The significance of the differences in soil phosphorus representation and transport procedures in the SWAT and HSPF models and a comparison of their performance in estimating phosphorus loss from an agriculture catchment in Ireland

Ahmed Nasr[1*], Michael Bruen[1], Richard Moles[2],
Paul Byrne[2] & Bernadette O'Regan[2]

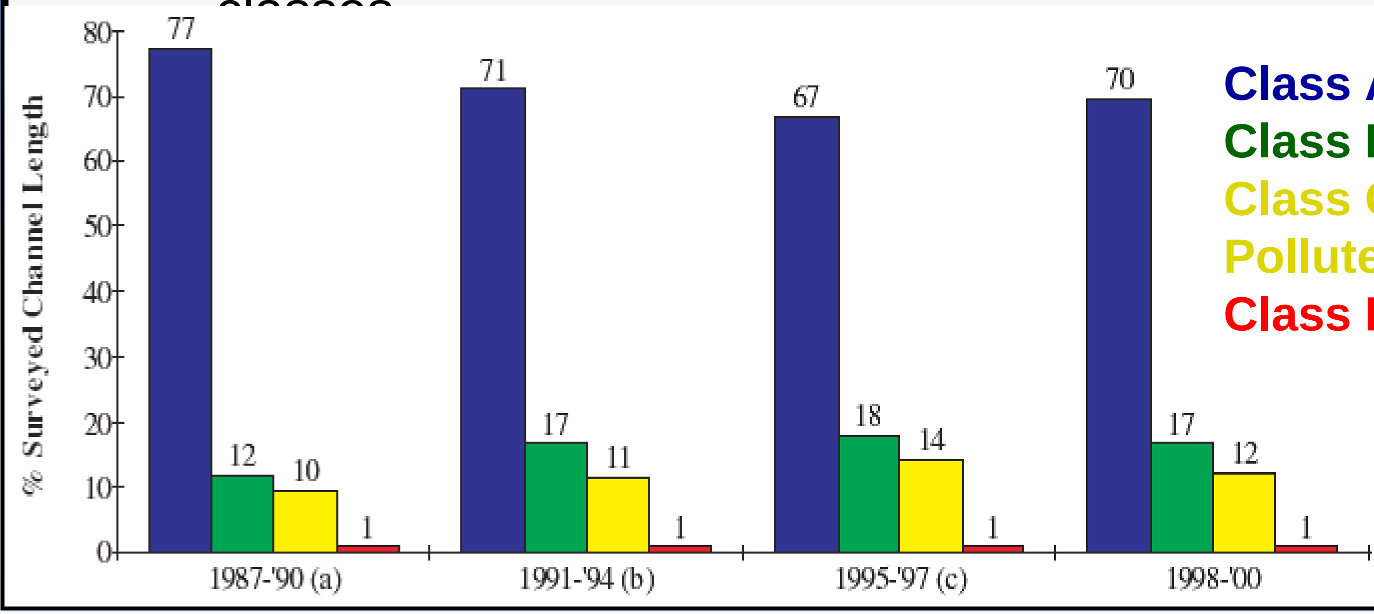
1 Centre for Water Resources Research, Civil Engineering Department, University College Dublin, Earlsfort Terrace, Dublin 2, Ireland.
Email: ahmed.nasr@ucd.ie
2 Department of Chemical and Environmental Science, University of Limerick, Limerick, Ireland.

ORGANIZATION OF THE PRESENATION

- Background of the water quality situation in Ireland
- The Clarianna catchment
- Objectives
- Outlines of the SWAT and HSPF models
  (flow and phosphorus components)
- Results
- Conclusions

SITUATION IN IRELAND - (1)

Percentage of channel length in four biological quality classes



Class A: Unpolluted
Class B: Slightly Polluted
Class C: Moderately Polluted
Class D: Seriously Polluted

- There is a continual increase in slight and moderate pollution (Classes A and B) in Irish rivers at the expense of previously unpolluted (Class A) watercourses.

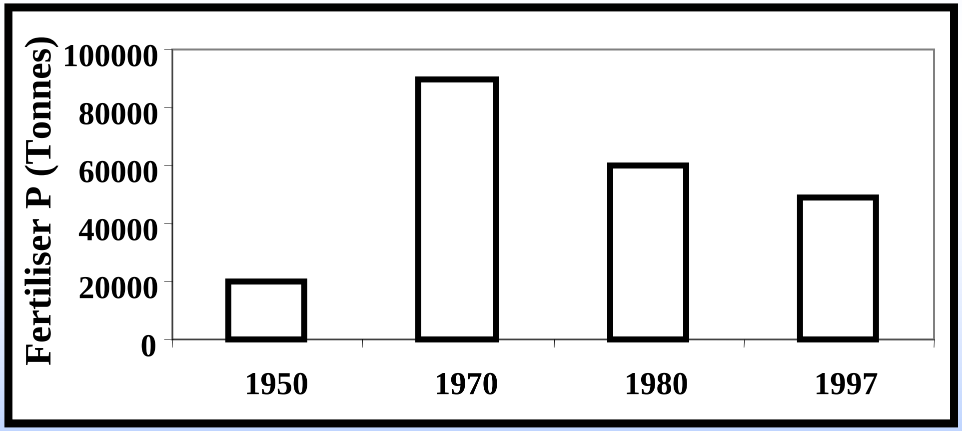
- Overloaded sewage treatment works (point source pollution) are likely to be responsible for seriously polluted rivers.

SITUATION IN IRELAND - (2)

• Inputs of nutrients (particularly phosphorus) from diffuse sources associated with agriculture are the primary causes of the increased levels in slight to moderate pollution of Irish rivers.

Inputs of P to the Irish soils :

- Trend of fertiliser phosphorus application over the Irish soils.



- 15000 Tonnes of P come from animal wastes.

SITUATION IN IRELAND - (3)

Point Source Pollution

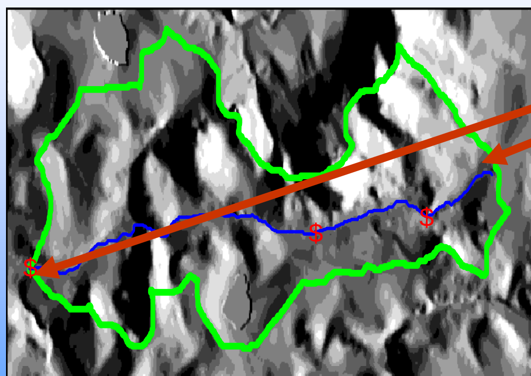
• Tacking this type of pollution has been addressed by upgrading the existing sewage treatment plants (including tertiary process).

Diffuse or Nonpoint Source Pollution

• This type of pollution still remains to be tackled however a Catchment-Based Strategy has been set to mitigate its effects.

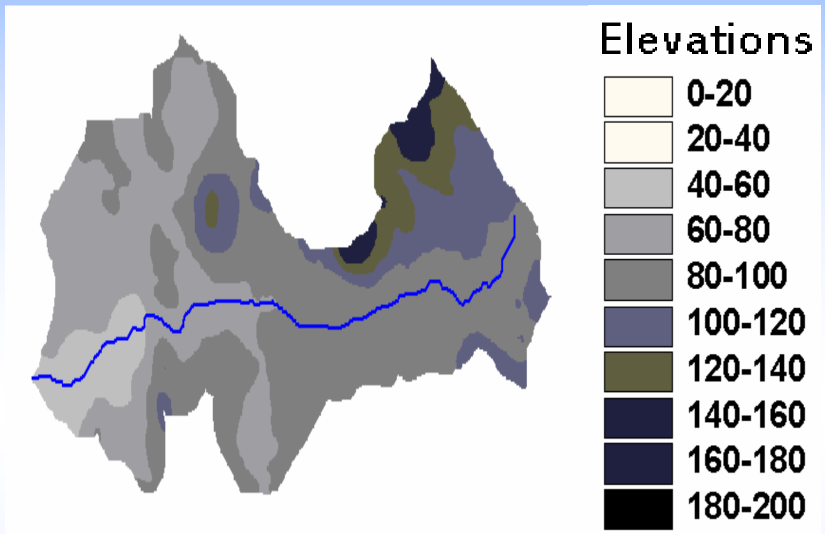
(One attempt is to employ existing physically-based models to quantify phosphorus losses from a number of Irish agriculture catchments).

LOCATION OF THE CLARIANNA CATCHMENT



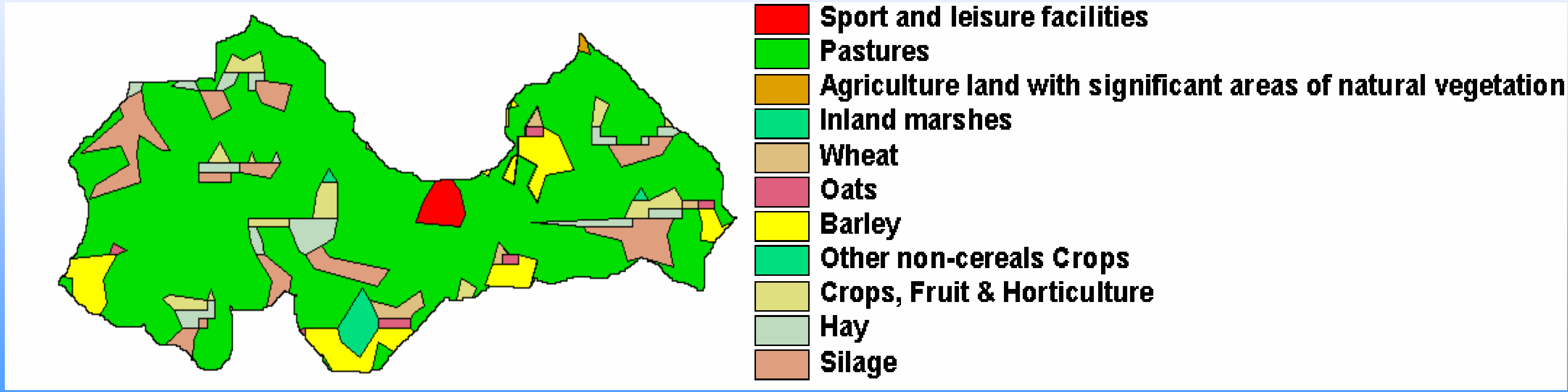
DEM, SOIL AND LAND USE MAPS OF THE CLARIANNA CATCHMENT

DEM



Soil Map

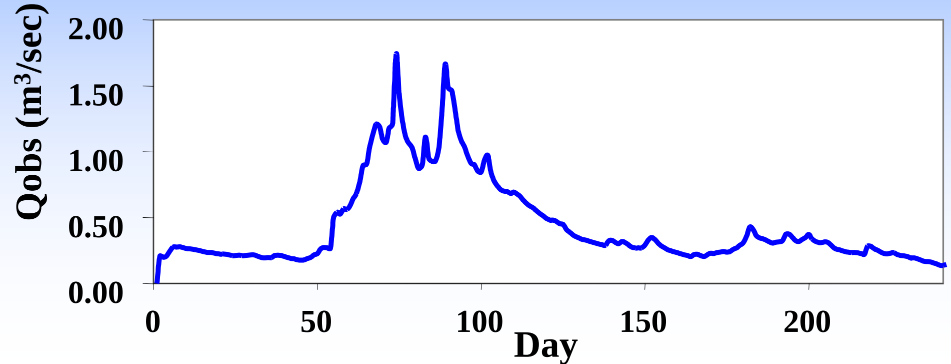
Land Use Map



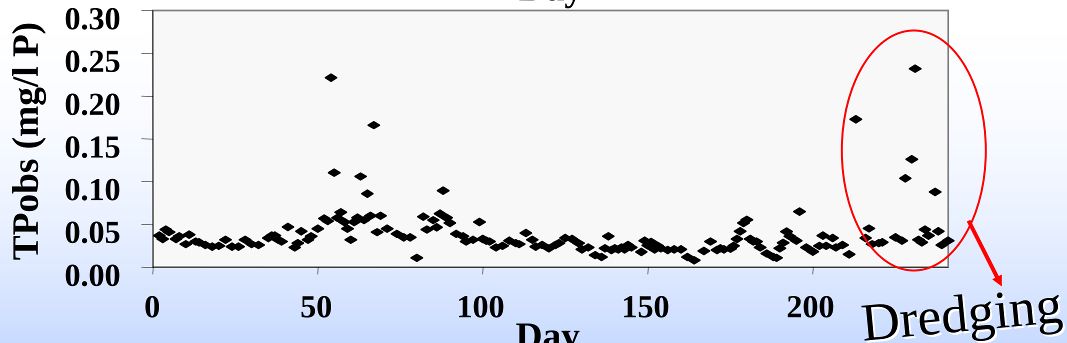
OBJECTIVES OF THE STUDY (1)

• To test the significance of phosphorus loss modelling in the SWAT and HSPF models in simulating the flow discharge and the total phosphorus (TP) at the outlet of the Clarianna catchment for the period 1/12/2001 - 29/7/2002

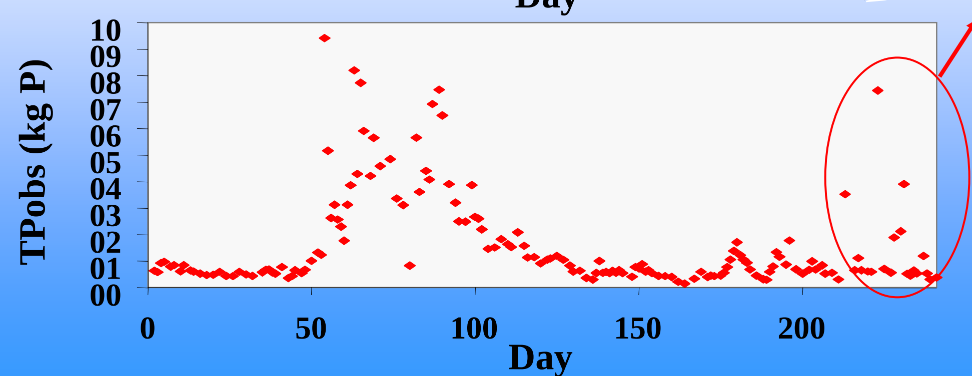
Flow Hydrograph



Total Phosphorus Graph (concentration)



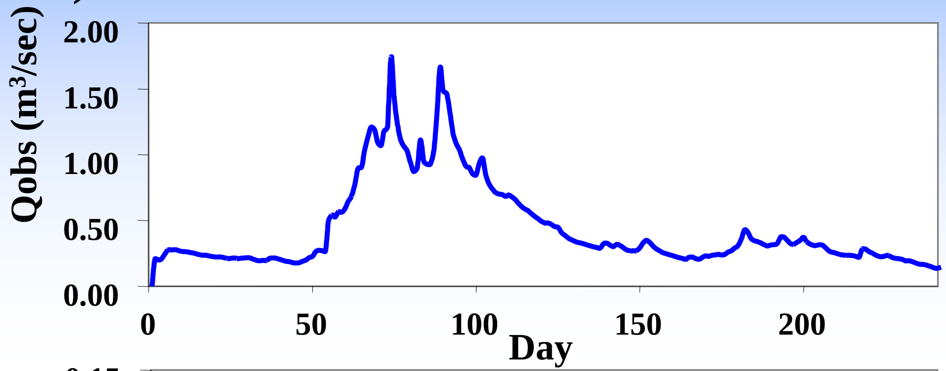
Total Phosphorus Graph (Load)



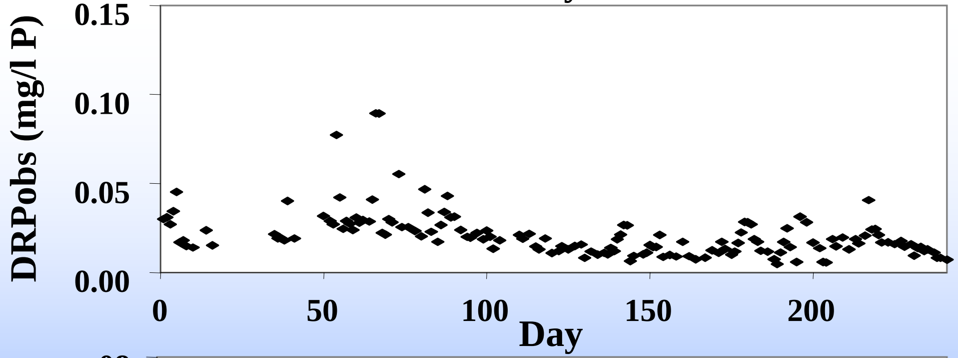
OBJECTIVES OF THE STUDY (2)

• To test the significance of the phosphorus loss modelling in the SWAT and HSPF models in simulating the flow discharge and the dissolved reactive phosphorus (DRP) at the outlet of the Clarianna catchment for the period 1/12/2001 - 29/7/2002

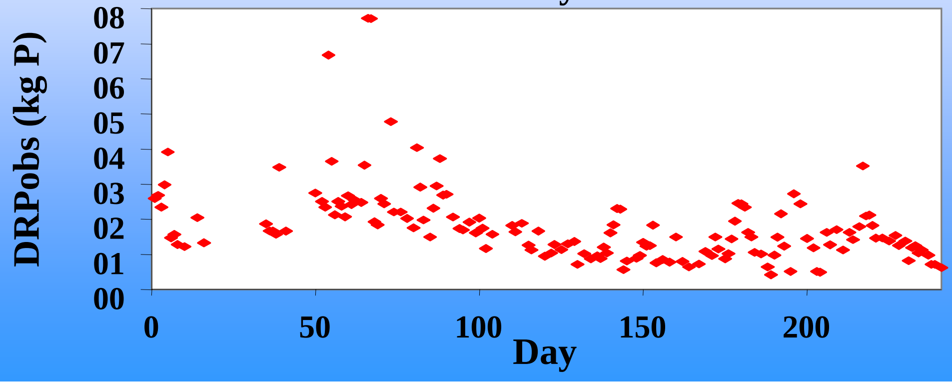
Flow Hydrograph



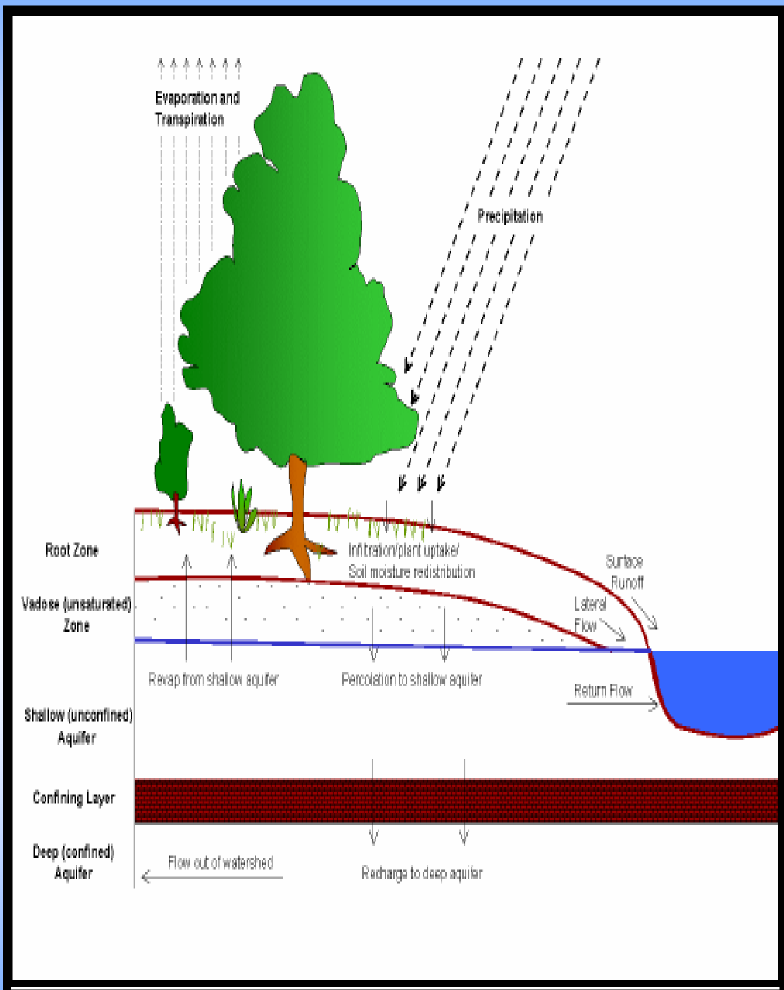
Dissolved Reactive Phosphorus Graph (concentration)

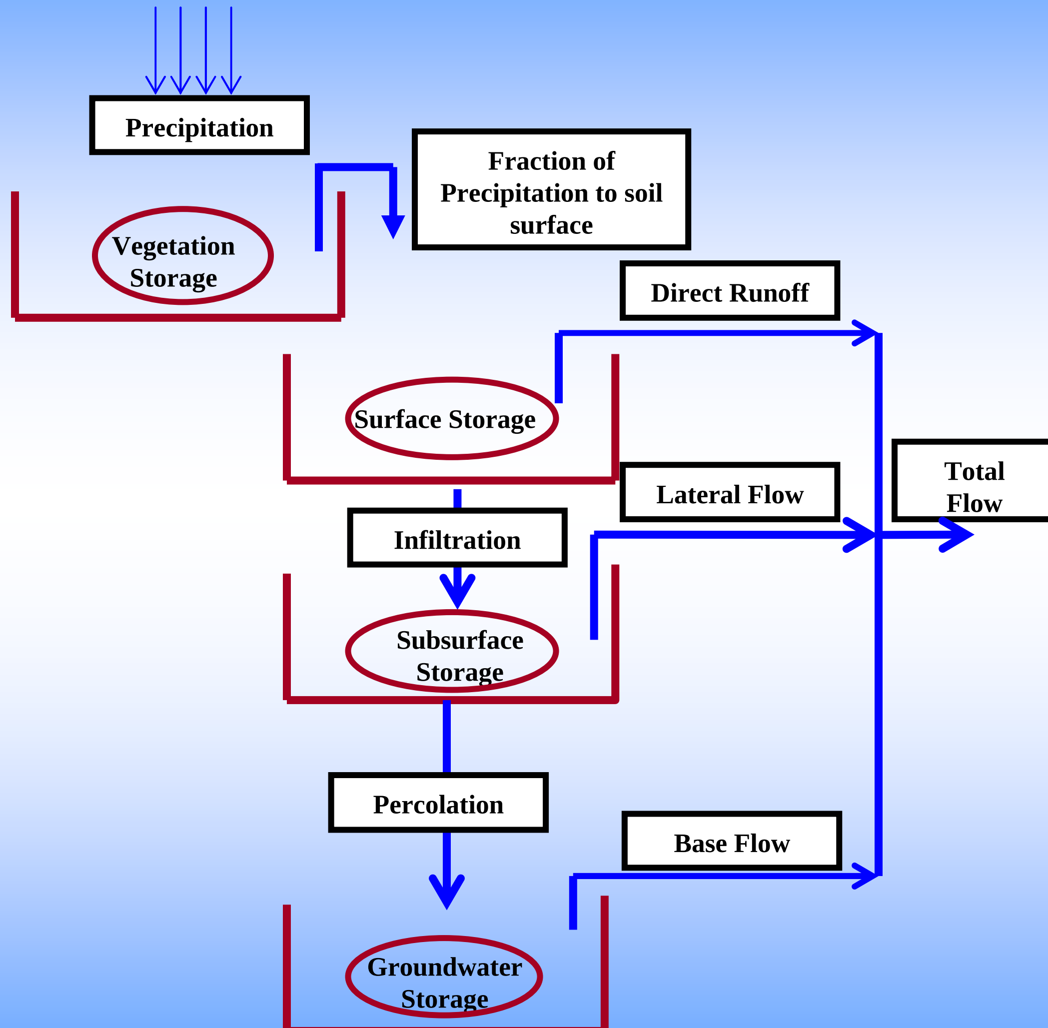


Dissolved Reactive Phosphorus Graph (Load)



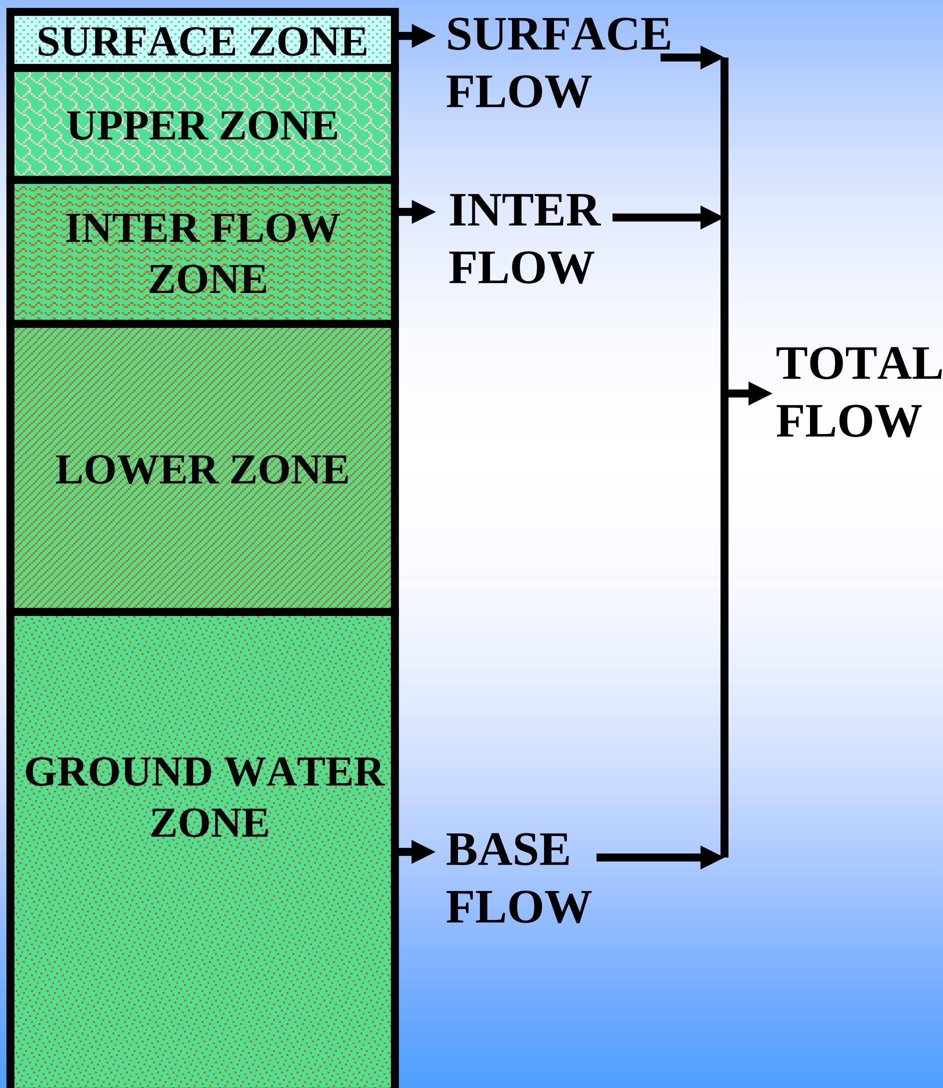
CONCEPTUAL REPRESENTATION OF THE WATER DYNAMIC MODELLING IN THE SWAT MODEL

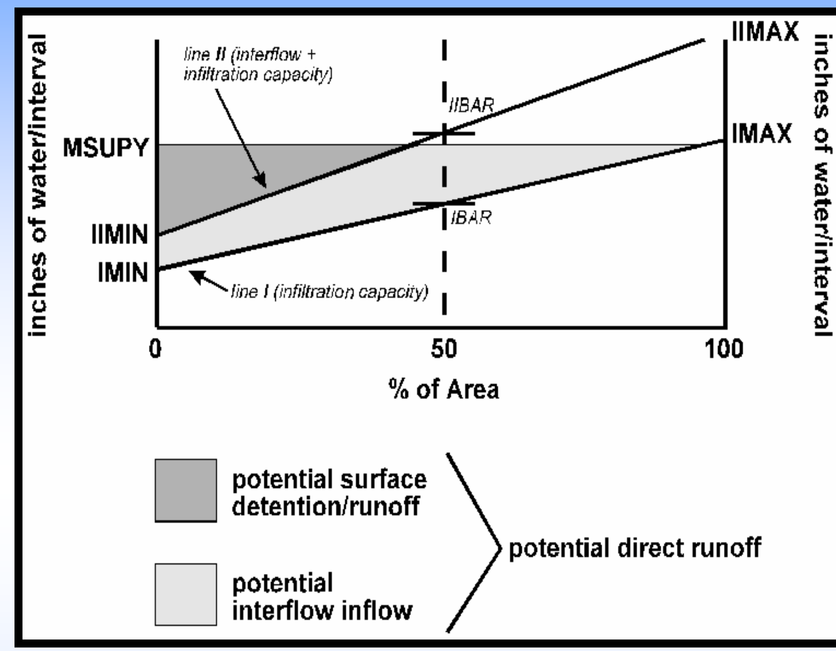




Interception, Surface Runoff, Infiltration, Evapotranspiration, Lateral flow, Percolation, Baseflow

CONCEPTUAL REPRESENTATION OF THE WATER DYNAMIC MODELLING IN THE HSPF MODEL

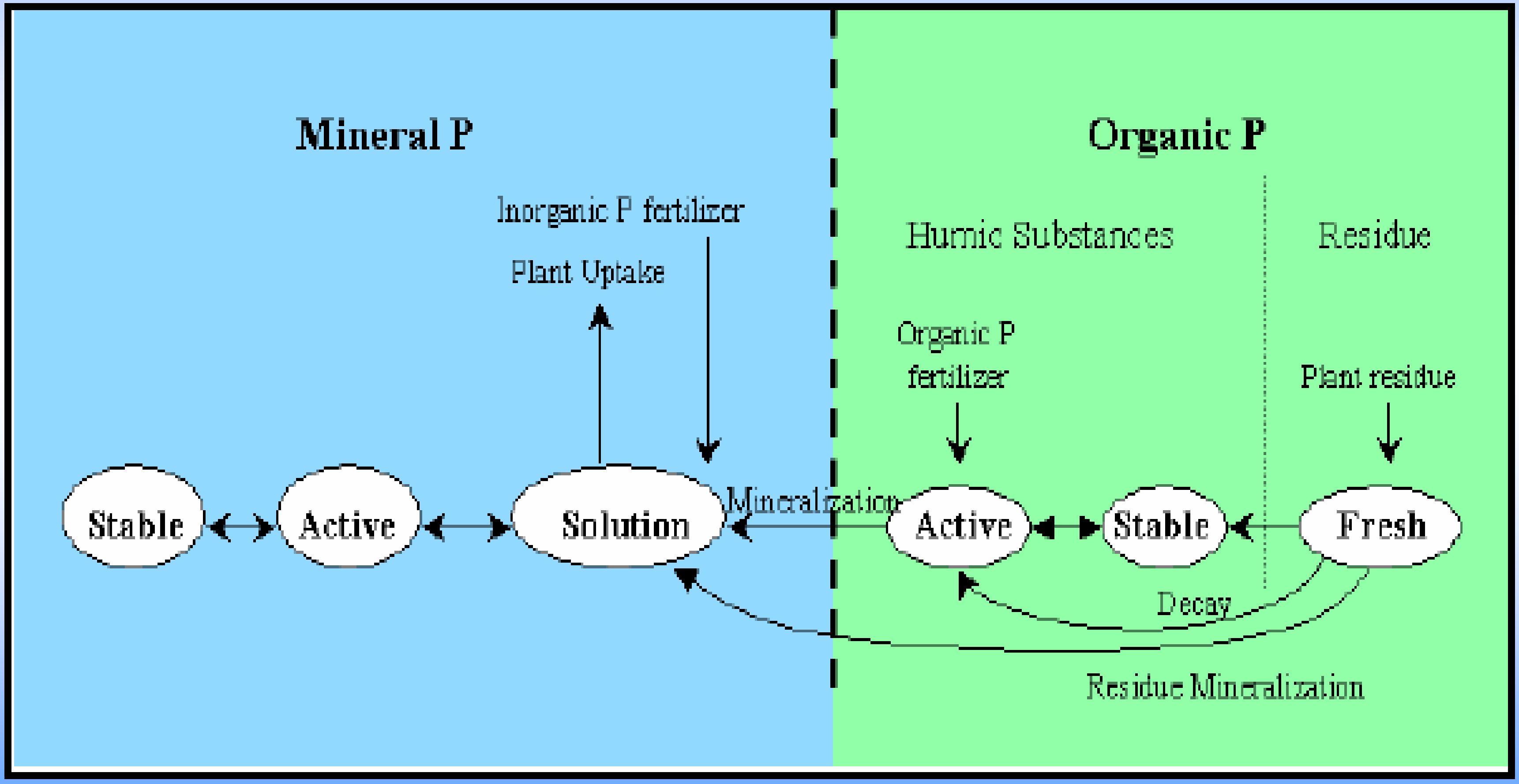




• The infiltration distribution is focused around the two lines which separate the moisture available to the land surface into what infiltrates and what goes to interflow.

PHOSPHORUS MODELLING IN THE SWAT MODEL (A)

Soil Phosphorus State Variables as described by SWAT



PHOSPHORUS MODELLING IN THE SWAT MODEL (B)

- Mineralization/immobilization of active organic phosphorus :- $(P_{\min})$

$$P_{\min} = 1.4 \times \beta \times \sqrt{\gamma_{tmp} \times \gamma_{sw}} \times P_{act}$$

$\Rightarrow \begin{cases} P_{act} : \text{active organic P} \\ \beta : \text{rate coefficient of mineralization} \\ \gamma_{tmp} : \text{nutrient cycle temperature factor} \\ \gamma_{sw} : \text{nutrient cycle water factor} \end{cases}$

- Mineralization/immobilization of fresh organic phosphorus :- (P_{dec})

$$P_{dec} = \delta_{ntr} \times P_{fresh}$$

$\Rightarrow \begin{cases} P_{fresh} : \text{fresh organic P} \\ \delta_{ntr} : \text{residue decay constant} \end{cases}$

- Adsorption/desorption :- $(P_{ads/des})$

$$P_{ads/des} = P_{sol} - P_{ads} \times \left(\frac{pai}{1 - pai} \right)$$

$\Rightarrow \begin{cases} P_{sol} : \text{soluble mineral inorganic P} \\ P_{ads} : \text{adsorbed inorganic P} \\ pai : \text{phosphorus availability index} \end{cases}$

- P transport in runoff water :- (P_Q)

$$P_Q = \left(\frac{P_{sol}}{\rho_b \times D \times k_d} \right) \times Q$$

$\Rightarrow \begin{cases} P_{sol} : \text{soluble P in the top layer} \\ \rho_b : \text{bulk density of the soil} \\ D : \text{depth of the top soil layer} \\ k_d : \text{soil P partitioning coefficent} \end{cases}$

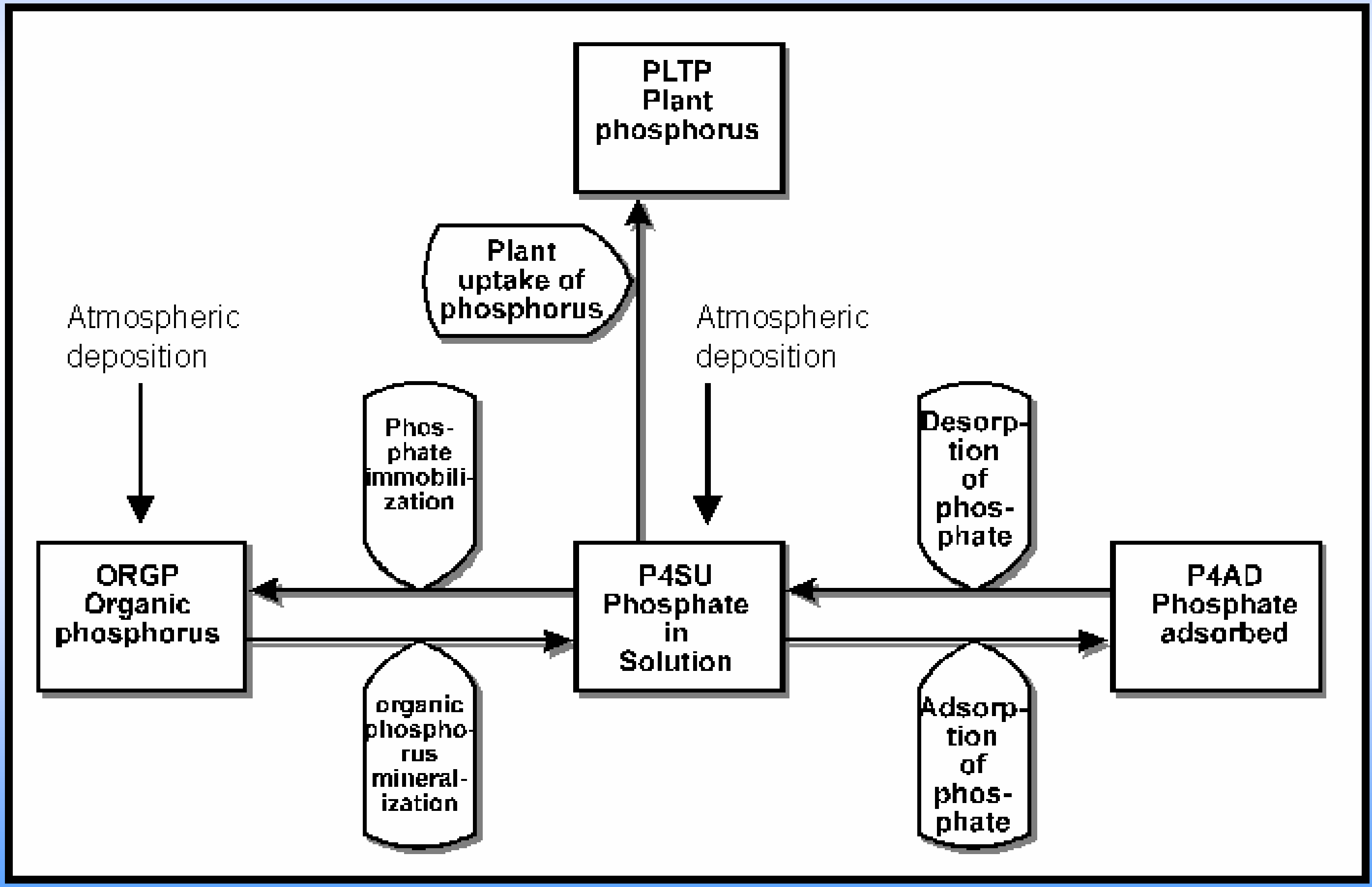
- P transport attached to sediment :- (P_{sed})

$$P_{sed} = P_{att} \times \left(\frac{SY}{A} \times \varepsilon \right)$$

$\Rightarrow \begin{cases} P_{att} : \text{amount of P in the soil parent material} \\ SY : \text{sediment yield} \\ A : \text{Area of the land} \\ \varepsilon : \text{P enrichment ratio} \end{cases}$

PHOSPHORUS MODELLING IN THE HSPF MODEL (A)

Soil Phosphorus Cycle



PHOSPHORUS MODELLING IN THE HSPF MODEL (B)

- Adsorption/desorption, mineralization, immobilization, plant uptake using first order kinetics :-

$$P_{flux} = P_{stor} \times K \times \theta^{(T-35)}$$

$\Rightarrow$
- P_{flux} : phosphorus flux
- P_{stor} : phosphorus storage
- K : first order rate parameter for the process
- θ : temperature correction factor for the process
- T : soil temperature

- P transport in runoff water :- (P_Q)

$$\frac{P_Q}{P_{sol}} = \left(\frac{Q}{sw}\right)$$

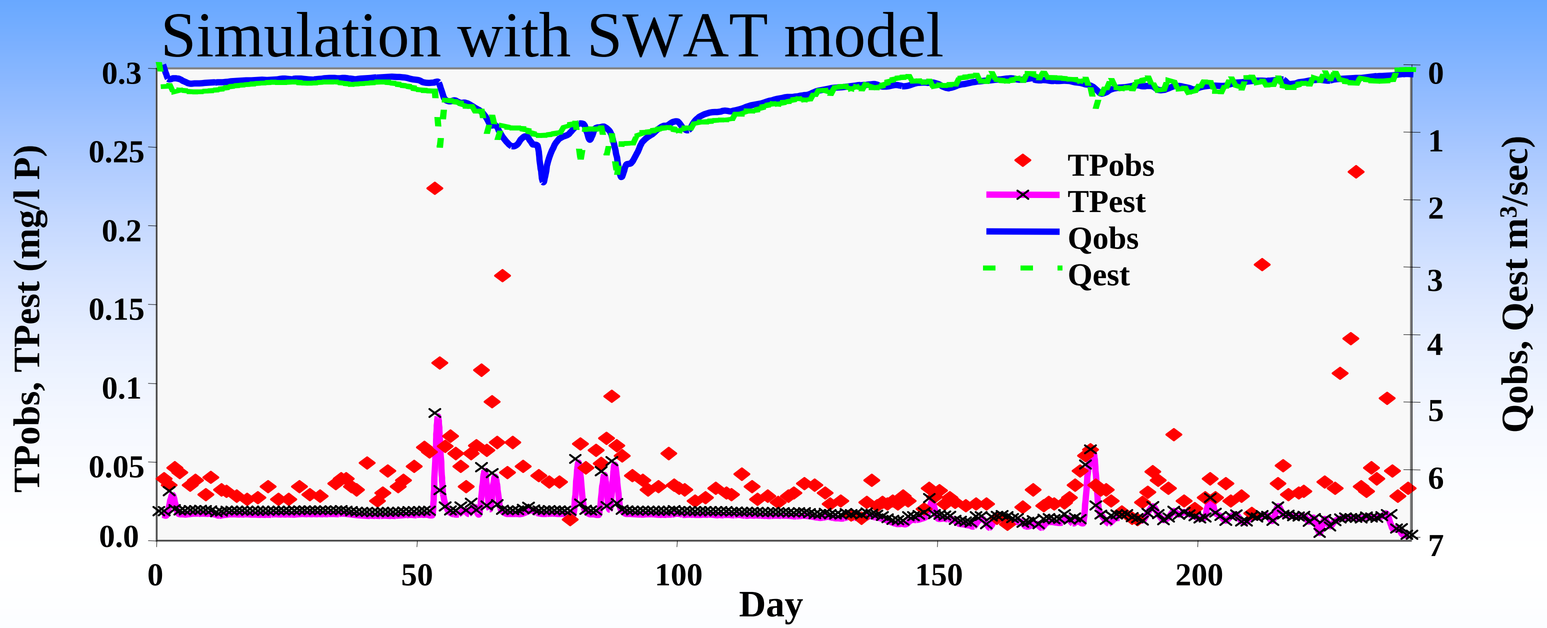
$\Rightarrow$
- P_{sol} : soluble P in the top layer
- Q : surface runoff
- sw : soil water

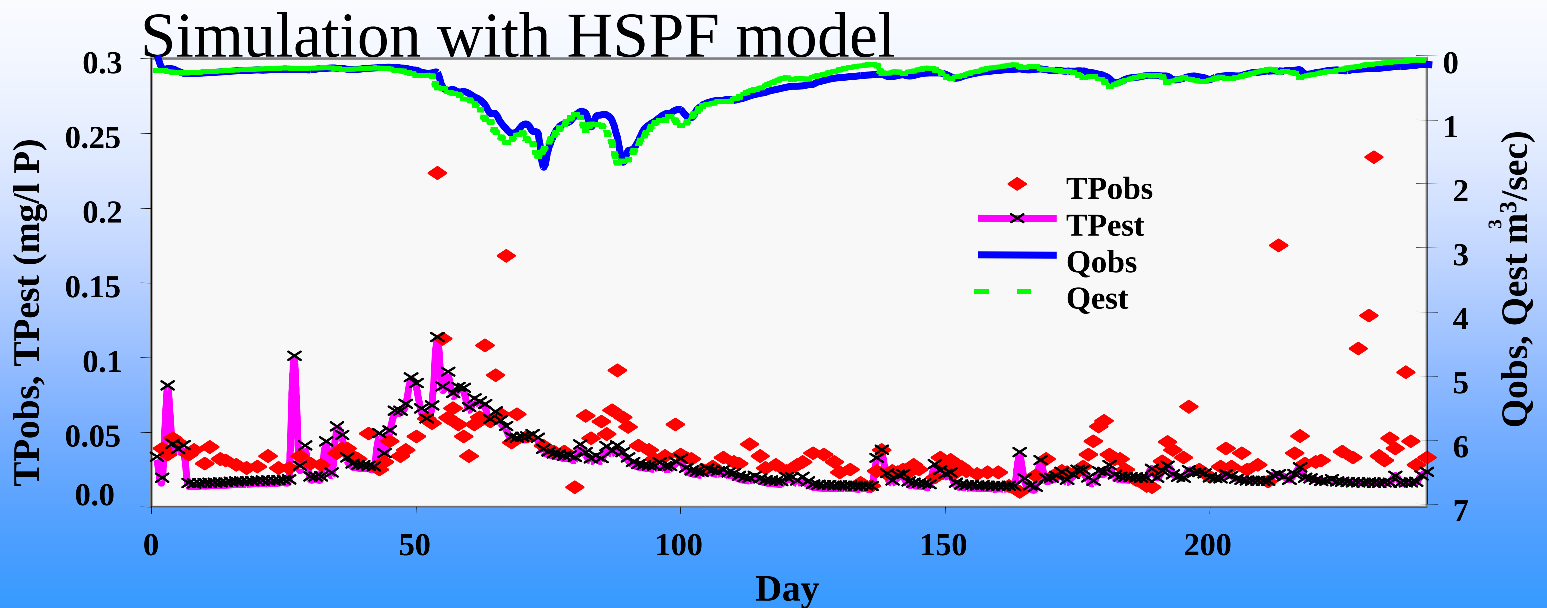
- P transport attached to sediment :- (P_{sed})

$$P_{sed} = Ratio \times P_{surf}$$

$\Rightarrow$
- P_{surf} : storage of P in the surface layer
- $Ratio$: ratio of sediment eroded to that exist in the surface layer

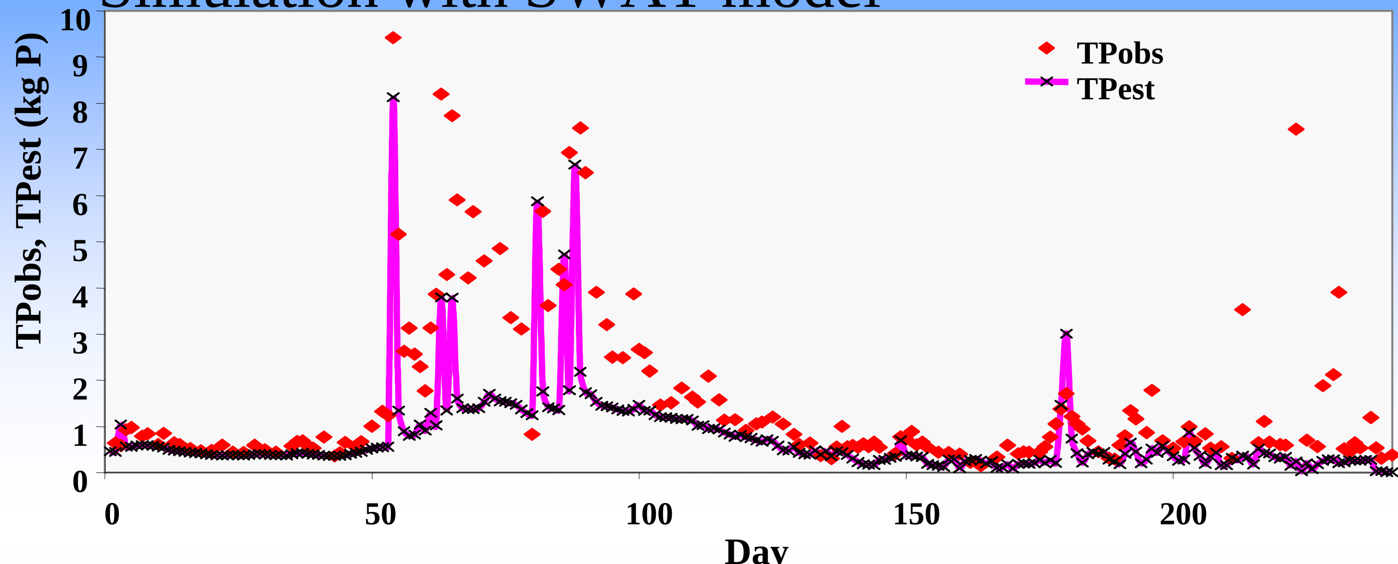
RESULTS OF THE FLOW AND TP SMULATIONS (1)



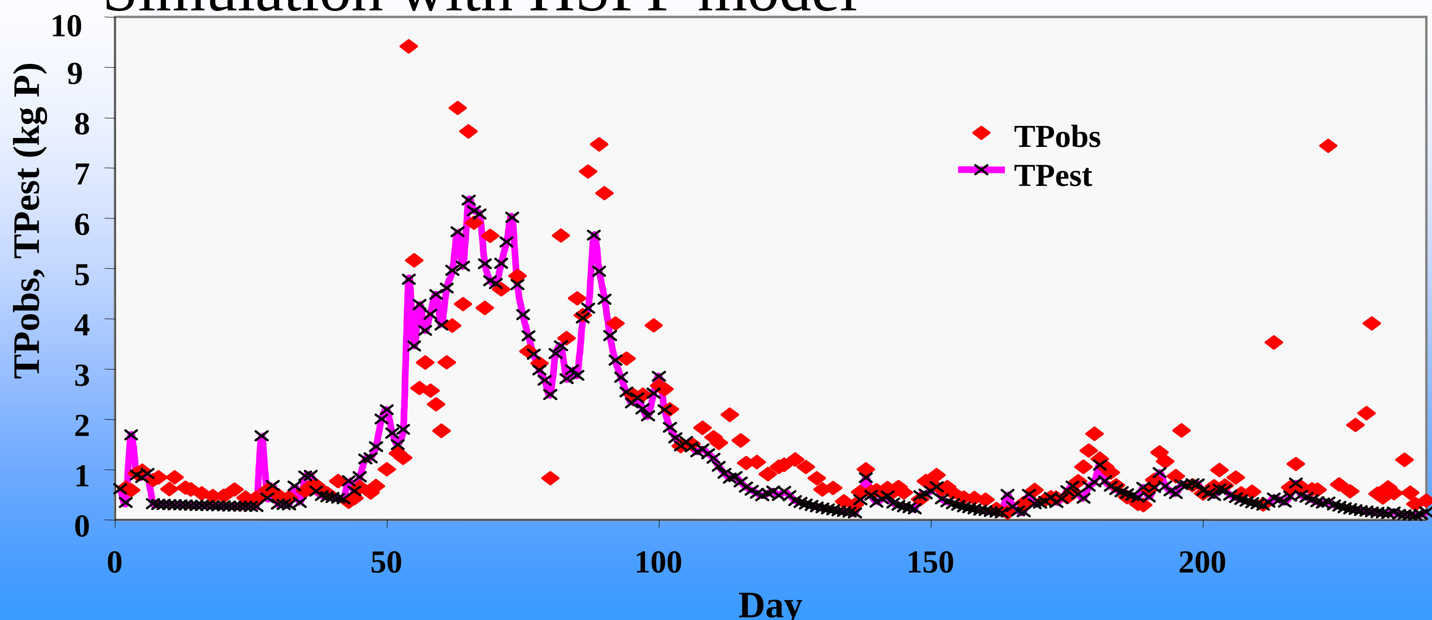


RESULTS OF THE FLOW AND TP SMULATIONS (2)

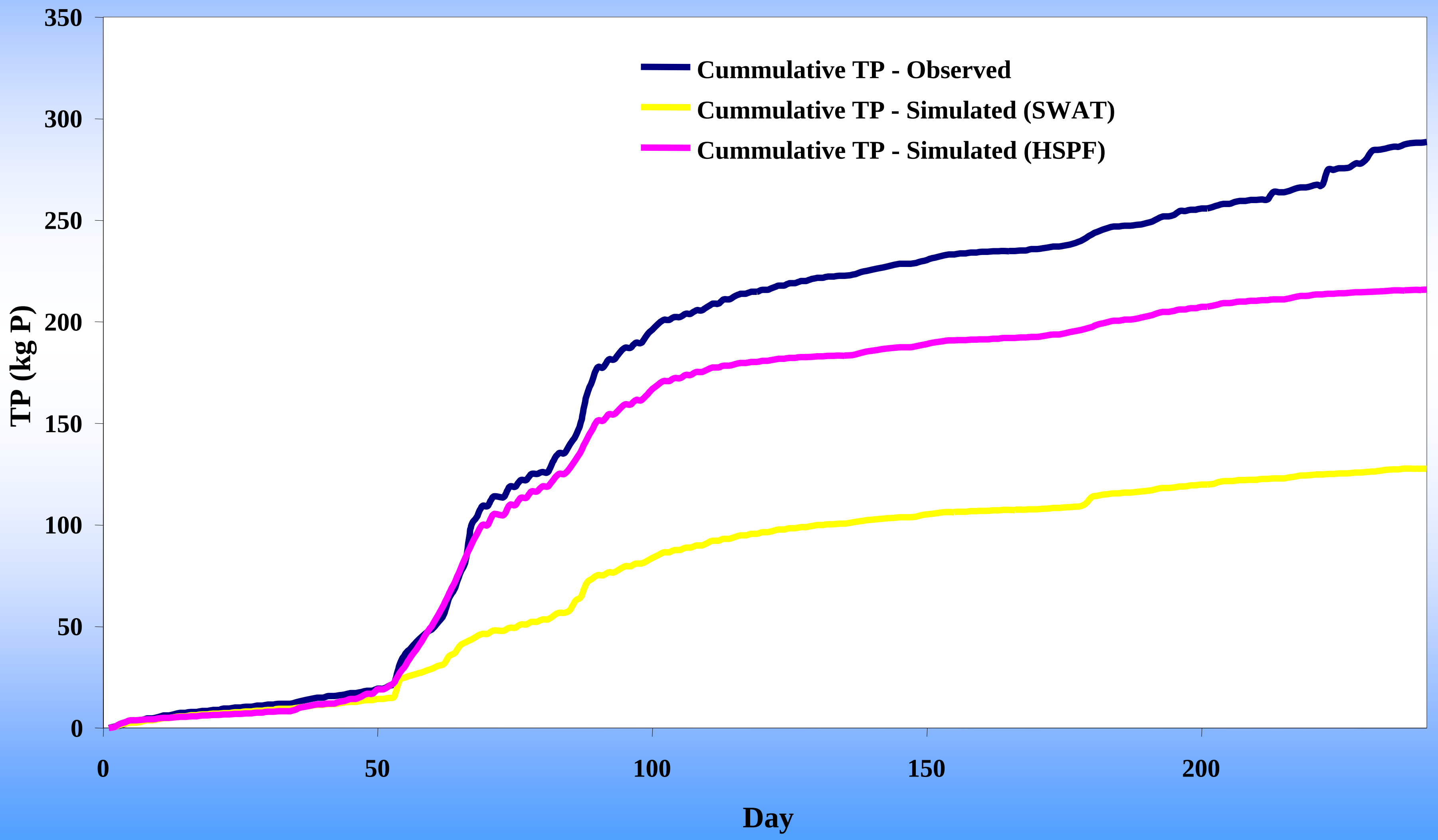
Simulation with SWAT model



Simulation with HSPF model

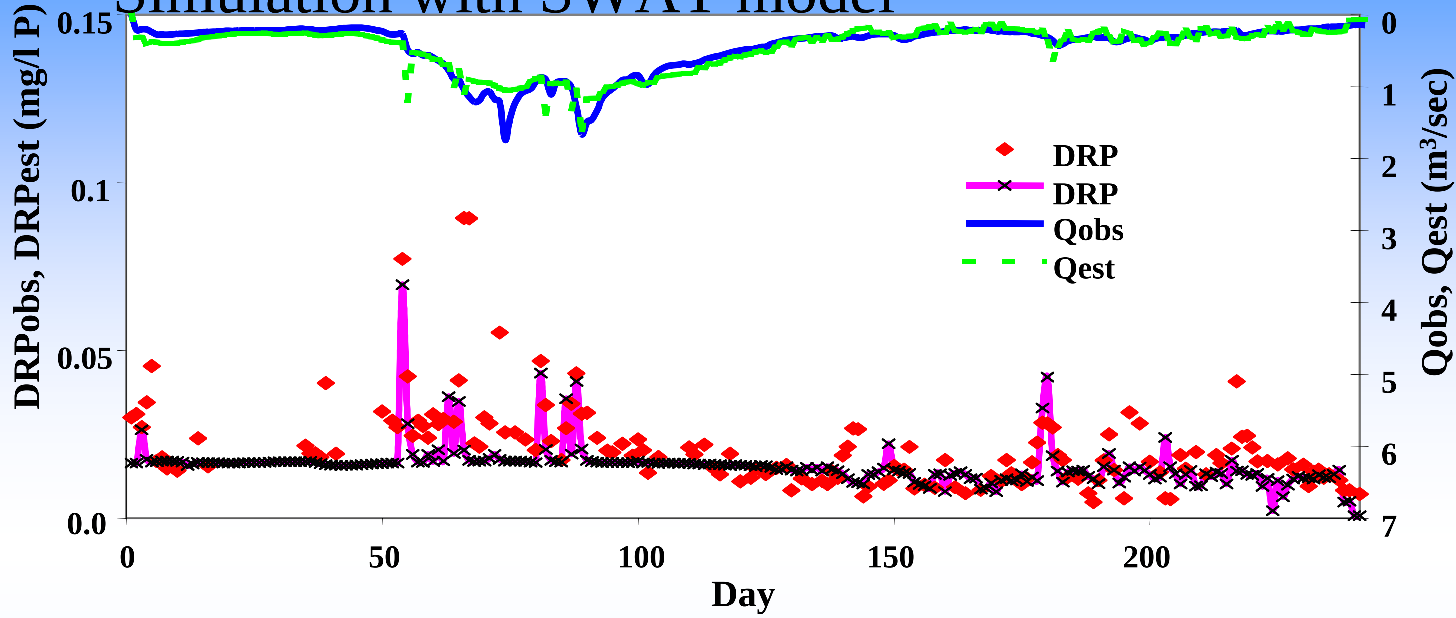


RESULTS OF THE FLOW AND TP SMULATIONS (3)

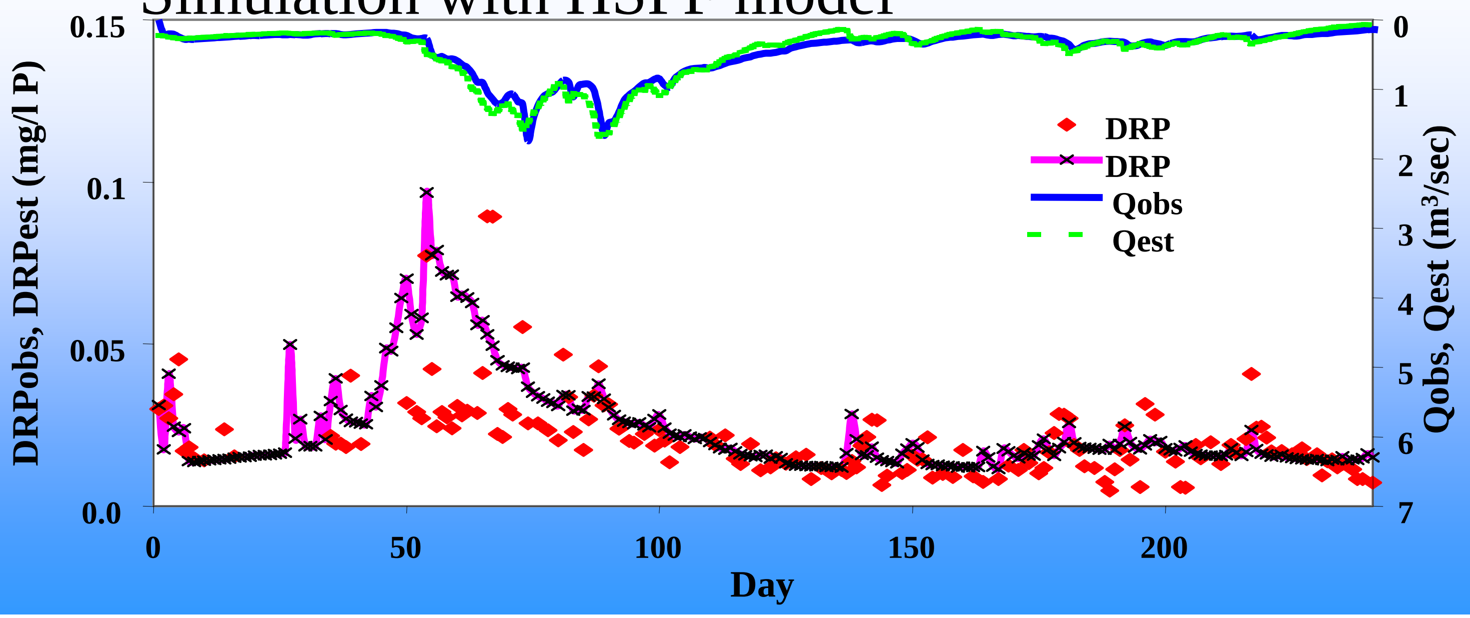


RESULTS OF THE FLOW AND DRP SMULATIONS (1)

Simulation with SWAT model

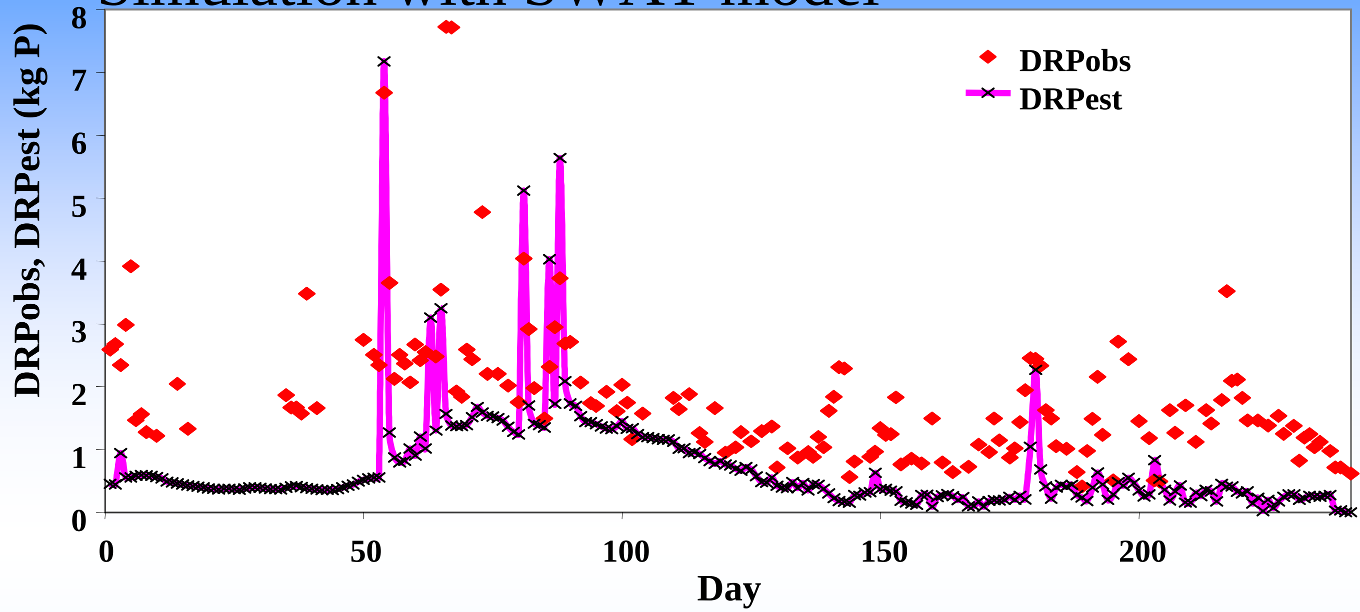


Simulation with HSPF model

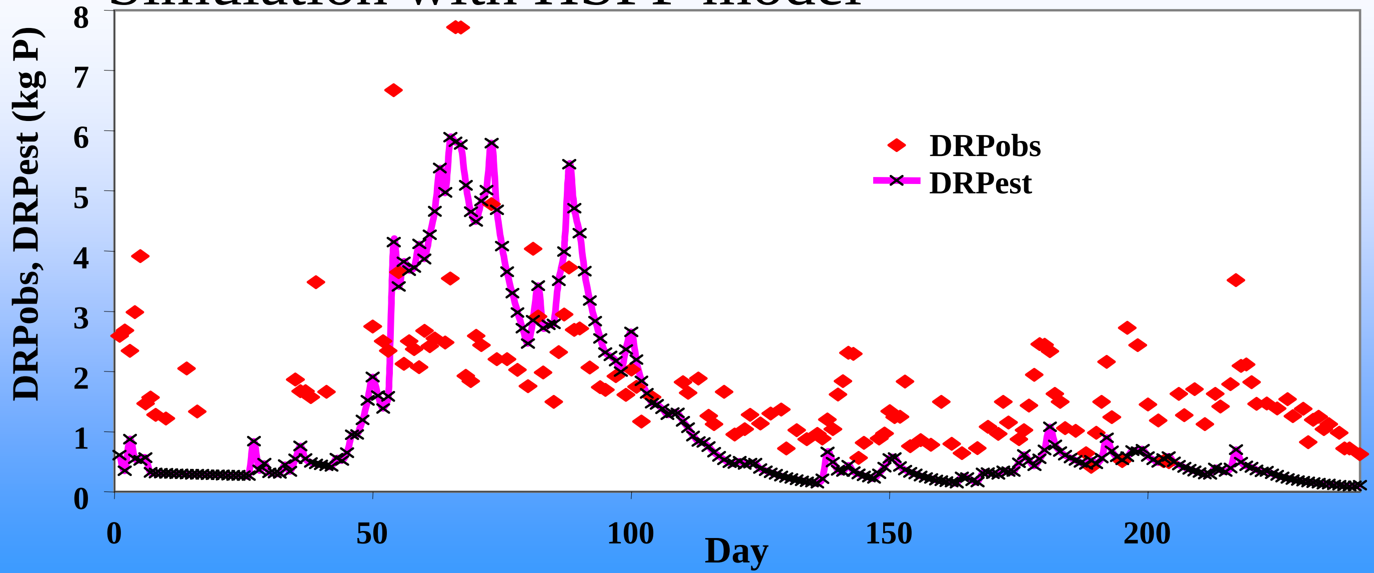


RESULTS OF THE FLOW AND DRP SMULATIONS (2)

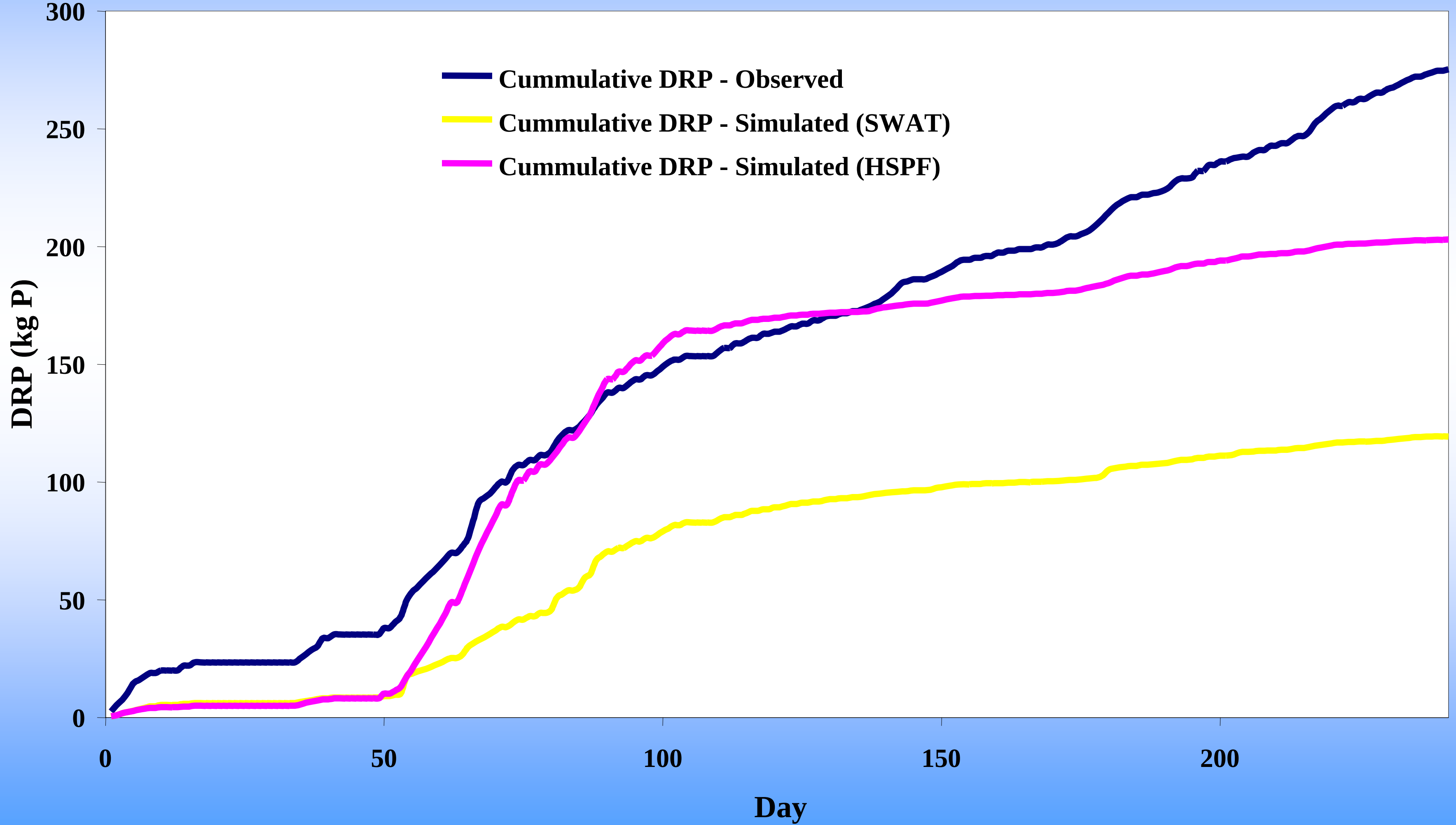
Simulation with SWAT model



Simulation with HSPF model



RESULTS OF THE FLOW AND DRP SMULATIONS (3)



CONCLUSIONS

• Flow simulation with the HSPF model was better than the SWAT model in the prediction of peak events.

• Total Phosphorus and Dissolved Reactive Phosphorus simulations with the SWAT and HSPF models were generally acceptable.

• Both models failed to simulate high values of Total Phosphorus and Dissolved Reactive Phosphorus due to the underestimation of removable soil phosphorus.

• Soil phosphorus modelling in the SWAT model includes parameters to account for the effect of soil moisture and soil temperature while the HSPF model parameters take into account the effect of soil temperature only.