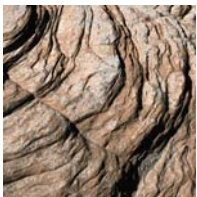




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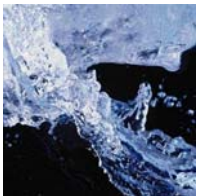
# **Modeling the Effect of a Riparian Buffer Strip on Off-Field Entrapment of Pesticides Using REMM2008**



**Tammara L. Estes**

**EMPM Meeting**

**December 9, 2008**



**STONE ENVIRONMENTAL INC**



# Objectives

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- Discuss basics of pesticide module of REMM2008
- Review results of measured versus REMM2008 predicted concentrations for atrazine and alachlor. Measured values from a 1992-1994 field study conducted in Georgia.
- Review results of measured versus REMM2008 predicted concentrations for atrazine and chlorpyrifos. Measured values from a buffer effectiveness study conducted by Dow in Iowa.



# **Riparian Ecosytem Management Model 2008 (REMM2008)**

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## **REMM2008:**

- Is a process based digital simulation model
- Originally based on buffer system specifications recommended by USDA-Forest Service and the USDA-NRCS as a national system.
- Simulates nutrient cycling, vegetation dynamics, water quality, and hydrology in riparian buffers

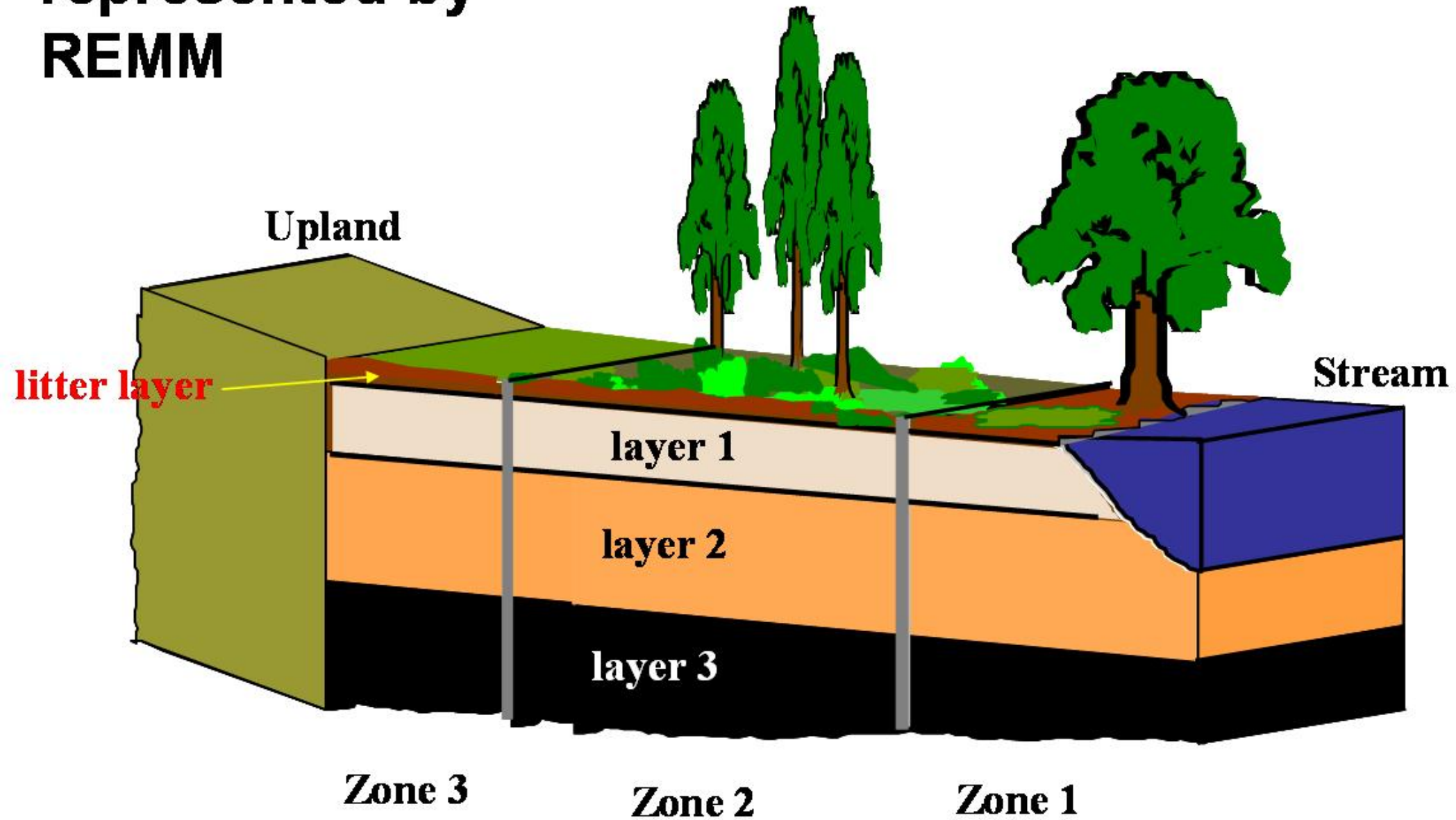


## **Riparian Ecosytem Management Model 2008 (REMM2008) continued...**

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- Used to predict buffer strip effectiveness for entrapment of non-point pollutants in surface and subsurface water flows which drain into and through a buffer.
- Daily time-step numeric model
- Latest version has improved hydrology algorithm and pesticide simulation module

# Spatial structure represented by REMM





To estimate riparian buffer effectiveness, REMM2008 simulates the movement through a buffer of

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- Water
- Sediment
- Carbon
- Nitrogen
- Phosphorous
- Pesticides

Crop plant growth is also simulated



# Hydrology in REMM2008

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Water movement and storage characterized by:

- Interception by vegetation (canopy and litter layer)
- Evapotranspiration
- Vertical drainage
- Surface Runoff
- Subsurface Lateral Flow
- Upward flux from the water table
- Deep seepage

Water movement through each REMM2008 zone is controlled by a combination of mass balances and transport rates.



## Hydrology (continued)...

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- Typically upland runoff and throughfall is less than infiltration capacity of soil in buffer. Thus, most runoff infiltrates the soil profile in the receiving zone.
- For high intensity storms, infiltration is simulated using a modified Green-Ampt equation. Excess water is added to surface runoff.
- Subsurface lateral movement of water over an impeding soil horizon is calculated using Darcy's Equation
- Preferential flow is not calculated
- Excess subsurface flow is released to the surface as surface seepage.



# Erosion

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- Simulated using Universal Soil Loss Equation (USLE)
- Fraction of sand, silt, clay, small aggregate, and large aggregate particle size classes at the point of detachment determined using the Foster approach.
- Separated into rill and interrill areas. Assumes straight channels which run parallel to each other downslope. Interrill areas lie between adjacent rills.
- Channel shapes are triangular, constant within a zone, determined by channel side slopes, and have interrill areas sloping toward the channels.
- Channel length and slope are assume identical to zone length and slope.
- User specified zone width, number of channels and channel widths.



# Erosion (continued)

## Simulated Sediment Processes:

- Erosion
- Transport
- Deposition

Current Zone = 3

Number of Channels:	<input type="text" value="1.000"/>	Total slope in steps(%):	<input type="text" value="0.000"/>
Days since tillage:	<input type="text" value="3650"/>	Degrees off contour:	<input type="text" value="1.000"/>
Soil Conditions:	<input type="text" value="1"/>	Mannings N:	<input type="text" value="0.600"/>
Bare soil (%):	<input type="text" value="15.000"/>	Channel side slope:	<input type="text" value="0.010"/>
Bare soil with fine roots(%):	<input type="text" value="100.000"/>	Interrill roughness:	<input type="text" value="0.400"/>
Bare soil canopy (%):	<input type="text" value="30.000"/>	Structure code:	<input type="text" value="2"/>
CanopyHeight(m):	<input type="text" value="30.000"/>	Permeability class:	<input type="text" value="2"/>
Invading Vegetation (%):	<input type="text" value="0.000"/>	Surface conditions:	<input type="text" value="0.490"/>

Ok



# Vegetation

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- On a stand basis.
- Up to 12 types of vegetation can be simulated

Deciduous Fall Upper Canopy

Deciduous Spring Live Upper Canopy

Deciduous Spring Dead Upper Canopy

Coniferous Quick Upper Canopy

Coniferous Medium Upper Canopy

Coniferous Slow Upper Canopy

Deciduous Fall Lower Canopy

Deciduous Spring Live Lower Canopy

Coniferous Quick Lower Canopy

Coniferous Medium Lower Canopy

Herbaceous Annual

Herbaceous Perennial



# Off-field Movement of Pesticides

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**Off-field movement of pesticides from agricultural fields can occur due to a combination of:**

- Dissolved residues in runoff water from an agricultural field
- Sorbed residues bound to eroded sediment from an agricultural field
- Dissolved residues in off-field laterally moved water from an agricultural field's soil profile
- Drift from pesticide application to an agricultural field

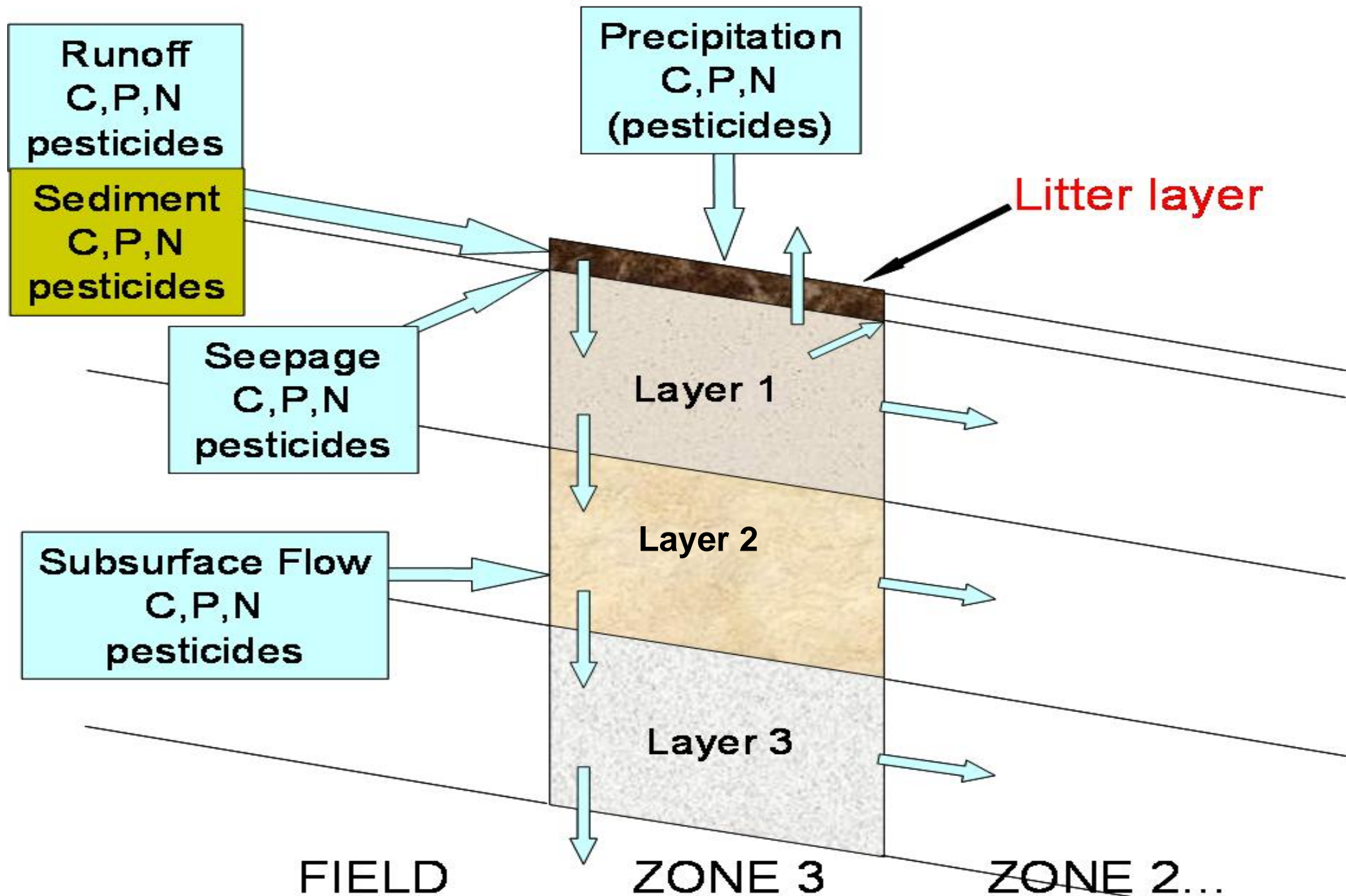


# Conservation Buffers and Pesticide Trapping

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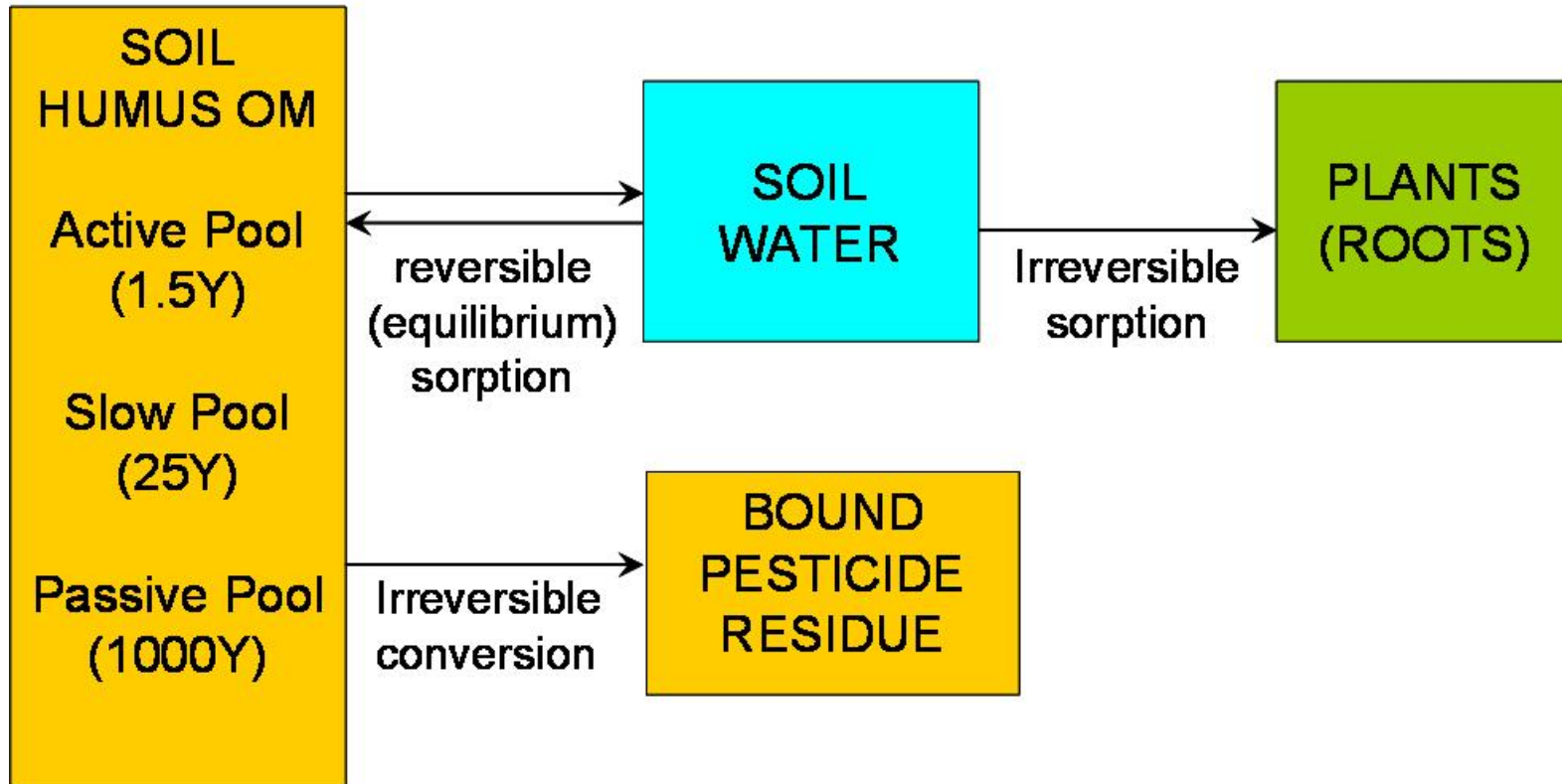
- Sorbed pesticide residues on eroded sediment can be trapped in the buffer in the same way that the eroded sediment is trapped.
- For a buffer to be effective in removing dissolved pesticide residues in runoff water, the runoff water must either infiltrate the soil in the buffer or the pesticide residues must be removed from the runoff water via contact with soil or vegetation.
- Buffers can also be used to intercept off-field drift from pesticide application

# PESTICIDE INPUTS INTO BUFFER



<b>Pesticide Environmental Fate Property Input into REMM2008</b>	<b>Units</b>
Aqueous solubility	mg/L
Soil OM binding half-life	d
Soil aerobic degradation half-life	d
Reference soil moisture content	%
Walker exponent	--
Reference soil temperature	°C
Aerobic energy of activation	kJ/mol
Soil anaerobic deg. half-life	d
Ionization constant	--
Soil OM sorption coef (Koc)	L/Kg
High- <i>pH</i> soil OM sorpt. coeff.	L/Kg
Octanol-water partition coeff.	--

# PESTICIDE POOLS IN SOIL AND LITTER LAYERS





# Pesticide adsorption/desorption

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- Simulated as two pools in equilibrium (water phase and soil phase)
- Adsorption/desorption based on pesticide  $K_{OC}$
- Water phase pool can
  - adsorb to soil phase if equilibrium disturbed
  - taken up into plant roots with water uptake if plant uptake simulated
  - degrade

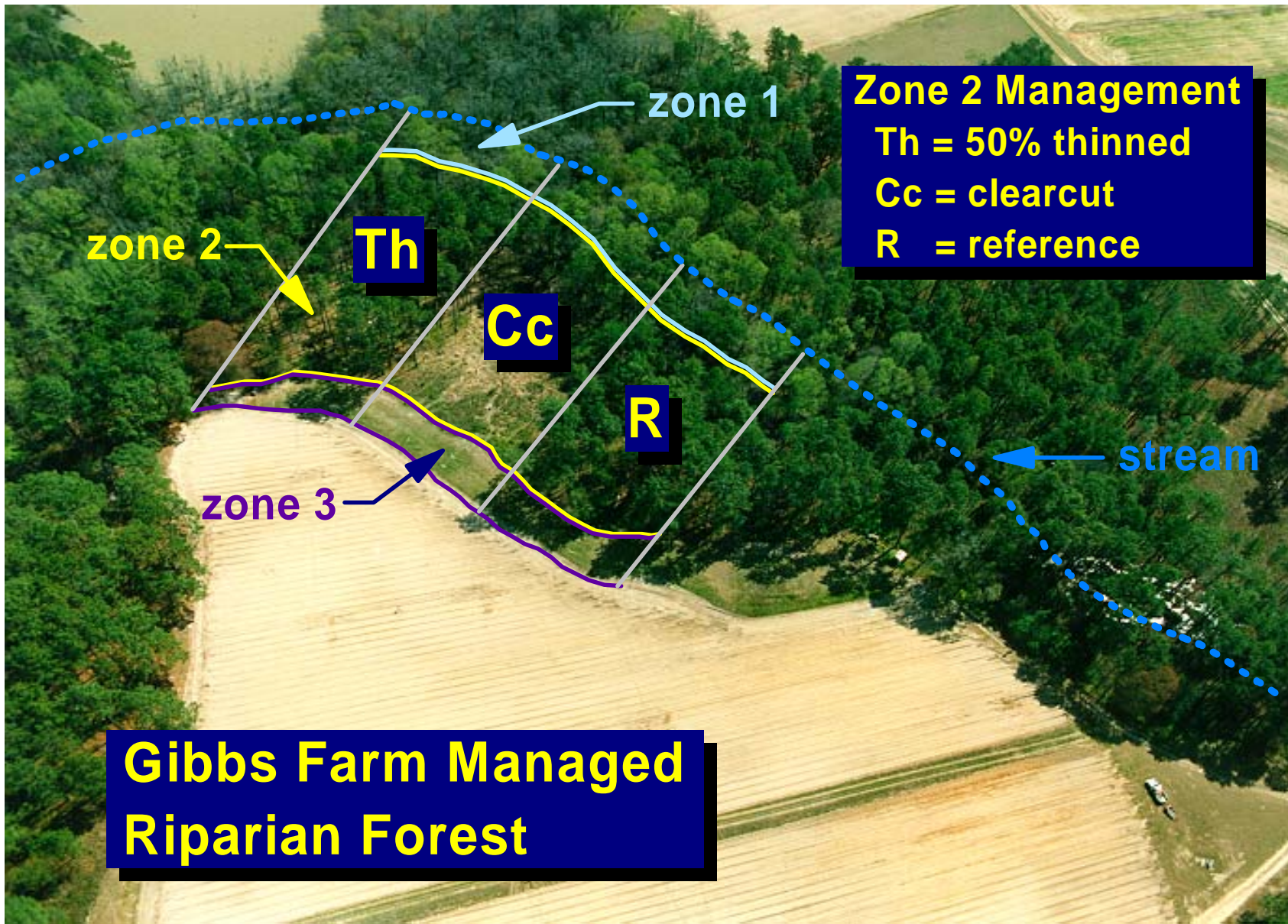


# Pesticide Degradation

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- First-order reaction constant and soil water concentration
- Binding calculated using first-order rate constant and soil phase concentration
- Plant uptake of pesticide calculated using Briggs “translocation stream concentration factor” which is a function of  $K_{OW}$ .
- Can perform temperature dependent degradation
- Binding, plant uptake, and degradation are all loss functions.

# Managed Three Zone Buffer: Gibbs Farm Site



Field Surface area = 0.32 ha

Field Subsurface area = 0.32 ha

		Zone		
		1	2	3
Layer Thickness (cm)	1	30	30	30
	2	70	70	70
	3	150	150	150
Vegetation		Hardwood	Pine	Grass
Length (m)		15.00	50.00	8.00
Width (m)		(50 ft)	(167 ft)	(27 ft)
Slope (%)		43.83	43.83	43.83
		2.0	3.8	2.6

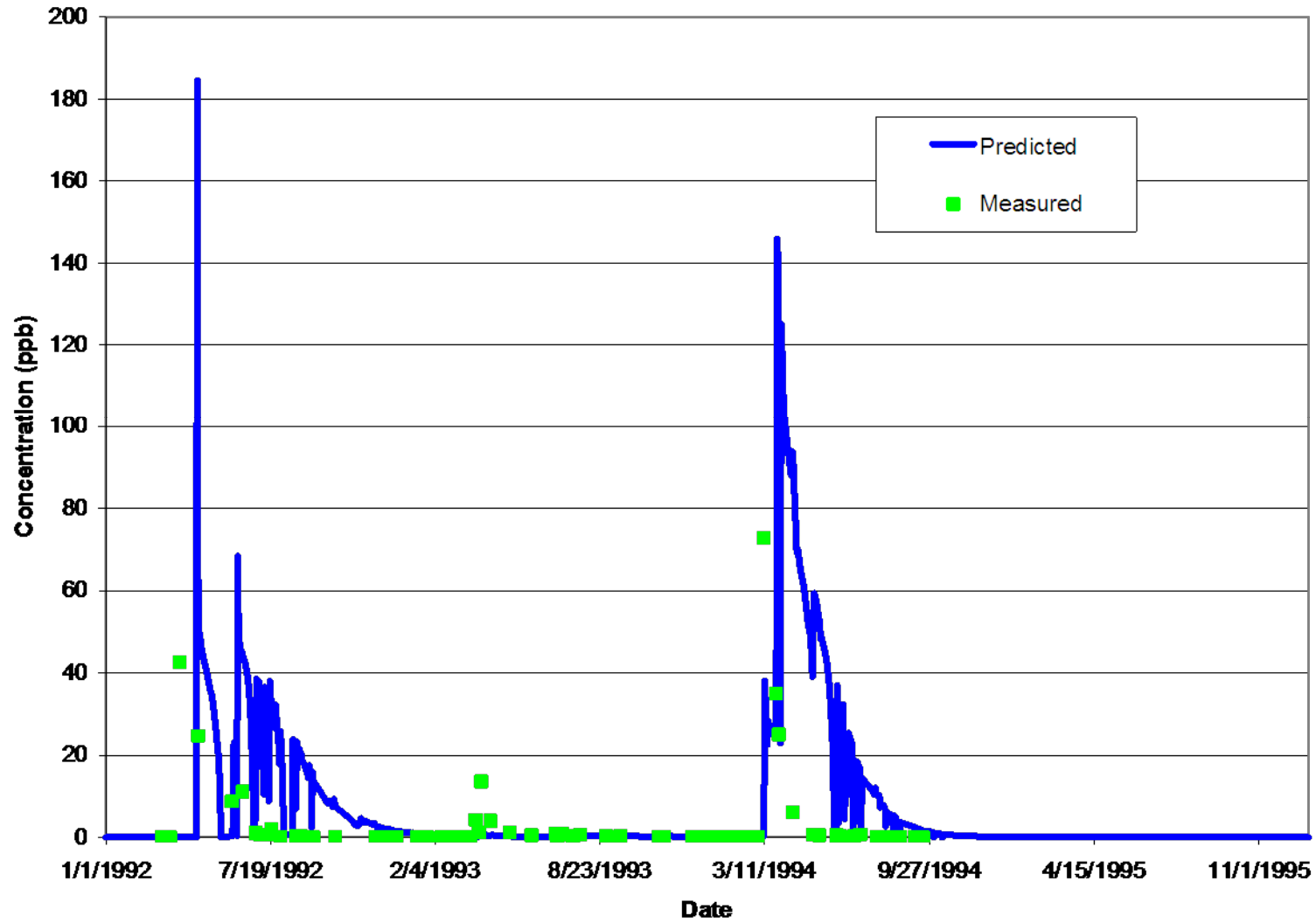


# Atrazine Modeling Parameters

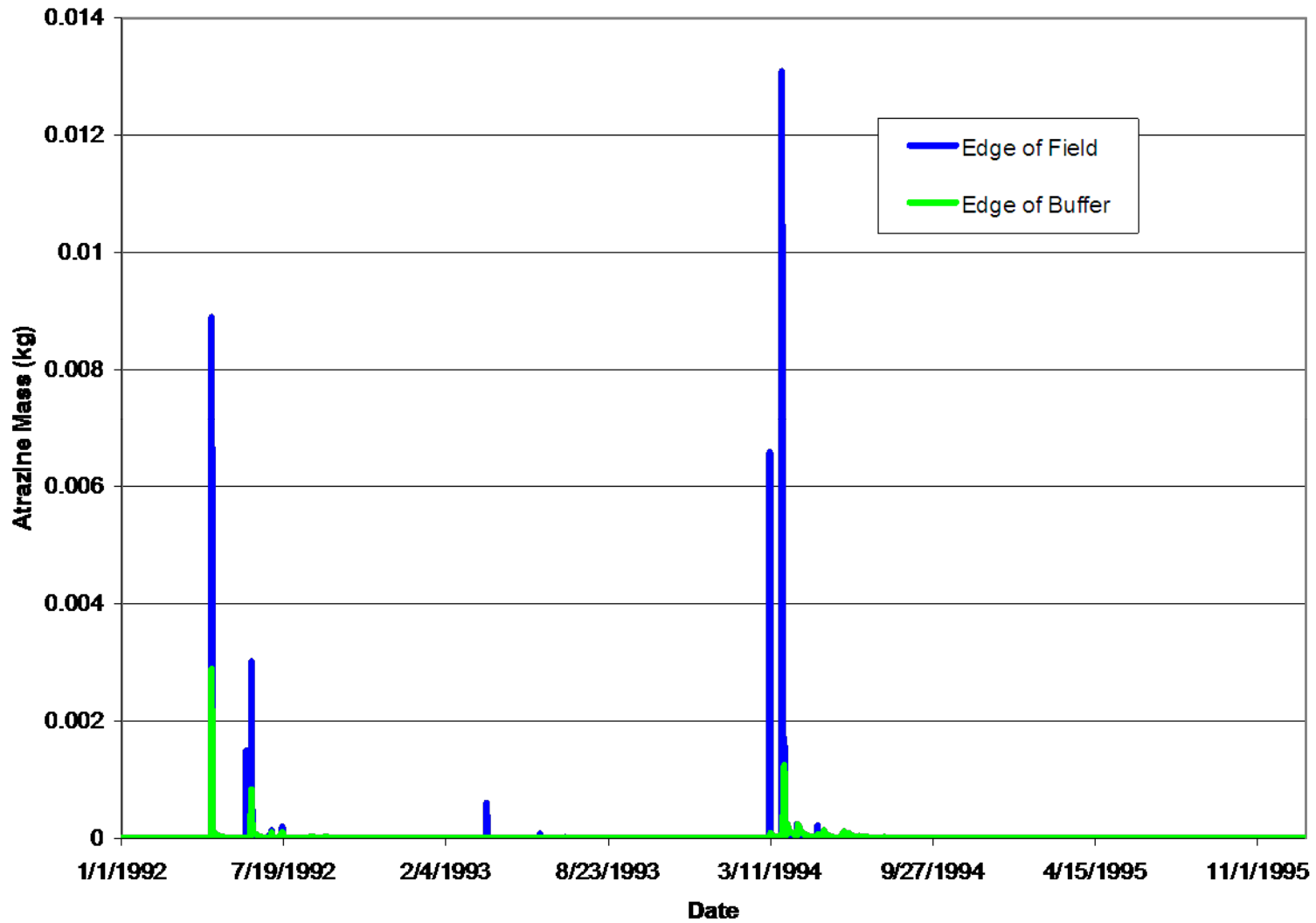
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- Water Solubility:  
33 ppm
- Aerobic Soil Half-life:  
60 days
- Anaerobic Soil  
Half-life: 60 days
- $K_{OC}$ : 100
- $K_{OW}$ : 437

### Atrazine - Edge of Zone 3 Concentrations



### Atrazine - Edge of Field versus Edge of Buffer Predicted Mass



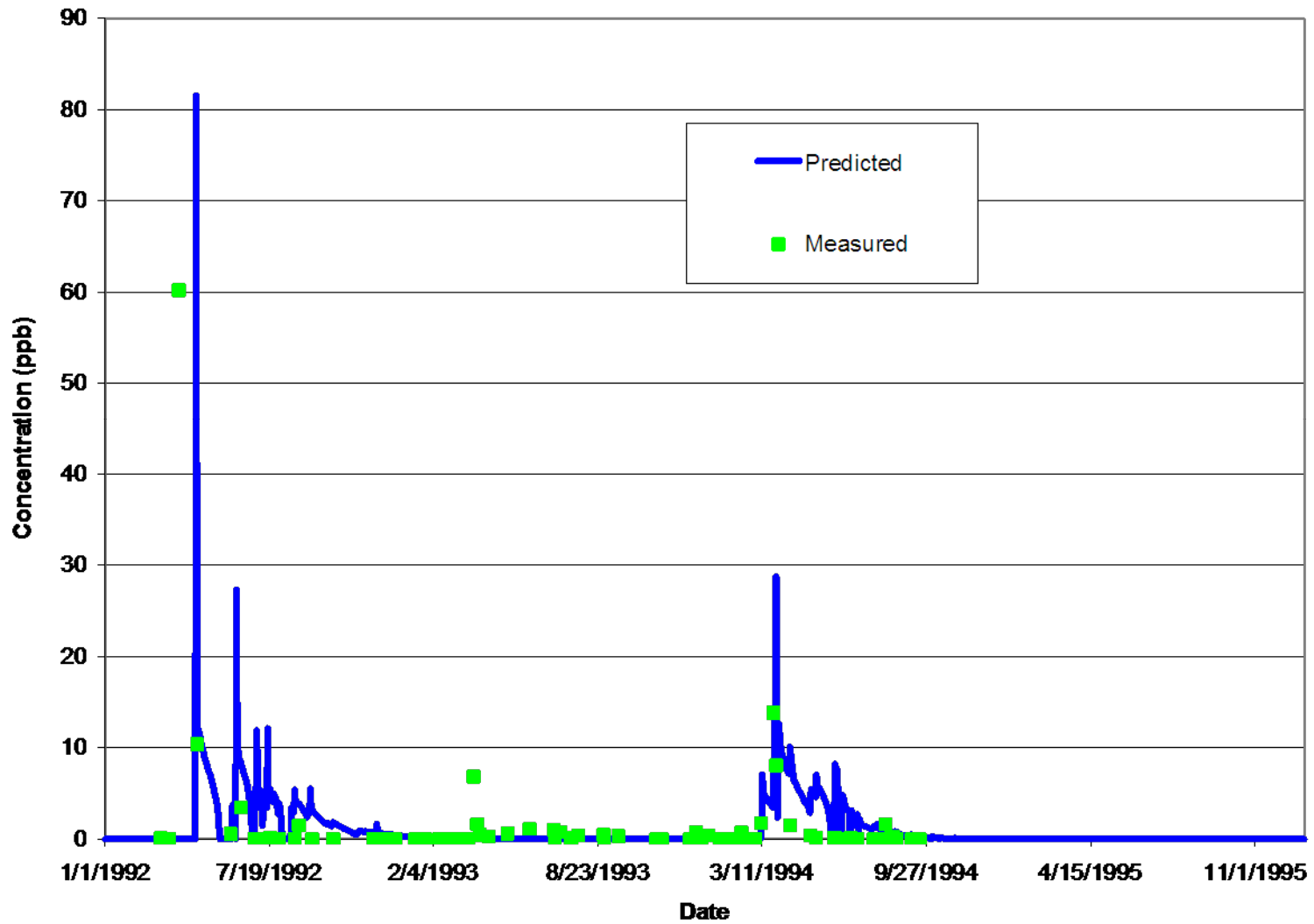


# Alachlor Modeling Parameters

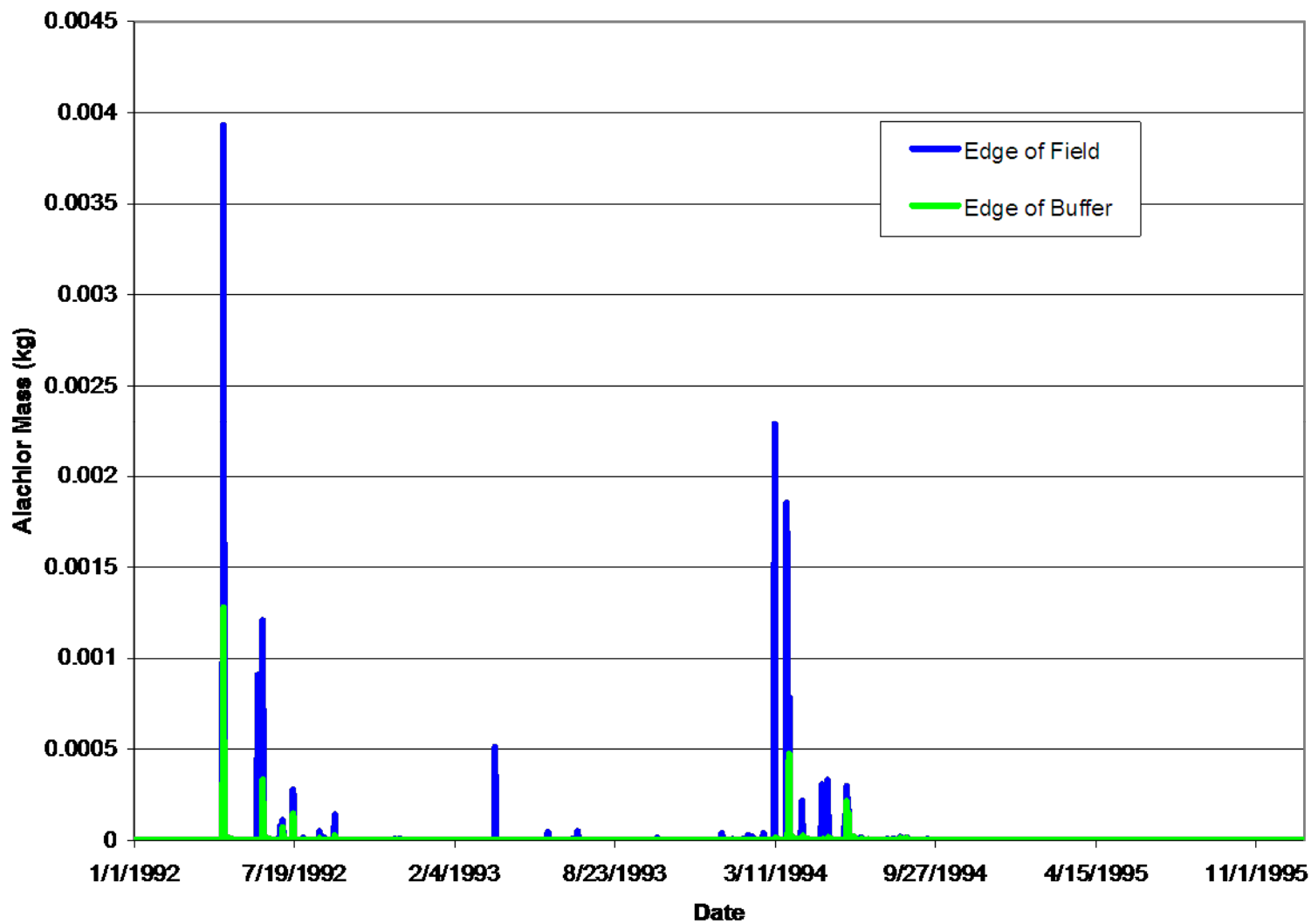
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- Water Solubility:  
24 ppm
- Aerobic Soil Half-life:  
15 days
- Anaerobic Soil  
Half-life: 15 days
- $K_{OC}$ : 100
- $K_{OW}$ : 794

### Aalachlor - Edge of Zone 3 Concentrations



**Aalachlor - Edge of Field versus Edge of Buffer Predicted Mass**





# % Entrapment by 27' Buffer

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<b><u>Pesticide</u></b>	<b><u>1992</u></b>	<b><u>1993</u></b>	<b><u>1994</u></b>
Atrazine	49.3	91.9	60.0
Alachlor	63.2	97.1	73.3



# Dow Buffer Effectiveness Study

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- Conducted in Iowa
- Four Different Treatments were studied:
  1. Field to Buffer Drainage area ratio of 15:1. Field drained into full buffer strip width
  2. Field to Buffer Drainage area ratio of 30:1. Field drained into full buffer strip width.
  3. Field to Buffer Drainage area ratio of 15:1. Field drained into 10% buffer plot width.
  4. Field to Buffer Drainage area ratio of 30:1. Field drained into 10% buffer plot width
- 3 Different Replicates for each Treatment type



## Dow Buffer Effectiveness Study (continued)

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- Buffer was comprised of Grass-smooth Bromgrass
- Slope 5.3%
- Simulated rainfall applied 90 minutes duration to field for each replicate/treatment event. Between 52 – 80 mm of rainfall applied for the events.
- Dimension of field:
  - For Treatments 1 and 3 – Area was 317 m<sup>2</sup>; Length of field in direction of flow was 69 m.
  - For Treatments 2 and 4 – Area was 635 m<sup>2</sup>; Length of field in direction of flow was 138 m.
- Dimension of buffer – 4.6 m x 4.6 m



## Dow Buffer Effectiveness Study (continued)

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- Soil at Site

Galva Silty Clay Loam

17.1 % Clay

54.05% Silt

28.85% Sand

Bulk Density: 1.3 g/cm<sup>3</sup>

4.429% Organic Matter



## REMM2008 Modeling of Dow Buffer Effectiveness Study Data

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- The study had 4 Treatment x 3 Replicate Data points each for dissolved and sorbed residues for both atrazine and chlorpyrifos
- Treatment #1 - Replicate #1 data points used to “calibrate” the hydrology and erosion.
- Remaining 11 treatment/replicate scenarios run with same hydrology and erosion parameters as identified in calibration phase.
- Observed off-field runoff, erosion, pesticide dissolved residues and pesticide sorbed residues directly input into REMM2008 for each treatment/replicate scenario.
- Atrazine simulated with Koc of 100 and Chlorpyrifos simulated with Koc of 6070. Only a single simulation day was modeled.



# REMM2008 Modeling of Dow Buffer Effectiveness Study Data

## – Atrazine Results

I	Buffer with 10% Plot Width with 15:1 Drainage Area	0.69	0.64	0.05	0.04	0.02	0.02	94.4	85.8	8.6
II	Buffer with 10% Plot Width with 15:1 Drainage Area	0.98	0.88	0.10	0.04	0.02	0.02	99.4	87.2	12.2
III	Buffer with 10% Plot Width with 15:1 Drainage Area	0.81	0.86	-0.05	0.06	0.02	0.04	86.6	87.2	-0.6
I	Buffer with 10% Plot Width with 30:1 Drainage Area	2.00	2.57	-0.57	0.08	0.03	0.05	73.8	92.4	-18.6
II	Buffer with 10% Plot Width with 30:1 Drainage Area	1.51	1.75	-0.24	0.09	0.03	0.06	82.4	91.2	-8.8
III	Buffer with 10% Plot Width with 30:1 Drainage Area	1.67	1.70	-0.03	0.11	0.03	0.08	93.4	90.6	2.8

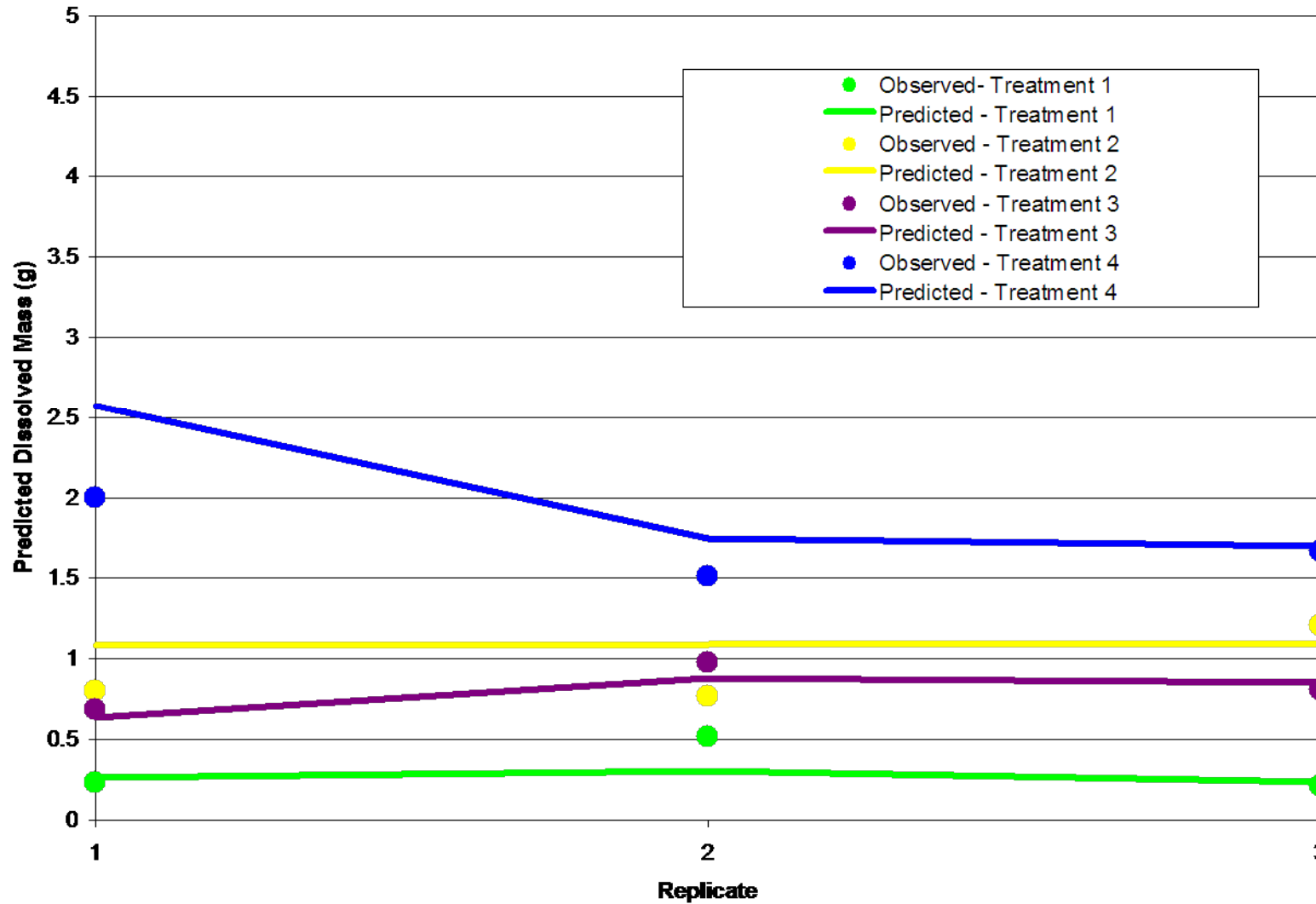
<b>Average Dissolved Difference (g)</b>	<b>-0.09</b>	<b>Average is overprediction by 0 .09 grams</b>								
<b>Average Sorbed Difference (g)</b>	<b>0.02</b>	<b>Average is underprediction by 0.02 grams</b>								
<b>Average Total % Difference</b>	<b>-1.38</b>	<b>Average is overprediction by 1.38%</b>								

I	Buffer with 10% Plot Width with 15:1 Drainage Area	0.69	0.64	0.05	0.04	0.02	0.02	94.4	85.8	8.6
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<b>Average Total % Difference</b>	<b>-1.38</b>	<b>Average is overprediction by 1.38%</b>								

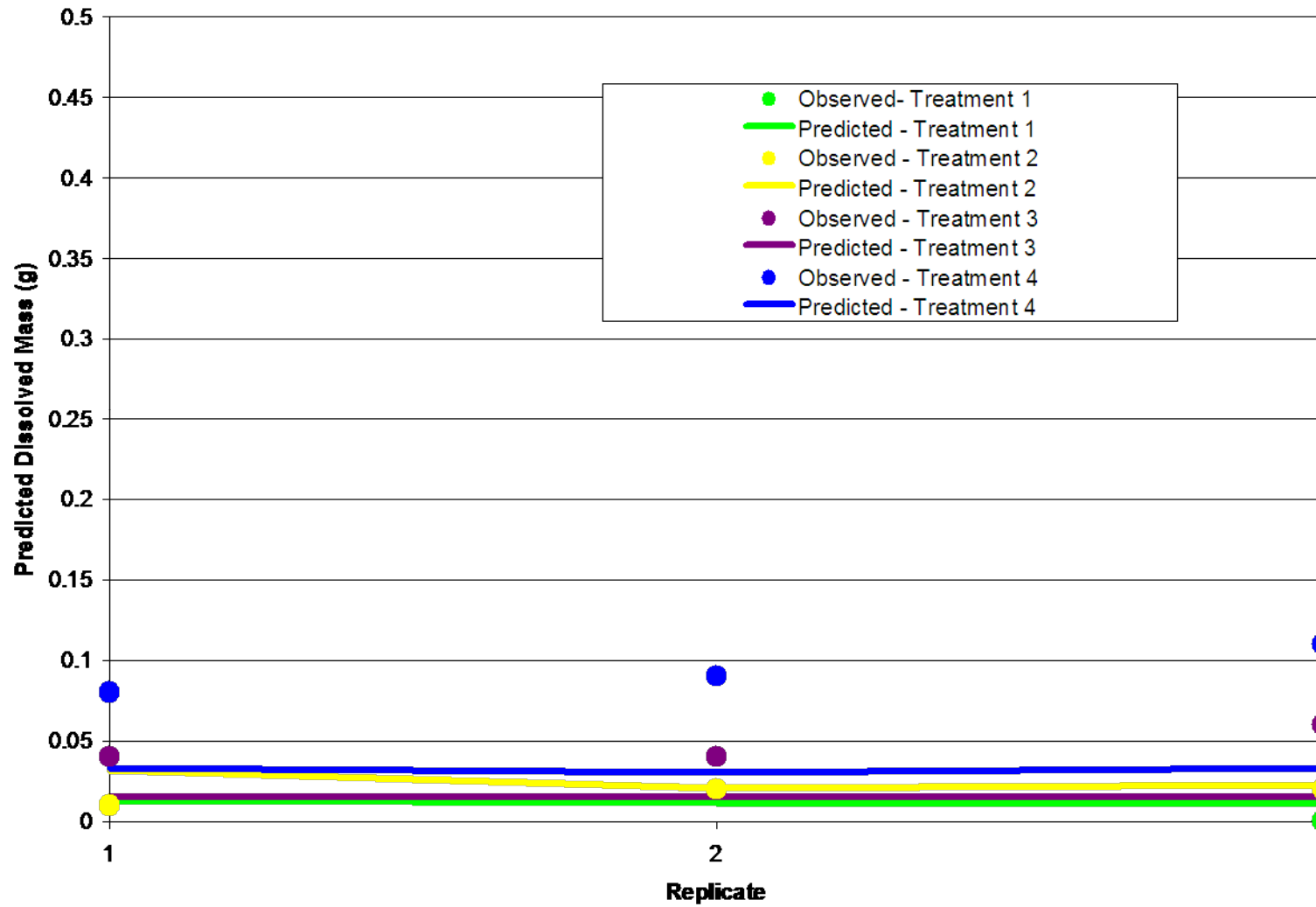


### Atrazine - Dissolved Mass Out of Buffer Observed vs REMM2008 Predicted



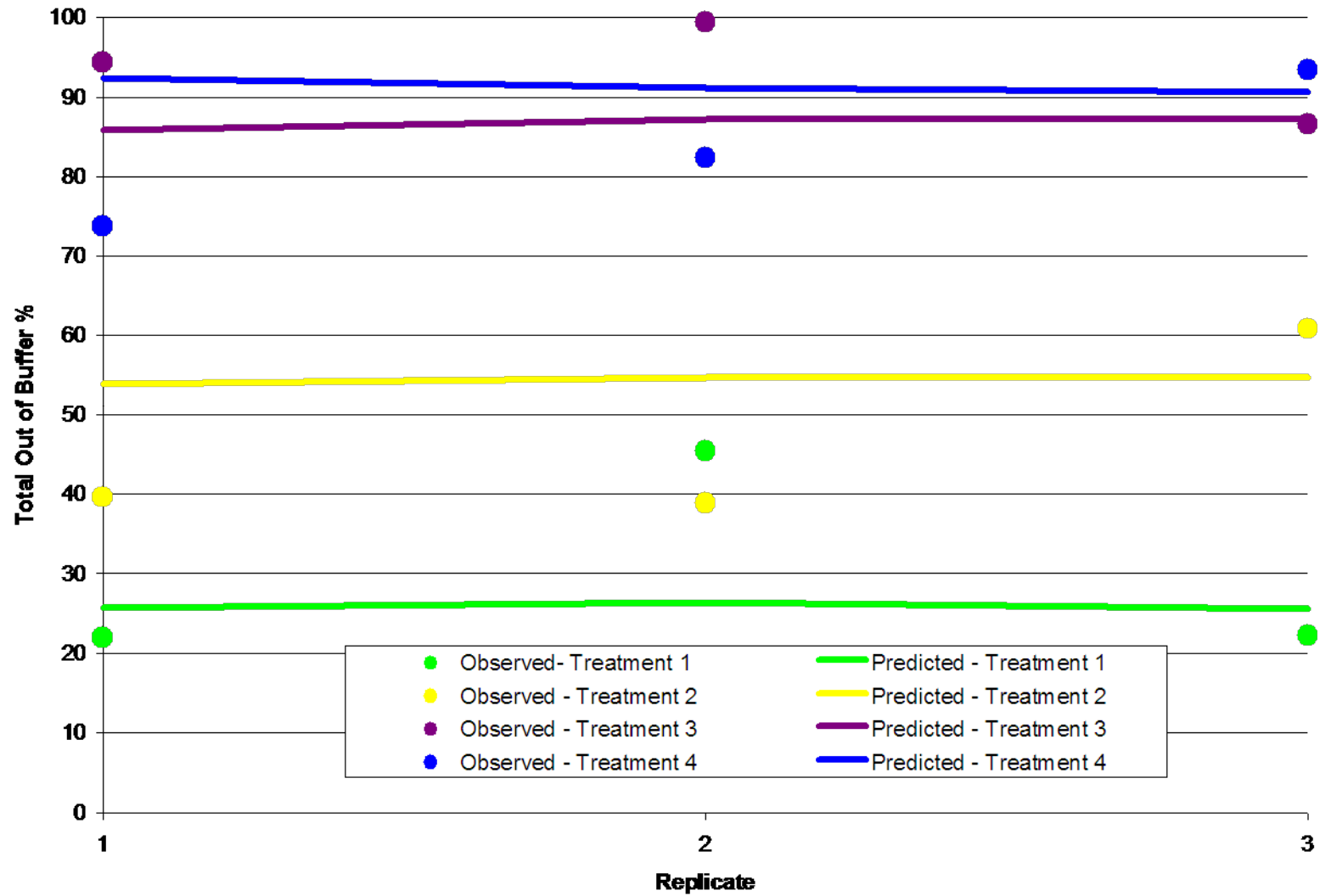


### Atrazine - Sorbed Mass Out of Buffer Observed vs REMM2008 Predicted





### Atrazine - Total % Out of Buffer Observed vs REMM2008 Predicted





# REMM2008 Modeling of Dow Buffer Effectiveness Study Data

## - Chlorpyrifos Results

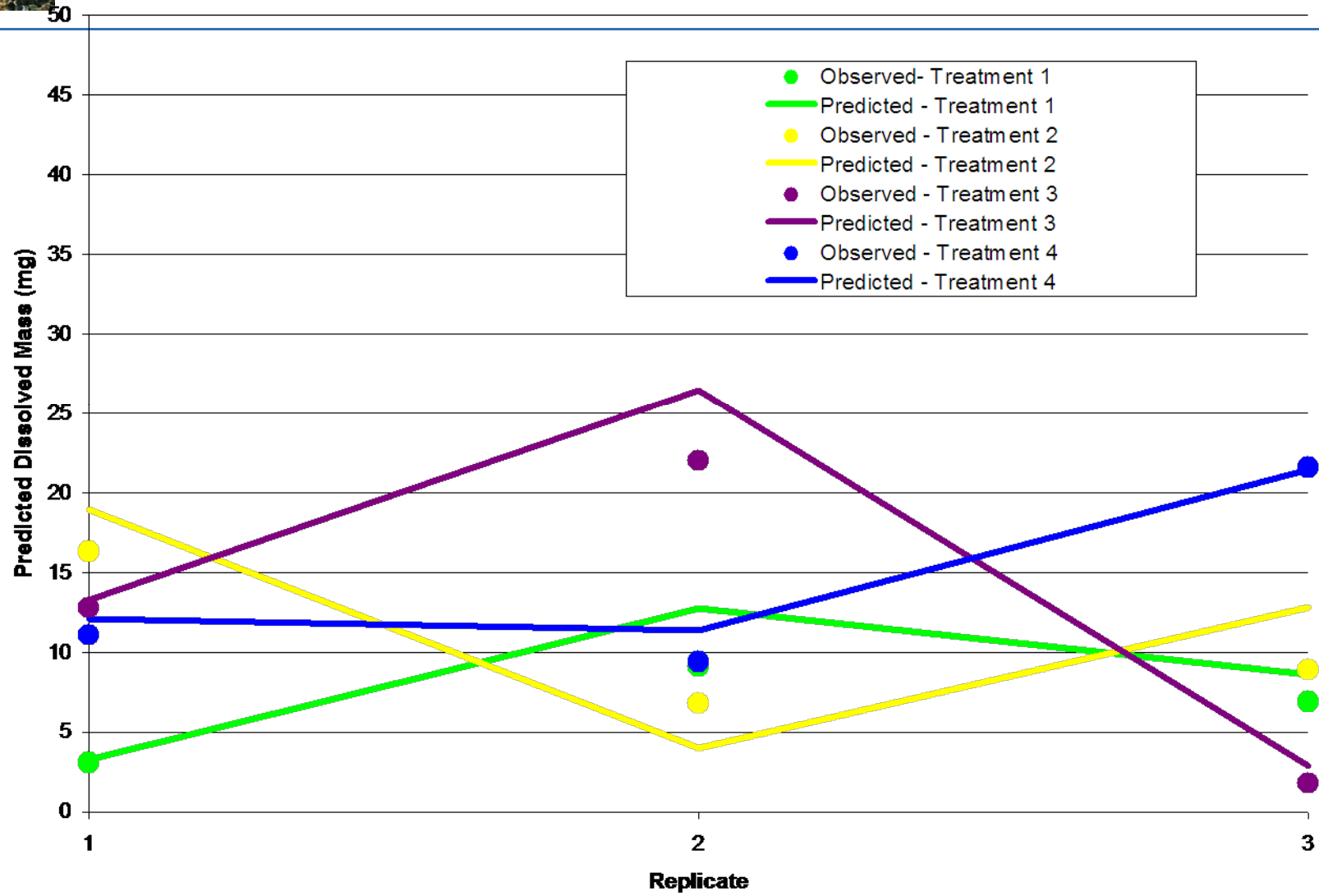
I	Buffer with 10% Plot Width with 15:1 Drainage Area	12.8	13.3	-0.50	6.3	2.2	4.05	81.3	66.18	15.1
II	Buffer with 10% Plot Width with 15:1 Drainage Area	22	26.5	-4.45	13.2	4.3	8.87	78.8	68.86	9.9
III	Buffer with 10% Plot Width with 15:1 Drainage Area	1.8	2.9	-1.06	0.6	1.6	-1.00	12.3	22.77	-10.5
I	Buffer with 10% Plot Width with 30:1 Drainage Area	11.1	12.1	-1.02	3.1	4.2	-1.09	35.7	40.77	-5.1
II	Buffer with 10% Plot Width with 30:1 Drainage Area	9.4	11.4	-1.96	8	2.1	5.90	83.6	64.71	18.9
III	Buffer with 10% Plot Width with 30:1 Drainage Area	21.6	21.5	0.13	19.8	4.3	15.47	105	65.31	39.7

<b>Average Dissolved Difference (g)</b>		<b>-1.52</b>	<b>Average is Overprediction by 1.52 mg</b>							
<b>Average Sorbed Difference (g)</b>		<b>2.68</b>	<b>Average is Underprediction by 2.68 mg</b>							
<b>Average Total % Difference</b>		<b>4.55</b>	<b>Average is Underprediction by 4.55 %</b>							
I	Buffer with 10% Plot Width with 15:1 Drainage Area	12.8	13.3	-0.50	6.3	2.2	4.05	81.3	66.18	15.1
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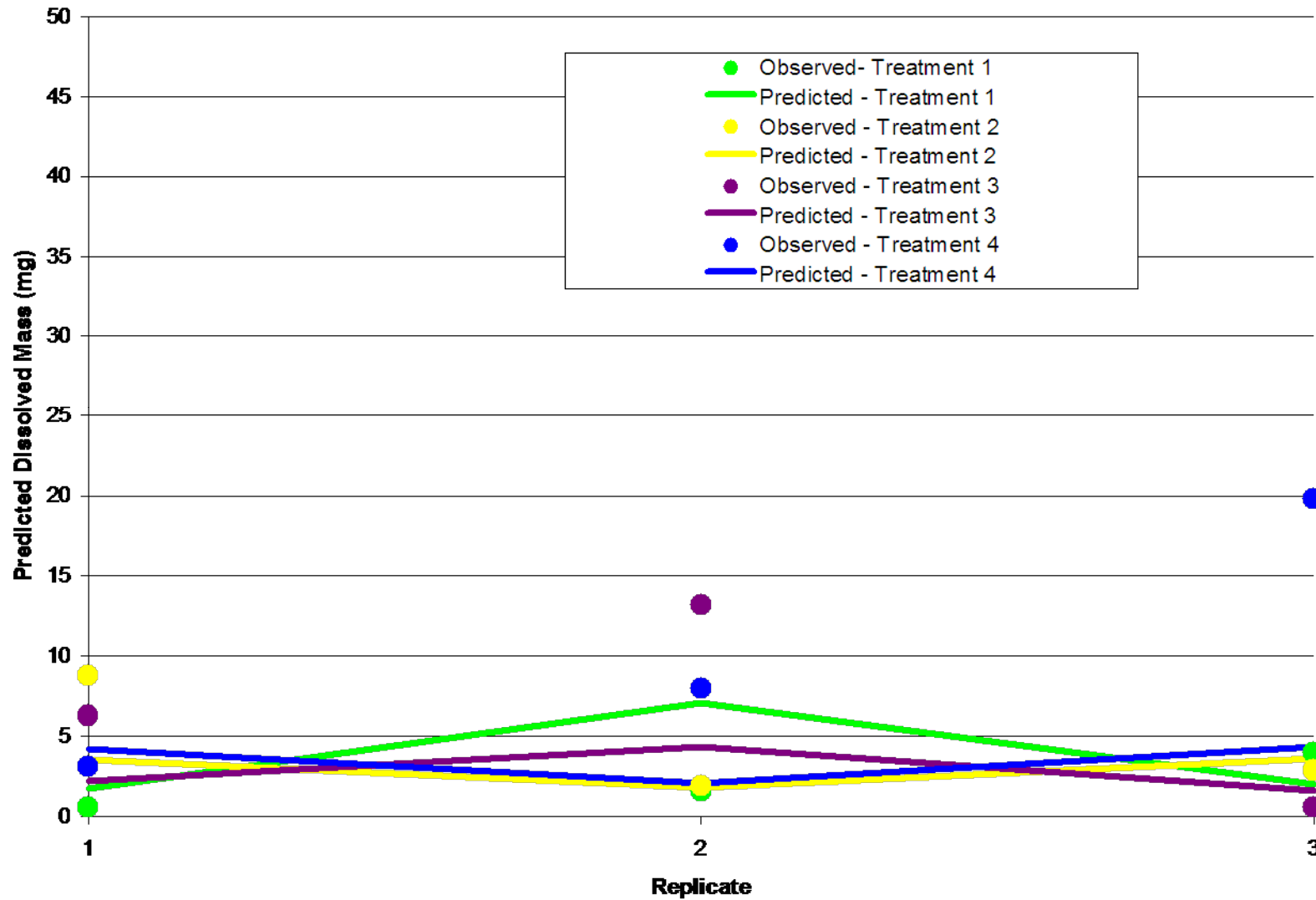


### Chlorpyrifos - Dissolved Mass Out of Buffer Observed vs REMM2008 Predicted



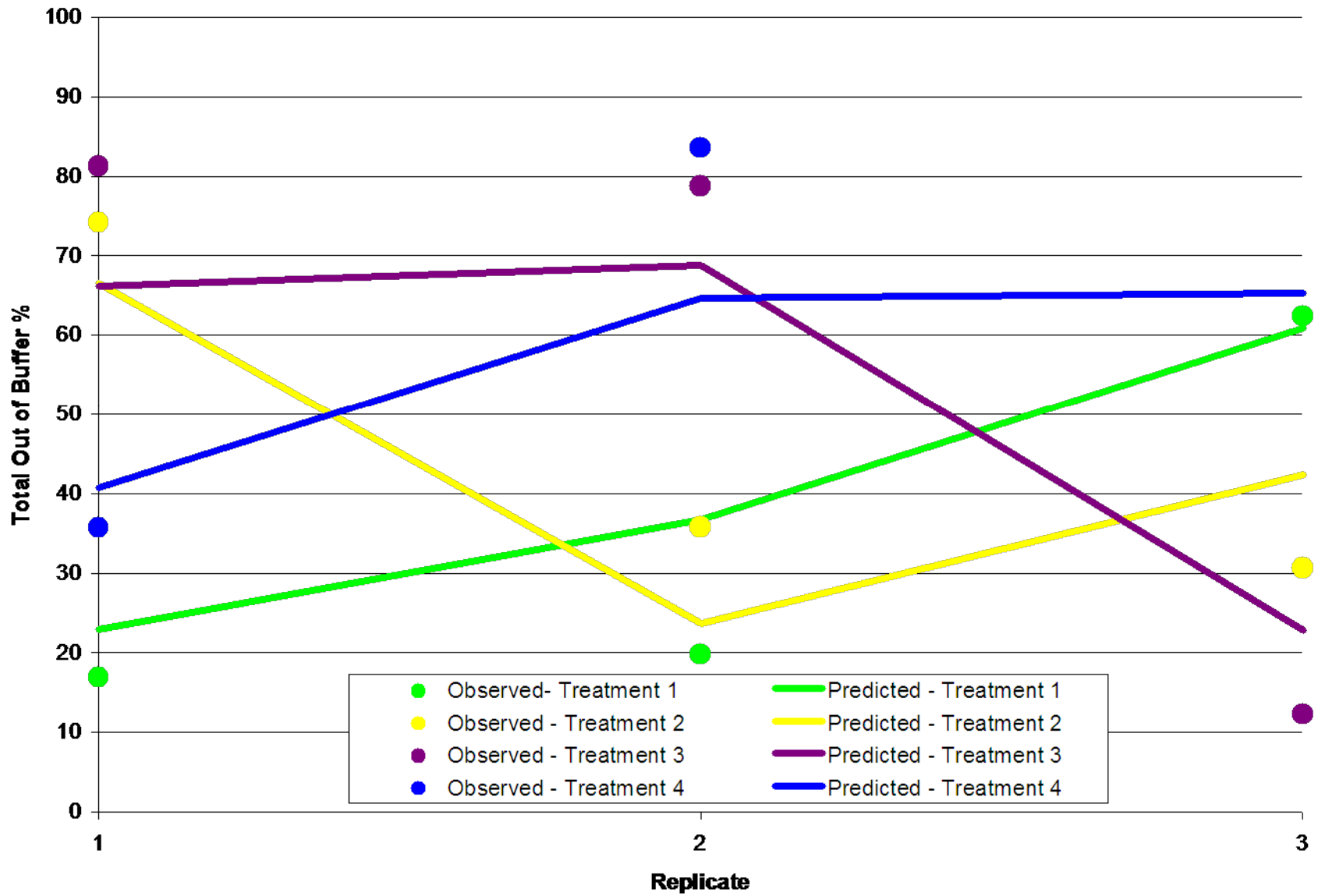


### Chlorpyrifos - Sorbed Mass Out of Buffer Observed vs REMM2008 Predicted





### Chlorpyrifos - Total % Out of Buffer Observed vs REMM2008 Predicted





# Conclusions

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- REMM2008 can be a useful tool for estimating buffer entrapment of pesticides. Allows for varying e-fate parameters, buffer vegetation, and buffer widths.
- New pesticide module exhibits good fit between measured and predicted off-buffer concentrations with slight over-estimation for water soluble compounds.
- % Pesticide entrapment is dependent on rainfall distribution and intensity in conjunction with environmental fate parameters.
- Pesticide entrapment is sensitive to choice of  $K_{OC}$



# Potential Future Work

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- Need for comparison of measured versus REMM2008 predicted concentrations for additional high and medium  $K_{OC}$  compounds.
- Examination of channel effect on buffer entrapment. Current modeling simulated sheet flow.
- Development of turf vegetation scenarios for regions outside of U.S. southeast.
- Development of standardized REMMM2008 scenarios for use with EPA standard scenarios for surface water risk assessments.