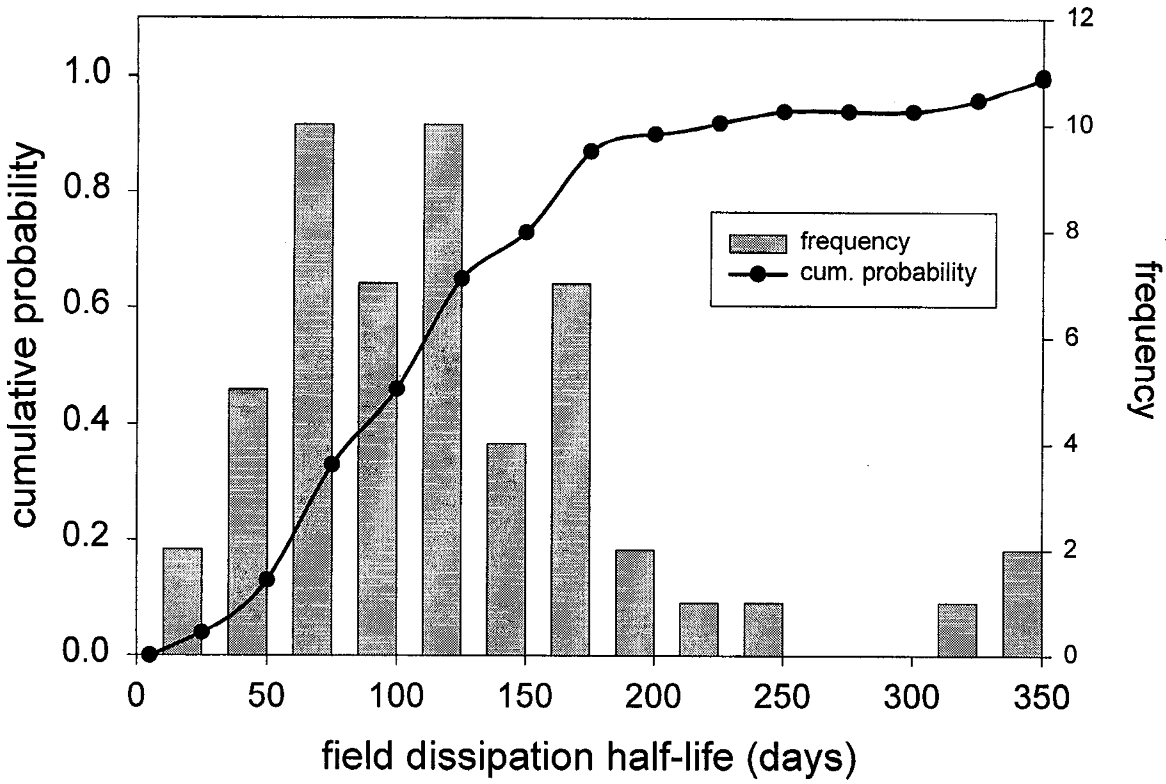


FIGURE 5. Atrazine, bromacil, diuron, hexazinone, norflurazon, simazine USDA-ARS K_{OC} values (n=56)

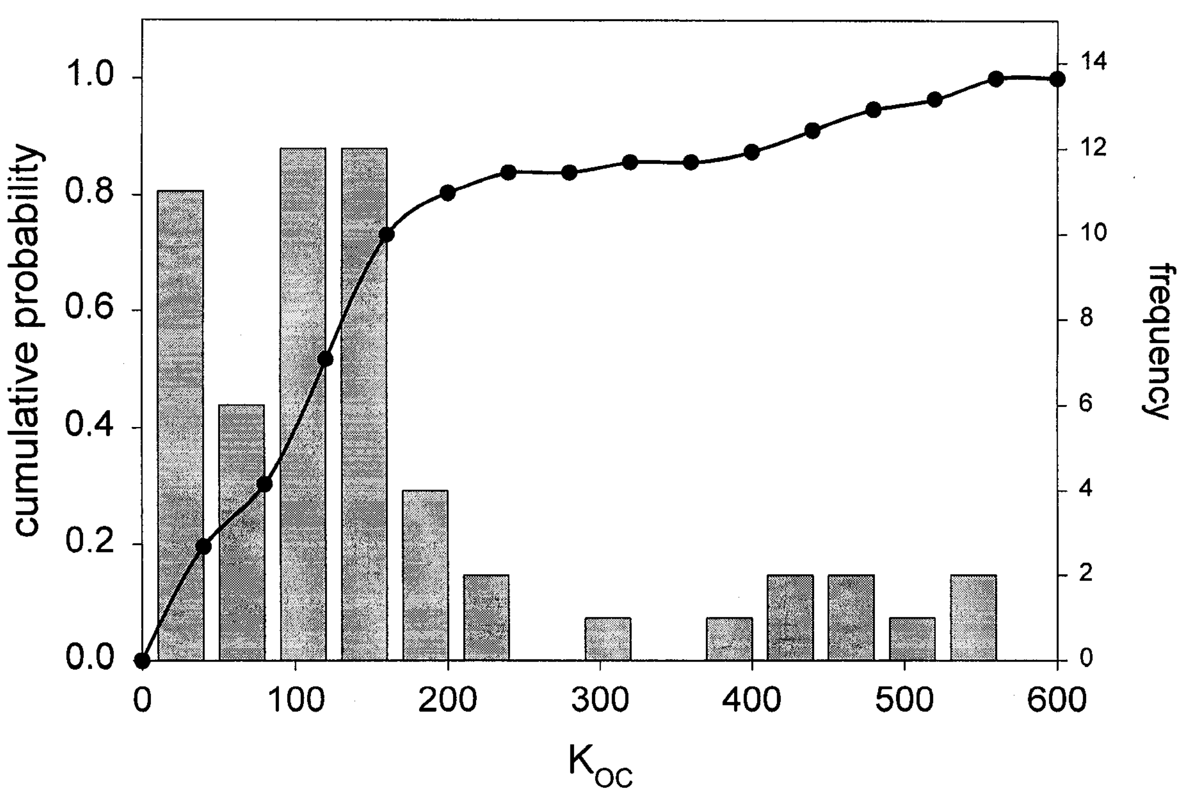
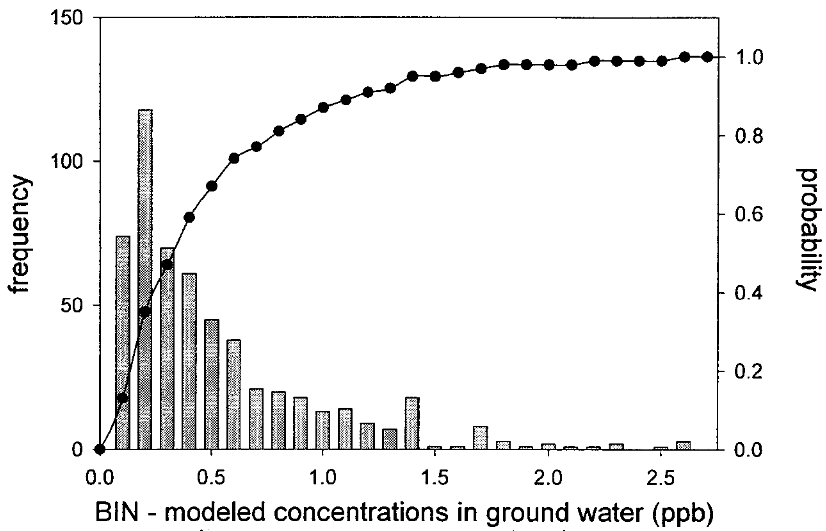


FIGURE 6. Comparison of modeled and observed 6800(a) concentrations – "baseline" simulations at 160% ET water applications

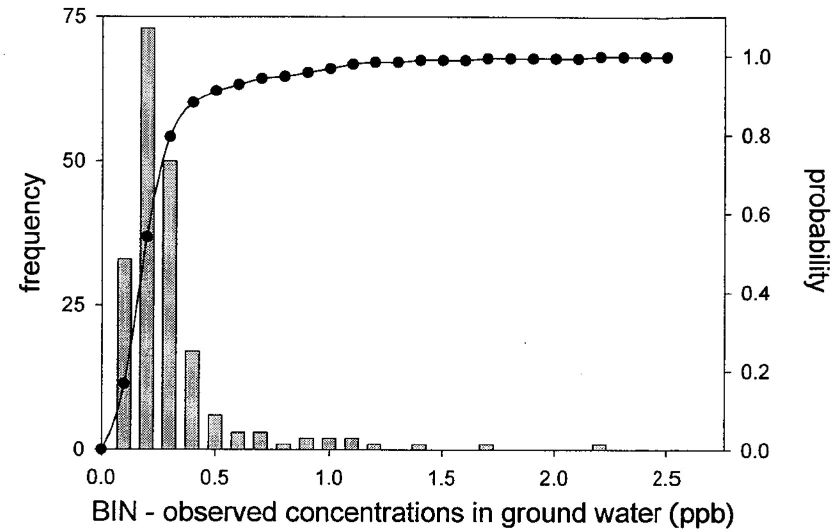
LEACHM Modeled concentrations:
coarse soils with irrigation at 160% ET



Quantiles		
maximum	100.0%	2.8464
	99.5%	2.6351
	97.5%	1.7682
	90.0%	1.1484
quartile	75.0%	0.6417
median	50.0%	0.3234
quartile	25.0%	0.1508
	10.0%	0.0885
	2.5%	0.0628
	0.5%	0.0520
minimum	0.0%	0.0507

Moments	
Mean	0.4830
Std Dev	0.4787
Std Error Mean	0.0204
Upper 95% Mean	0.5230
Lower 95% Mean	0.4430
N	552.0000

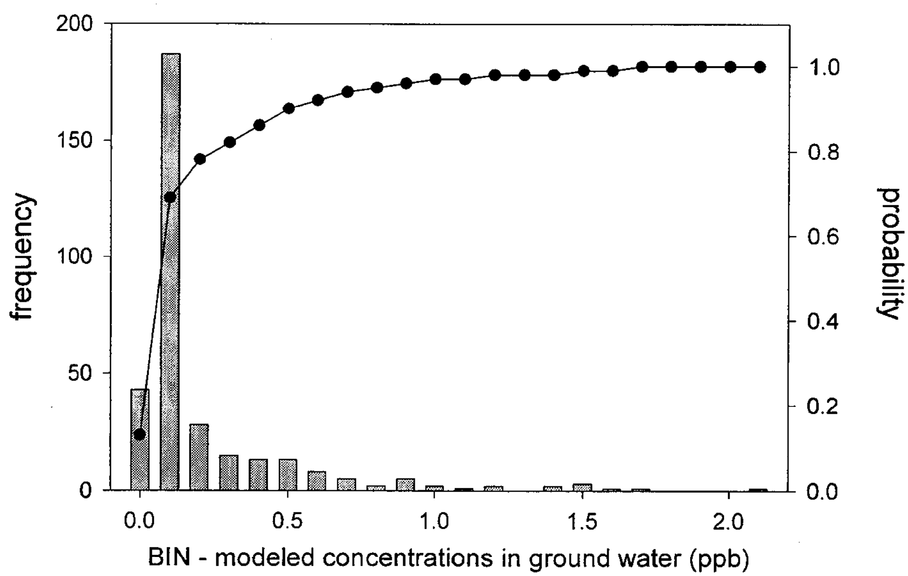
Observed 6800(a) pesticide detections in coarse Fresno County
soils: Townships 14S-17S, Ranges 20E-23E



Quantiles		
maximum	100.0%	2.1650
	99.5%	2.1650
	97.5%	1.0408
	90.0%	0.4795
quartile	75.0%	0.2700
median	50.0%	0.1867
quartile	25.0%	0.1150
	10.0%	0.0873
	2.5%	0.0639
	0.5%	0.0500
minimum	0.0%	0.0500

Moments	
Mean	0.2566
Std Dev	0.2667
Std Error Mean	0.0190
Upper 95% Mean	0.2942
Lower 95% Mean	0.2190
N	196.0000

FIGURE 7. Distribution of estimated ground water concentrations for case of 4 month irrigation at 133 per cent crop water need



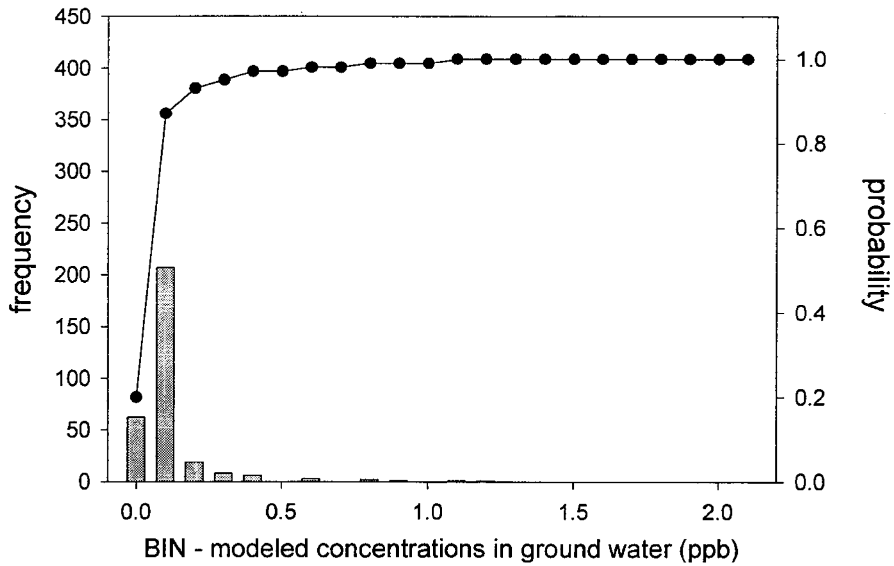
Quantiles

maximum	100.0%	2.0274
	99.5%	1.8084
	97.5%	1.3200
	90.0%	0.5013
quartile	75.0%	0.1726
median	50.0%	0.0255
quartile	25.0%	0.0018
	10.0%	0.0000
	2.5%	0.0000
	0.5%	0.0000
minimum	0.0%	0.0000

Moments

Mean	0.1626
Std Dev	0.3109
Std Error Mean	0.0171
Upper 95% Mean	0.1961
Lower 95% Mean	0.1290
N	332.0000

FIGURE 8. Distribution of estimated ground water concentrations for case of 5 month irrigation at 133 per cent crop water need



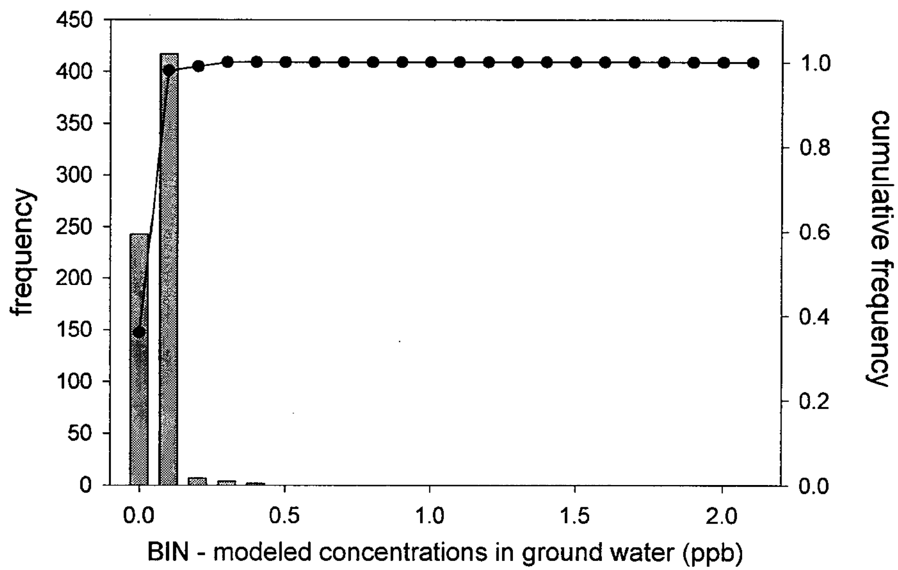
Quantiles

maximum	100.0%	1.1311
	99.5%	1.0585
	97.5%	0.5462
	90.0%	0.1307
quartile	75.0%	0.0407
median	50.0%	0.0051
quartile	25.0%	0.0002
	10.0%	0.0000
	2.5%	0.0000
	0.5%	0.0000
minimum	0.0%	0.0000

Moments

Mean	0.0534
Std Dev	0.1409
Std Error Mean	0.0080
Upper 95% Mean	0.0692
Lower 95% Mean	0.0377
N	310.0000

FIGURE 9. Distribution of estimated ground water concentrations for case of 6 month irrigation at 133 per cent crop water need



Quantiles

maximum	100.0%	0.32376
	99.5%	0.27122
	97.5%	0.08390
	90.0%	0.02128
quartile	75.0%	0.00691
median	50.0%	0.00074
quartile	25.0%	0.00000
	10.0%	0.00000
	2.5%	0.00000
	0.5%	0.00000
minimum	0.0%	0.00000

Moments

Mean	0.0101
Std Dev	0.0327
Std Error Mean	0.0013
Upper 95% Mean	0.0126
Lower 95% Mean	0.0076
N	673.0000
Sum Weights	673.0000

Table 1. Summary of Monte Carlo modeling results – estimated ground water concentrations from LEACHM output.

Duration of irrigation restriction	95th percentile estimated ground water concentrations (ppb)	max	median	number of simulations
0 months†	1.2	2.8	0.32	969
4 months	0.88	2.4	0.03	332
5 months	0.29	1.1	0.01	310
6 months	0.047	0.32	0.00	673

† simulation results for no irrigation restrictions ("baseline" case) with irrigation at 160% of evapotranspirative crop water demand.

LIMITATIONS/SOURCES OF UNCERTAINTY

There are several potential sources of uncertainty/limitations to the modeling of pesticide leaching in soils. Some of the most important are discussed below:

Pesticide transport was modeled as a one-dimensional process, so that potential preferential flow pathways or fingering phenomena are not considered. While the particular coarse soil modeling scenario here might be expected to best approximate one-dimensional transport (as opposed to finer soils), observations of nonuniform downward movement are common even in coarse soils (Rice et al., 1991; Troiano et al., 1993).

The simulations conducted are representative of uniform water application methods such as sprinkler irrigation. A variety of nonuniform irrigation methods are used throughout the San Joaquin Valley, including drip and furrow irrigation. Nonetheless, the general trend of decreased leaching with increasing irrigation efficiency should be generally applicable across all irrigation methods.

Several studies have shown that pesticide degradation rates often decrease with depth, particularly when microbial degradation is the primary route of breakdown (Miller et al., 1997; Kordel et al., 1995; Johnson and Lavy, 1994; Anderson, 1984; Kruger et al., 1993). This occurs because microbial activity and soil organic carbon decrease markedly below the root zone. Currently there is insufficient information to simulate the vertical distribution of degradation rates in the soil profile, therefore degradation was assumed constant throughout the profile in these simulations.

The simulated water inputs included both irrigation and rainfall. Rainfall amounts were based on climatic averages, and distributed evenly during the rainy season. Actual rainfall events are highly variable with regard to distribution over time and total annual rainfall. Leaching is sensitive to both the distribution of and total water input, so that results here are best considered as demonstrating the relative impact of efficient irrigation water management and not the absolute prediction of depth of leaching.

Finally, the simulations performed here do not consider formation and subsequent fate of pesticide degradates. In the case of the triazine herbicides, degradates have been shown to comprise a large percentage of total triazines in many ground water samples (Spurlock et al., 2000). However, due to the large uncertainty in parent pesticide degradation pathways and rates under varying environmental conditions, and a lack of fate data for degradates themselves, meaningful predictions of degradate occurrence, fate, and transport are not currently possible using computer simulations.

SUMMARY

Monte Carlo analysis of 3 year one-dimensional vadose zone transport modeling simulations was used to evaluate the effect of duration of irrigation restrictions on pesticide movement to ground water in a representative grape production/coarse soil scenario. Actual soil texture and soil organic carbon data were used along with long-term mean precipitation, evapotranspiration, and climatic average data from a representative coarse soil area in Fresno County, California. Soil hydraulic parameters were determined by calibration to experimental data from a coarse soil area. An initial baseline modeling scenario yielded a frequency distribution of ground water contaminant concentrations that was similar to those actually observed in a coarse Fresno County area, suggesting that the modeling procedure was a reasonable representation of actual pesticide transport to ground water. Modeling outputs under efficient irrigation scenarios yielded results consistent with short-term field experimental data: increasing irrigation efficiency can be an effective method for mitigating movement of pesticides to ground water in coarse irrigated agricultural soils. Imposition of maximum water applications of 133 per cent of evapotranspirative demand for six months following spring applications suggests a >95 per cent probability that current section 6800(a) ground water contaminants would not be detected in ground water above current detection limits. However, a variety of modeling limitations are discussed which are a source of uncertainty in the modeling results.

LITERATURE CITED

Anderson, J.P.E., 1984. Herbicide degradation in soil: Influence of microbial biomass. Soil Biol. Biochem. 16:483-489.

Campbell, G. 1974. A simple method for determining unsaturated conductivity from moisture retention data. Soil Science 117:311-314.

Carsel, R.F., J.C. Imhoff, P.R. Hummel, J.M. Cheplick, and A.S. Donigan. 1998. PRZM-3, A model for predicting pesticide and nitrogen fate in the crop root and unsaturated soil zones: User's manual for release 3.0.

California Agricultural Technology Institute. 1988. Irrigation systems and water application efficiencies. CATI Center for Irrigation Technology, publication 880104. California State University, Fresno, California.

Hutson, J.L., and R.J. Wagenet. 1992. LEACHM, Leaching Estimation and Chemistry Model version 3. Research Series No. 92-3, Dept. of Soil, Crop, and Atmospheric Sciences, Cornell University, Ithaca New York.

Johnson, W.G., and T.L. Lavy. 1994. In-site dissipation of benomyl, carbofuran, thiobencarb, and triclopyr at three soil depths. J. Env. Qual. 23:556-562.

Kollman, W., and R. Segawa. 1995 Interim Report of the Pesticide Chemistry Database. EH95-04

Kordel, W, U. Wahle, H. Knoche, and K. Hund. 1995. Degradation capacities of chlorotoluron and simazine in subsoil horizons. Sci. of the Tot. Environ. 171:43-50.

Kruger, E.L., L. Somasundaram, R.S. Kanwar, J.L. Coats. 1993. Persistence and degradation of 14C-atrazine and 14Cdeisopropylatrazine as affected by soil depth and moisture conditions. Env. Tox. Chem. 12:1959-1967.

Miller, J.L., A.G. Wollum, and J.B. Weber. 1997. Degradation of carbon-14-atrazine and carbon-14-metolachlor in soil from four depths. J. Environ. Qual. 26:633-638.

Rice, R.C., D.B. Jaynes, and R.S. Bowman. 1991. Preferential flow of solutes and herbicide under irrigated fields. Transactions of the ASAE, 34: 914-918.

Snyder, R.L., Hanson, B.R., Coppock, R. 1986. How farmers irrigate in California. Univ. of Calif. Division of Ag. and Nat. Res., Leaflet 21414. Oakland, Calif.

Spurlock, F, K. Burow, and N. Dubrovsky. 2000. Chlorofluorocarbon dating of herbicide containing well waters in Fresno and Tulare Counties, California. J. Env. Qual., In Press, scheduled for publication 29:2, 2000.

Spurlock, F. 1998. Protocol for study 177: Evaluation of current simulation models to predict pesticide movement to ground and surface water in California. Environmental Hazards Assessment Program.

Troiano, J., C. Garretson, C. Krauter, J. Brownell, and J. Hutson. 1993. Influence of amount and method of irrigation water application on leaching of atrazine. J. Environ. Qual. 22: 290-298.

University of California. 1989. Irrigation scheduling. A guide for efficient on-farm water management. UC DANR publication 21454.

USDA-ARS. 1999. The pesticide properties database. http://www.arsusda.gov/rsml/ppdb.html

Watermark Computing. 1998. PEST98 - Model Independent Parameter Estimation.

APPENDIX 1

Sample LEACHM Input File

APPENDIX 1 - Sample LEACHM Input File

```
6moirrig< DOS Filename, 8 characters with no extension. Used in batch runs(started as
LEACHP<filename).
---------------------------------------------------------------------------
                LEACHP PESTICIDE DATA FILE.
All numeric data are in positions 1 to 78, comments may extend to position 120.
Unless defined as 'not read' a value must be present for each item, although it may not be
used.
Free format with blank delimiters. Preserve division and heading records.  No. of depth
segments may be changed.
*******************************************************************************
********************************
 1      <Date format (1: month/day,year;  2: day/month/year).  Dates must be 6 digits, 2
each for day, mo, yr.
 010195 <Starting date.  No date in the input data should precede this date.
 000300 <Ending date or day number.  The starting date is day 1. (A value <010101 is treated
as a day number).
 0.05   <Largest time interval within a day (0.1 day or less).
 0.010  <Maximum water flux per time step. (Dimensionless: flux (mm)/segment thickness (mm).
 1      <Number of repetitions of rainfall, crop and chemical application data.
 3030   <Profile depth (mm), preferably a multiple of the segment thickness.
 30.3    &lt;Segment thickness (mm).  (The number of segments should be between about 8 and 30.
 2      <Lower boundary condition: 1:fixed depth water table; 2:free drainage, 3:zero flux
4:lysimeter.
 0000   <If the lower boundary is 1 or 5: initial water table depth (mm).
*******************************************************************************
********************************
*******************************************************************************
********************************
 2      <Number of output files: 1: OUT only; 2: OUT + SUM; 3: OUT + SUM + BTC
--------------------------------------
--- For the *.OUT file :
 1      <Units for depth data: 1: ug/kg, 2: mg/m2 per segment.  (Not used in LEACHW)
 1      <Node print frequency (print data for every node (1), alternate nodes(2).
 3      <Print options: 1, 2 or 3.  To select one of the following 3 options.
 1      <Option 1: Time steps/print (not practical for most applcations!)
 5.00   <Option 2: Print at fixed time intervals (days between prints)
 1      <Option 3: No. of prints (the times for which are specified below)
 2      <Tables printed: 1: mass balance; 2: + depth data; 3: + crop data
---------------------------------------
--- For the * .SUM file :
 50     <Summary print interval (d)
 000    <Surface to [depth 1?] mm     ( Three depth segments for the
 000    <Depth 1 to [depth 2?] mm      summary file. Zero defaults to nodes
 000    <Depth 2 to [depth 3?] mm      closest to thirds of the profile)
---------------------------------------
--- For the *.BTC (breakthrough) file :
 1.0    <Incremental depth of drainage water per output (mm)
---------------------------------------------------------------------------
-- List here the times at which the *.OUT file is desired for print option 3.
-- The number of records must match the 'No. of prints' under option 3 above.
     Date or    Time of day          (At least one must be specified
     Day no.  (to nearest tenth)      even if print option is not 3)
     --------  ----------------
     000300        .5       (These dates can be past the last day)
**************************************************************************
```

```
****************************************************************************
            SOIL PHYSICAL PROPERTIES
----------------------------------------------------------------------------
-- Retentivity model 0 uses listed Campbell's retention parameters, otherwise
-- the desired particle size-based regression model (Table 2.1 in manual) isused.
----------------------------------------------------------------------------
 Soil |                     |Retention|   Starting    |   Roots    | Starting
layer | Clay  Silt  Organic |  model  |theta or pot'l|  (for no   | temp (C)
 no.  |             carbon  |         |(one is used) |  growth)   | (not read in
      |   %     %     %     |         |          kPa | (relative)| LEACHW,C)
 ---    ----  ----   ----     ------   -----   -----     ------    -----------
      1       3       8    0.71       0   0.045     -10     0.2       20
      2       3       8    0.71       0   0.045     -10     0.2       20
      3       3       8    0.71       0   0.045     -10     0.2       20
      4       3       8    0.71       0   0.045     -10     0.2       20
      5       3       8    0.71       0   0.045     -10     0.2       20
      6       4       6    0.25       0    0.06     -10     0.2       20
      7       4       6    0.25       0    0.06     -10     0.2       20
      8       4       6    0.25       0    0.06     -10     0.2       20
      9       4       6    0.25       0    0.06     -10     0.2       20
     10       4       6    0.25       0    0.06     -10     0.2       20
     11       5       6     0.1       0    0.09     -10    0.15       20
     12       5       6     0.1       0    0.09     -10    0.15       20
     13       5       6     0.1       0    0.09     -10    0.15       20
     14       5       6     0.1       0    0.09     -10    0.15       20
     15       5       6     0.1       0    0.09     -10    0.15       20
     16       5       4     0.1       0   0.135     -10    0.13       20
     17       5       4     0.1       0   0.135     -10    0.13       20
     18       5       4     0.1       0   0.135     -10    0.13       20
     19       5       4     0.1       0   0.135     -10    0.13       20
     20       5       4     0.1       0   0.135     -10    0.13       20
     21       6       4   0.067       0    0.15     -10     0.1       20
     22       6       4   0.067       0    0.15     -10     0.1       20
     23       6       4   0.067       0    0.15     -10     0.1       20
     24       6       4   0.067       0    0.15     -10     0.1       20
     25       6       4   0.067       0    0.15     -10     0.1       20
     26       5       4   0.009       0   0.144     -10    0.08       20
     27       5       4   0.009       0   0.144     -10    0.08       20
     28       5       4   0.009       0   0.144     -10    0.08       20
     29       5       4   0.009       0   0.144     -10    0.08       20
     30       5       4   0.009       0   0.144     -10    0.08       20
     31       6       4   0.058       0   0.135     -10    0.05       20
     32       6       4   0.058       0   0.135     -10    0.05       20
     33       6       4   0.058       0   0.135     -10    0.05       20
     34       6       4   0.058       0   0.135     -10    0.05       20
     35       6       4   0.058       0   0.135     -10    0.05       20
     36       6       5    0.05       0    0.12     -10    0.04       20
     37       6       5    0.05       0    0.12     -10    0.04       20
     38       6       5    0.05       0    0.12     -10    0.04       20
     39       6       5    0.05       0    0.12     -10    0.04       20
     40       6       5    0.05       0    0.12     -10    0.04       20
     41       5       4   0.025       0   0.128     -10    0.02       20
     42       5       4   0.025       0   0.128     -10    0.02       20
     43       5       4   0.025       0   0.128     -10    0.02       20
     44       5       4   0.025       0   0.128     -10    0.02       20
     45       5       4   0.025       0   0.128     -10    0.02       20
     46       6       5   0.017       0   0.114     -32    0.02       20
```

47	6	5	0.017	0	0.114	-32	0.02	20
48	6	5	0.017	0	0.114	-32	0.02	20
49	6	5	0.017	0	0.114	-32	0.02	20
50	6	5	0.017	0	0.114	-32	0.02	20
51	6	5	0.025	0	0.144	-100	0.02	20
52	6	5	0.025	0	0.144	-100	0.02	20
53	6	5	0.025	0	0.144	-100	0.02	20
54	6	5	0.025	0	0.144	-100	0.02	20
55	6	5	0.025	0	0.144	-100	0.02	20
56	6	5	0.025	0	0.15	-316	0.02	20
57	6	5	0.025	0	0.15	-316	0.02	20
58	6	5	0.025	0	0.15	-316	0.02	20
59	6	5	0.025	0	0.15	-316	0.02	20
60	6	5	0.025	0	0.15	-316	0.02	20
61	7	5	0.017	0	0.12	-1000	0.02	20
62	7	5	0.017	0	0.12	-1000	0.02	20
63	7	5	0.017	0	0.12	-1000	0.02	20
64	7	5	0.017	0	0.12	-1000	0.02	20
65	7	5	0.017	0	0.12	-1000	0.02	20
66	6	5	0.008	0	0.105	-3000	0.02	20
67	6	5	0.008	0	0.105	-3000	0.02	20
68	6	5	0.008	0	0.105	-3000	0.02	20
69	6	5	0.008	0	0.105	-3000	0.02	20
70	6	5	0.008	0	0.105	-3000	0.02	20
71	7	6	0	0	0.09	-3000	0.02	20
72	7	6	0	0	0.09	-3000	0.02	20
73	7	6	0	0	0.09	-3000	0.02	20
74	7	6	0	0	0.09	-3000	0.02	20
75	7	6	0	0	0.09	-3000	0.02	20
76	7	5	0	0	0.105	-3000	0.02	20
77	7	5	0	0	0.105	-3000	0.02	20
78	7	5	0	0	0.105	-3000	0.02	20
79	7	5	0	0	0.105	-3000	0.02	20
80	7	5	0	0	0.105	-3000	0.02	20
81	6	6	0	0	0.09	-3000	0.02	20
82	6	6	0	0	0.09	-3000	0.02	20
83	6	6	0	0	0.09	-3000	0.02	20
84	6	6	0	0	0.09	-3000	0.02	20
85	6	6	0	0	0.09	-3000	0.02	20
86	7	6	0	0	0.105	-3000	0.02	20
87	7	6	0	0	0.105	-3000	0.02	20
88	7	6	0	0	0.105	-3000	0.02	20
89	7	6	0	0	0.105	-3000	0.02	20
90	7	6	0	0	0.105	-3000	0.02	20
91	7	7	0.008	0	0.12	-3000	0.01	20
92	7	7	0.008	0	0.12	-3000	0.01	20
93	7	7	0.008	0	0.12	-3000	0.01	20
94	7	7	0.008	0	0.12	-3000	0.01	20
95	7	7	0.008	0	0.12	-3000	0.01	20
96	9	7	0	0	0.135	-3000	0.01	20
97	9	7	0	0	0.135	-3000	0.01	20
98	9	7	0	0	0.135	-3000	0.01	20
99	9	7	0	0	0.135	-3000	0.01	20
100	9	7	0	0	0.135	-3000	0.01	20

---

1   < Use listed water contents (1) or potentials (2) as starting values.

Particle density: Clay   Silt and sand   Organic matter (kg/dm3) (to calculate porosity)

```
             2.65         2.65              1.10
***************************************************************************
For a uniform profile: Any non-zero value here will override those in
the table below (only if retentivity model is 0).
----------------------------------------------------------------------
  0        <Soil bulk density (kg/dm3)
  0       <'Air-entry value' (AEV) (kPa) (a in eq 2.1 to 2.4).
  0        <Exponent (BCAM) in Campbell's water retention equation (b in eq. 2.1 to 2.4).
2019.0000 -0.5  <Conductivity (mm/day) and corresponding matric potential (kPa) (for
potential-based version of eq. 2.5).
  1         <Pore interaction parameter (P) in Campbell's conductivity equation (eq.2.5 in
manual).
 48.8075123 <Dispersivity (mm) (eq. 3.12).  (Read, but not used in LEACHW)
**************************************************************************
 Soil |  Soil retentivity |   Bulk  |  Match K(h) curve at: | Dispersivity
segment      parameters   | density |   K    Matric   using |  (not read
 no.  |    AEV     BCAM   |         |         pot'l     P   |  in LEACHW)
      |    kPa            |  kg/dm3 |  mm/d    kPa            |      mm
----- |  ------   -----     ------    -----   -----   -----      -----
1     -.01644000000 5.1910000E+00   1.53     1   -15     3    30
2     -.01644000000 5.1910000E+00   1.53     1   -15     3    30
                                    .
                                    .
                                    .
                                    .
                                    .
                                    .
                                    .
99    -.01644000000 5.1910000E+00   1.64     1   -15     3    30
100   -.01644000000 5.1910000E+00   1.64     1   -15     3    30
*************************************************************************
*************************************************************************
                 CROP DATA
-------------------------------------------------------------------------
  Data for at least one crop must be specified, even if no crop desired.
  For fallow soil, set flag below to 0, or germination past the simulation enddate.
-------------------------------------------------------------------------
1      <Plants present: 1 yes, 0 no.  This flag overrides all other crop data.
1      <No. of crops (>0), even if bypassed.  Dates can be past last day of simulation.
2      <Growth: 1:No(use root data specified above, crop cover below); 2:Yes.
-1500  <Wilting point (soil) kPa.
-3000  <Min.root water pot'l(kpa).
1.1    <Maximum ratio of actual to potential transpiration (dry surface).
1.05   <Root resistance (weights water uptake by depth). (>1, No weighting: 1.0). See Eq. 2-
16.
-------------------------------------------------------------------------
Crop Germination Emergence  Maturity    Harvest Rel.  Crop      Pan   | Annual (read in
 no                        Root  Plant          root  cover    factor | N uptake LEACHN
    ......... Date or Day no ...........        depth fraction        | kg/ha  only)
-----------------------------------------------------------------------
  1     031595    031695  061595 061595  101595  2.00   0.95    0.82     102
***********************************************************************
***********************************************************************
            INITIAL PROFILE CHEMICAL DATA
-----------------------------------------------------------------------
  2  < Number of chemical species.  At least one must be specified.
-----------------------------------------------------------------------
```

```
 Soil     Chem1     Chem2     Chem3     Chem4
layer         ----mg/kg dry soil----
-----------------------------------------------------------------------
          1          0          0          0          0
          2          0          0          0          0
          3          0          0          0          0
                                 .
                                 .
                                 .
                                 .
                                 .
                                 .
                                 .
         98          0          0          0          0
         99          0          0          0          0
        100          0          0          0          0
-----------------------------------------------------------------------
Concentration (mg/l) below profile, used with lower boundaries 1 or 5
                0.0       0.0       0.0       0.0      0.0
 0.0       < Depth (mm) of water in mixing cell (boundaries 1 and 5 only). Enter 0 for no
mixing cell.
***********************************************************************
***********************************************************************
                 CHEMICAL PROPERTIES
                 -------------------
Chem                   Solubility  Vapour Density    Link        Plant
 No.        Name         mg/dm3       mg/dm3                     Uptake
-------     ----         ------       --------     -------    1(yes),0(no)
  1  '    Atrazine'    .33E+04         .800E-05       0            0
  2  '     Bromide'    .5000E+06     .0000E-00       0            0
-------------------------------------------------------------------------------
       Linear(1)     |      Linear isotherm     | Freundlich isotherm   (See Table 3.1,
Chem     or          |   Koc    2-site model    |   Kfoc  Exponent        p.3-24 in
 No.  Freundlich(2)  |  l/kg    f      alpha    | (unit dependent!)       manual)
----   -----            -----   ---    ------      ------     ---
  1        1         230.00000 1.0       .693        100       1.0
  2        1           000.0  1.0      .693        100.0    0.9
--------------------------------------------------------------------------------
Diffusion coefficients: (see pages 3-5 to 3-7 in manual)
--------------------
 120       <Molecular diffusion coefficient in water (mm2/day)
 0.001     <Adjustment in Bresler's equation (a in equation 3.10 (ver.3)
 10        <Adjustment in Bresler's equation (b in equation 3.10)
 .4300E+06 <Molecular diffusion coefficient in air (mm2/day)
 .1400E+06 <Air diff. coeff. enhancement to account for atmospheric pressure fluctuations.
***********************************************************************
*  The values of L1,L2--->Ln ('Link' in the Chemical Properties above)
*   determine which species form a transformation chain.
*   Setting Ln = 0 breaks the pathway, Ln = 1 restores it.
*
*                    Transformation pathways------------------->
*     |    RATE 1         RATE 2         RATE 3        RATE 4
*    SE1----/L1/--->SE2----/L2/--->SE3----/L3/--->SE4---/L4/--->...
*     |               |              |             |
*     | RATE 5        | RATE 6       | RATE 7      | RATE 8     Degradation
*     |               |              |             |              pathways
*     v               v              v             v                 |
```

```
*  PRODUCT         PRODUCT        PRODUCT       PRODUCT             |
*                                                                   v
****************************************************************************
              TRANSFORMATION AND DEGRADATION RATE CONSTANTS
----------------------------------------------------------------------------
     1   <Rate constants apply to bulk soil (1), or solution phase only (0)
 Temperature and water content effects (transformation rate constants only):
     0   <Include temperature subroutine and adjustments? yes(1), no(0)
     3   <Q10: factor by which rate constant changes per 10 C increase
    20   <Base temperature: at which rate constants below apply
    35   <Optimum temperature: Q10 relationship applies from 0 C to here
    50   <Maximum temperature: Rate constants decrease from optimum to here
   .08   <High end of optimum water content range: air-filled porosity
  -300   <Lower end of optimum water content: matric potential kPa
 -1500   <Minimum matric potential for transformations kPa
   0.6   <Relative transformation rate at saturation
**************************************************************************
     TRANSFORMATION RATE CONSTANTS (may be adjusted as specified above)
--------------------------------------------------------------------------
Layer          Chemical 1     Chemical 2     Chemical 3    Chemical 4
 no            ----------     ----------     ----------    ----------
---------      <--------------------- day ^ -1 --------------------->
1           .00578000000          0           0           0
2           .00578000000          0           0           0
3           .00578000000          0           0           0
4           .00578000000          0           0           0
5           .00578000000          0           0           0
6           .00578000000          0           0           0
7           .00578000000          0           0           0
8           .00578000000          0           0           0
9           .00578000000          0           0           0
10          .00578000000          0           0           0
11          .00578000000          0           0           0
12          .00578000000          0           0           0
13          .00578000000          0           0           0
14          .00578000000          0           0           0
15          .00578000000          0           0           0
16          .00578000000          0           0           0
17          .00578000000          0           0           0
18          .00578000000          0           0           0
19          .00578000000          0           0           0
20          .00578000000          0           0           0
21          .00578000000          0           0           0
22          .00578000000          0           0           0
23          .00578000000          0           0           0
24          .00578000000          0           0           0
25          .00578000000          0           0           0
26          .00578000000          0           0           0
27          .00578000000          0           0           0
28          .00578000000          0           0           0
29          .00578000000          0           0           0
30          .00578000000          0           0           0
31          .00578000000          0           0           0
32          .00578000000          0           0           0
33          .00578000000          0           0           0
34          .00578000000          0           0           0
35          .00578000000          0           0           0
```

36	.00578000000	0	0	0
37	.00578000000	0	0	0
38	.00578000000	0	0	0
39	.00578000000	0	0	0
40	.00231	0	0	0
41	.00231	0	0	0
42	.00231	0	0	0
43	.00231	0	0	0
44	.00231	0	0	0
45	.00231	0	0	0
46	.00231	0	0	0
47	.00231	0	0	0
48	.00231	0	0	0
49	.00231	0	0	0
50	.00231	0	0	0
51	.00231	0	0	0
52	.00231	0	0	0
53	.00231	0	0	0
54	.00231	0	0	0
55	.00231	0	0	0
56	.00231	0	0	0
57	.00231	0	0	0
58	.00231	0	0	0
59	.00231	0	0	0
60	.00231	0	0	0
61	.00231	0	0	0
62	.00231	0	0	0
63	.00231	0	0	0
64	.00231	0	0	0
65	.00231	0	0	0
66	.00231	0	0	0
67	.00231	0	0	0
68	.00231	0	0	0
69	.00231	0	0	0
70	.00231	0	0	0
71	.00231	0	0	0
72	.00231	0	0	0
73	.00231	0	0	0
74	.00231	0	0	0
75	.00231	0	0	0
76	.00231	0	0	0
77	.00231	0	0	0
78	.00231	0	0	0
79	.00231	0	0	0
80	.00231	0	0	0
81	.00231	0	0	0
82	.00231	0	0	0
83	.00231	0	0	0
84	.00231	0	0	0
85	.00231	0	0	0
86	.00231	0	0	0
87	.00231	0	0	0
88	.00231	0	0	0
89	.00231	0	0	0
90	.00231	0	0	0
91	.00231	0	0	0
92	.00231	0	0	0

```
93              .00231                0           0           0
94              .00231                0           0           0
95              .00231                0           0           0
96              .00231                0           0           0
97              .00231                0           0           0
98              .00231                0           0           0
99              .00231                0           0           0
100             .00231                0           0           0
***************************************************************************
    DEGRADATION RATE CONSTANTS (not influenced by water or temperature)
---------------------------------------------------------------------------
Layer          Chemical 1     Chemical 2     Chemical 3    Chemical 4
 no            ----------     ----------     ----------    ----------
---------      <--------------------- day ^ -1 --------------------->
           1           0           0           0           0
           2           0           0           0           0
                                    .
                                    .
                                    .
                                    .
                                    .
                                    .
                                    .
          99           0           0           0           0
         100           0           0           0           0
***************************************************************************
***************************************************************************
                CHEMICAL   APPLICATIONS
                 -----------------------
 1    <  Number of broadcast applications. (At least 1.  Can be past last date.
-----------------------------------------------------------------------
    Date       Incorporation   Chem1      Chem2      Chem3     Chem4
(or day no.)   (segments, 0           mg/sq.m (1mg/sq.m = .01kg/ha)
    -----       is surface)   --------     -----      -----      -----
   030595         0           3800.0      7200.0       .00    .00
***************************************************************************
***************************************************************************
             RAIN/IRRIGATION AND WATER COMPOSITION
             -------------------------------------
Choosing the steady-state flow option will prevent calls to the water flowsubroutine, fix
fluxes and concentrations
at those specified below and maintain theta constant with time. Interruptedsteady-state can
be specified by
appropriate times and amounts.  For the steady-state flow option, use a uniform soil column.
----------------------------------------------------------------------------
    1     < Water flow: Richards (1), modified Addiscott (2), steady-state (3).
   -5     < For Addiscott : matric potential at field capacity (kPa).
   -200   <               : division between mobile and immobile water (kPa).
    0.4   < For steady-state: Water content in uniform column (theta)
    13     < Number of water applications.  Some or all can be past last day.
----------------------------------------------------------------------------
  Start time     Amount  Surface flux      Dissolved in water (can be 0)
Date or  Time of    mm     density      Chem1     Chem2    Chem3    Chem4.....
Day no.    day               mm/d                      mg/l
-------  ------  ------  ------------  -----     -----    -----    -----
010795     .5     100  2000    0.000E+00  .000E+00  .000E+00  .000E+00
030495     .5     100  2000    0.000E+00  .000E+00  .000E+00  .000E+00
```

042995	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
052795	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
061095	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
062495	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
071595	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
072995	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
081295	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
082695	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
090995	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
100795	.5	100	2000	0.000E+00	.000E+00	.000E+00	.000E+00
102195	.5	41	2000	0.000E+00	.000E+00	.000E+00	.000E+00

****
****

POTENTIAL ET (WEEKLY TOTALS, mm), DEPTH TO WATER TABLE (mm)
MEAN WEEKLY TEMPERATURES AND MEAN WEEKLY AMPLITUDE (degrees C)

Week no.	ET	Water table	Mean temp	Amplitude
1	5.33	0	6.1	4.2
2	6.10	0	7.3	4.3
3	7.37	0	7.9	4.8
4	8.64	0	8.1	5.5
5	10.16	0	8.6	5.0
6	11.18	0	9.9	5.4
7	13.21	0	10.8	5.8
8	15.75	0	11.4	6.7
9	18.03	0	11.9	6.3
10	18.54	0	12.3	6.2
11	20.07	0	12.4	6.2
12	22.10	0	13.3	6.8
13	25.40	0	13.9	6.9
14	30.48	0	14.9	7.2
15	33.27	0	16.1	7.5
16	36.83	0	15.8	7.5
17	36.58	0	17.1	7.9
18	41.91	0	18.5	8.1
19	44.96	0	19.2	8.1
20	46.48	0	21.1	8.9
21	50.29	0	21.5	8.5
22	52.58	0	22.3	8.5
23	54.61	0	23.3	8.5
24	56.90	0	24.2	8.8
25	56.64	0	25.8	9.3
26	56.13	0	26.1	9.1
27	55.63	0	26.5	9.3
28	56.13	0	27.6	9.4
29	58.42	0	27.9	9.2
30	55.88	0	28.5	9.3
31	54.86	0	28.0	9.3
32	52.83	0	28.3	9.3
33	51.31	0	26.5	8.8
34	48.26	0	25.6	8.8
35	46.74	0	25.8	9.1
36	44.45	0	25.6	9.0
37	42.93	0	23.9	8.8
38	39.88	0	22.5	8.5
39	35.31	0	22.4	8.6

40	33.02	0	21.4	8.6
41	32.00	0	19.7	8.2
42	27.18	0	18.1	8.1
43	23.37	0	17.1	7.7
44	19.05	0	15.0	7.7
45	16.76	0	14.2	7.1
46	14.22	0	12.2	5.8
47	11.68	0	10.2	5.7
48	10.41	0	9.2	5.5
49	8.89	0	8.5	5.2
50	7.62	0	6.9	5.1
51	7.87	0	7.2	4.7
52	6.35	0	6.6	4.1
53	5.08	0	6.2	4.3

APPENDIX 2

PESTICIDE INPUT DATA

Appendix 2 - Input data for 6800(a) pesticides

Field dissipation half-life (days)- USDA-ARS, 1999; Kollman and Segawa, 1995

atrazine	bromacil	diuron	hexazinone	norflurazon	simazine
173	207	90	105	163	26
61	227	102	60	33	87
48	165	134	90	180	125
64	350	100	79	304	369
18	61	127	75		55
74	120		75		186
119	350		120		44
70	175		154		119
102	155		123		33
	168				89
	124				84
	137				9
					144

K_{OC} - USDA-ARS, 1999

atrazine	bromacil	diuron	hexazinone	norflurazon	simazine
148	12	453	41	490	138
288	33	418	37	430	230
214	2.3	560	41	370	112
149	14	476	300	120	160
163			34		155
111			74		124
170			54		115
163			38		114
160					144
127					114
107					103
174					
88					
38					
72					
157					
102					
90					
57					
120					
139					
155					
87					
39					
70					

Document Review and Approval
Environmental Hazards Assessment Program
Department of Pesticide Regulation
830 K Street
Sacramento, CA 95814

Document Title: Effect of Irrigation Scheduling on Movement of Pesticides to Ground Water in Coarse Soils: Monte Carlo Analysis of Simulation Modeling

Author(s): Frank Spurlock

Document Date: January 2000

APPROVED: ______________________ Date: 12/19/99
Frank Spurlock, Ph.D.
Author

APPROVED: ______________________ Date: 12/21/99
Bruce Johnson, Ph.D.
Senior Environ. Research Scientist (Specialist)

APPROVED: ______________________ Date: 12/28/99
Kean S. Goh, Ph.D.
Ag. Program Supervisor

APPROVED: ______________________ Date: 12/30/99
John Sanders, Ph.D.
Branch Chief