# Predicting diffuse-source transfers of sewage-sludge- associated chemicals to surface waters using SWAT

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# Introduction to surfactants

Sewage Sludge : Sulphates, Phosphates, metals , synthetic waste, organic waste, and surfactants

Definition: Surface active agent

Occurrence: Detergents, Dishwashing liquids, All purpose cleaners

Purpose of surfactants : to decrease surface tension and improve the cleaning action



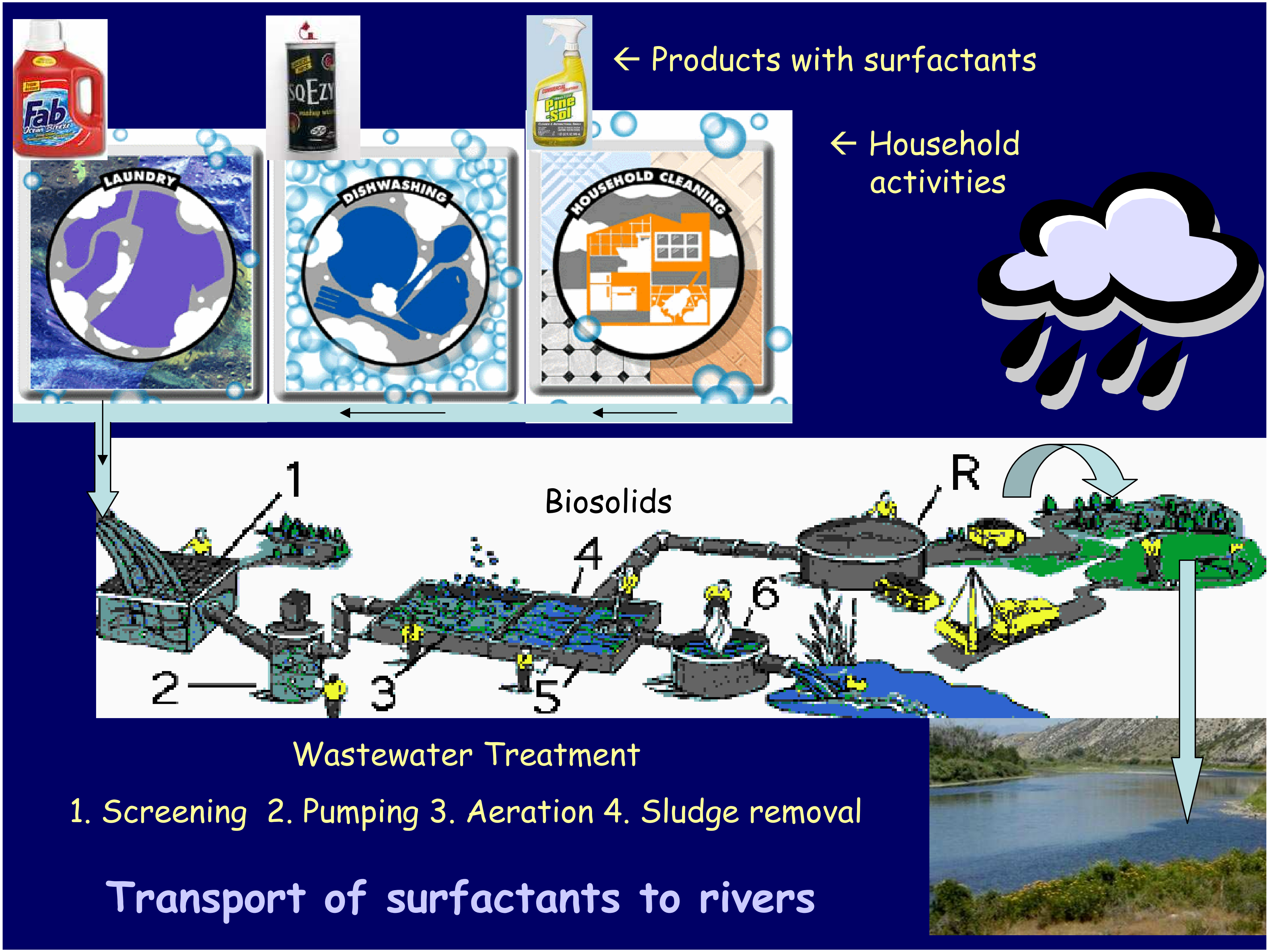
Surfactant also performs

- Cleaning
- emulsifying

(Courtesy: The soap and detergent association: www.cleaning101.com/cleaning/chemistry)

Types : Anionic / cationic depending on charge

Surfactant Name: Linear Alkylbenzene Sulphonate (LAS)



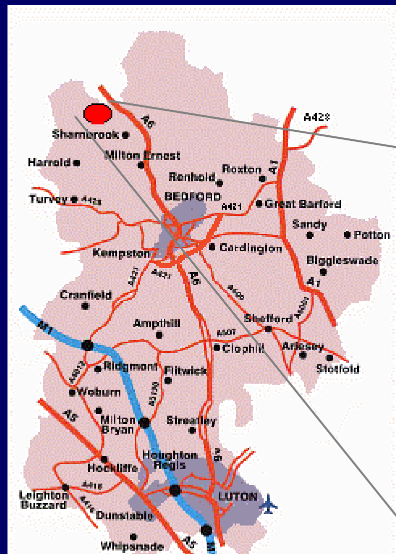
← Products with surfactants
← Household activities
LAUNDRY
DISHWASHING
HOUSEHOLD CLEANING
Fab
Pine-Sol
1
2
3
4
5
6
R
Biosolids
Wastewater Treatment
1. Screening 2. Pumping 3. Aeration 4. Sludge removal
Transport of surfactants to rivers

# Why a modelling study is important for this chemical?

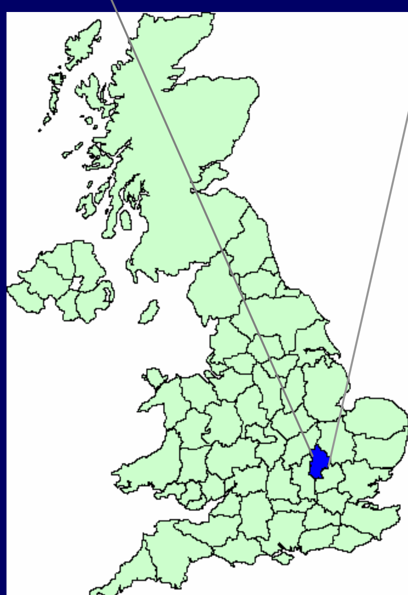
•Companies using LAS claim that "Use of LAS in laundry and household cleaning products will not result in water pollution"

-Statements like these are based on extrapolation of existing eco-toxicity data – Need to be verified by observations/modelling studies
-No reported modelling study on this chemical so far
- Increased use (Europe: 330 kton in year 2000)-Getting more attention recently
-Expected to behave similar to pesticides
- Properties easily available

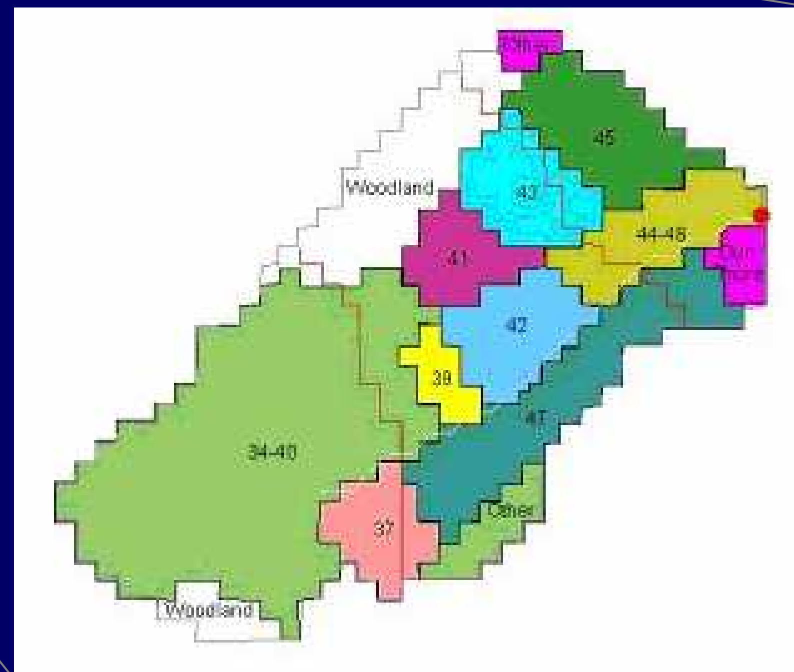
# Study Area




Bedfordshire



United Kingdom




Colworth

Area: 1.415 $km^2$

Soil: Clay loam over stony calcareous clay - Hanslope

Crop rotation: Wheat-Oilseed rape, grass, beans, peas

# This study ..

- Based on a previous pesticide modelling study for the same catchment
- Is aimed to answer "what if" scenarios
- Uses real data on a real catchment
- Hypothetical scenarios
- Has no observations to compare the model results

# Assumptions

1) Winter Wheat is growing throughout the cultivable areas of the catchment

..and throughout simulation period (i.e. Crop growth of Winter Wheat is simulated every year)

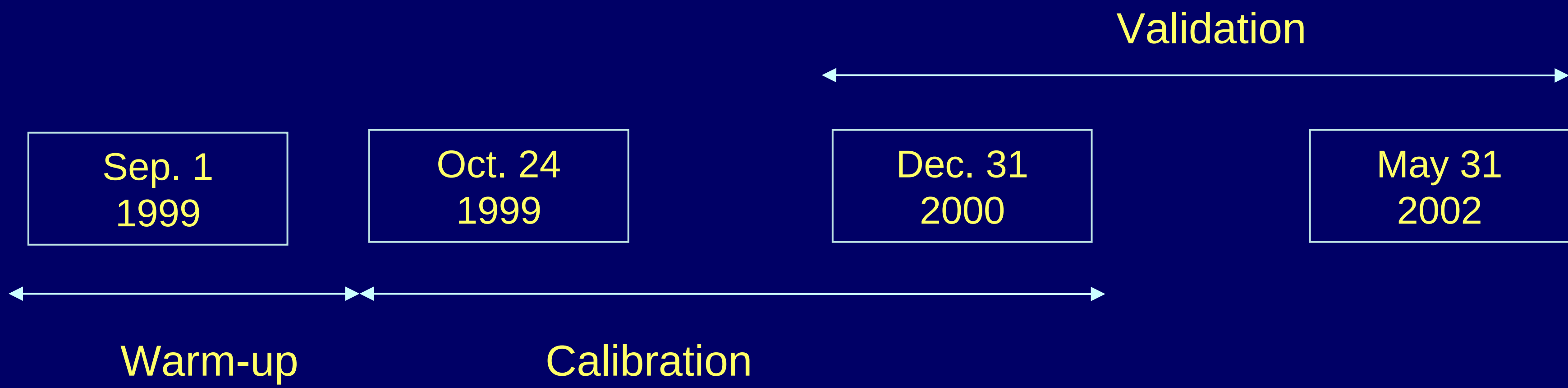
2) Same set of management operations (including rates and dates) for every crop growth cycle.

# Data Availability and Calendar of Simulation

| Simulation period | | 1999 | | | 2000 | | | 2001 | | | 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | May | Sep | Jan | May | Sep | Jan | May | Sep | Jan | May | Sep |
| **Data** | **Source** | | | | | | | | | | | | |
| | | | | | Calibration | | | Validation | | | | | |
| **Rainfall** | *Unilever-Colworth* | | | | | | | | | | | | |
| **Temperature** | *Unilever-Colworth* | | | | | | | | | | | | |
| **Wind speed** | *BADC-Bedford* | | | | | | | | | | | | |
| **Solar radn.** | *BADC-Bedford* | | | | | | | | | | | | |
| **Dew point** | *BADC-Bedford* | | | | | | | | | | | | |
| **Management** | *Unilever-Colworth* | | | | | | | | | | | | |
| **Streamflow** | *Unilever-Colworth* | | | | | | | | | | | | |

BADC – British Atmospheric Data Centre

## Calibration / Validation




## Rainfall pattern in the study area

| | **Water year** | | |
|---|---|---|---|
| | **1999-2000** | **2000-2001** | **2001-2002** |
| **Total yearly rainfall** | 663.8 | 755.4 | 527.2 |
| | Average | Wet | Dry |

# Different Calibration Schemes

| | Runoff | | Evapotranspiration | |
|---|---|---|---|---|
| | CN | GA | Har-greaves | Penman Montieth |
| Scheme 1 | X | | X | |
| Scheme 2 | X | | | X |
| Scheme 3 | | X | X | |
| Scheme 4 | | X | | X |

## Performance of hydrological modelling

| Period | Method | PBIAS | PME | NSE | DRMS |
|---|---|---|---|---|---|
| Oct. 1999 to Dec. 2000 | Calibration | 16.85 | 56.17 | 60.12 | 0.81 |
| Jan. 2001 to May 2002 | Validation | 3.17 | 51.15 | 59.32 | 0.74 |

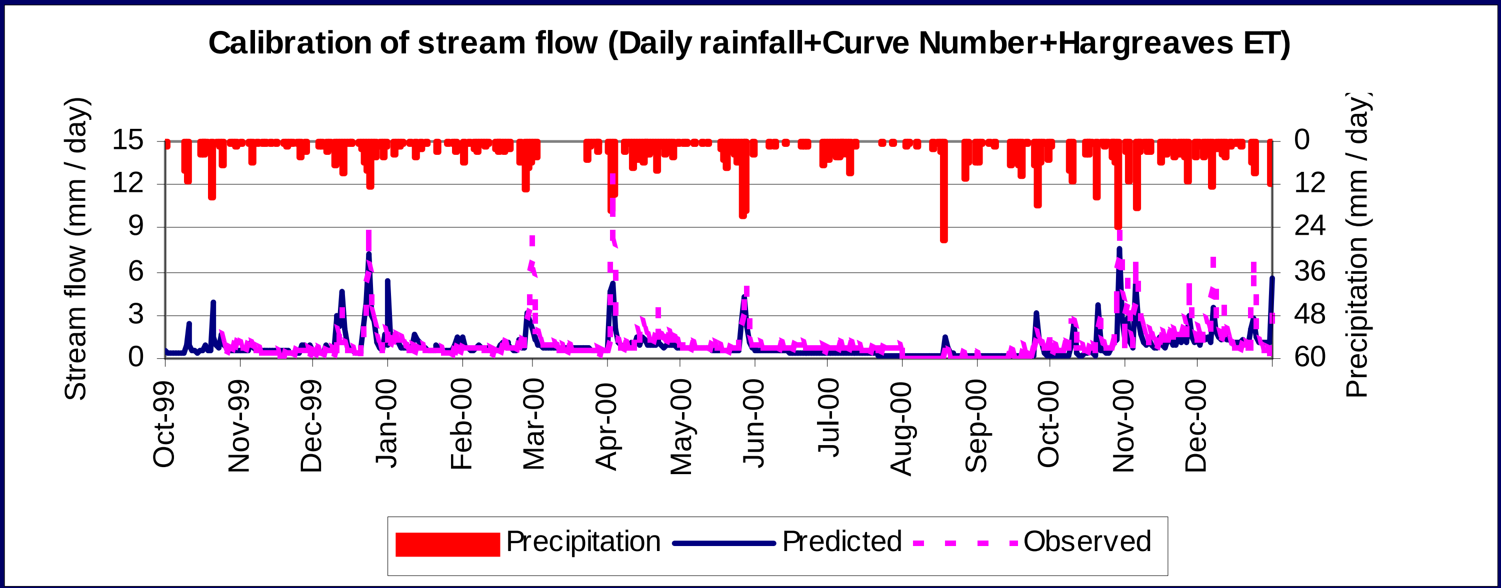
PBIAS - Percent Bias → Under / Over estimation

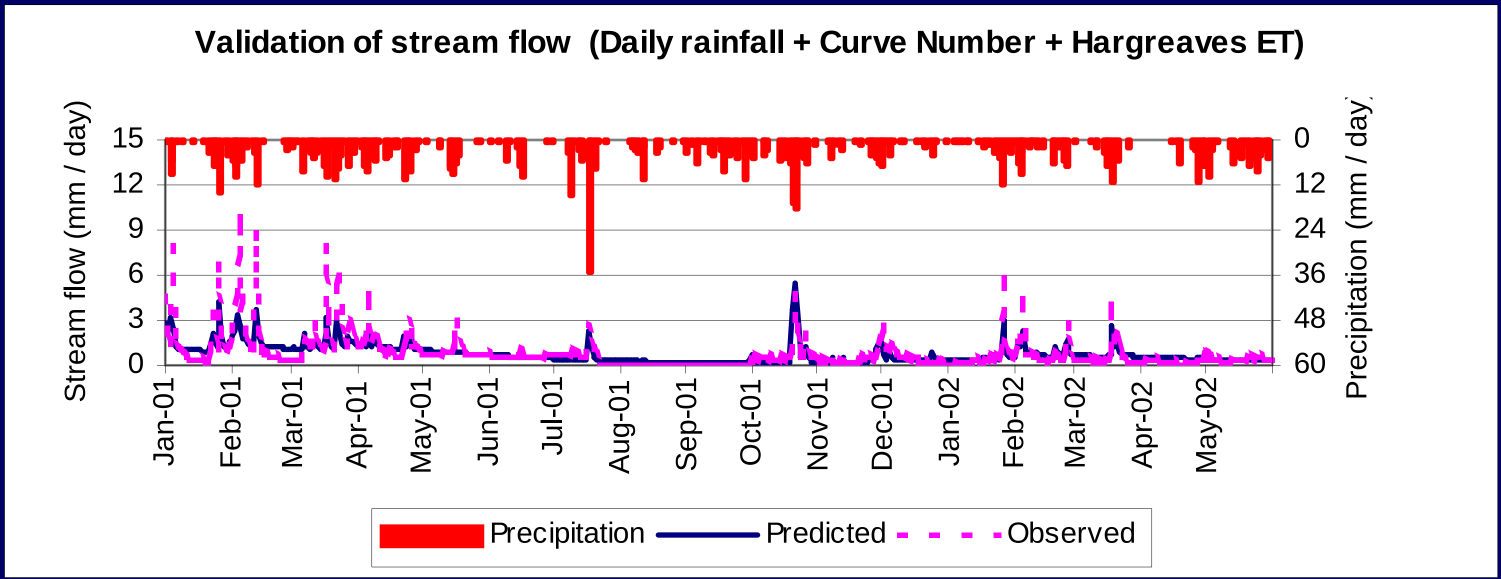
PME – Persistence Model Efficiency → Performance compared to a simple persistence model

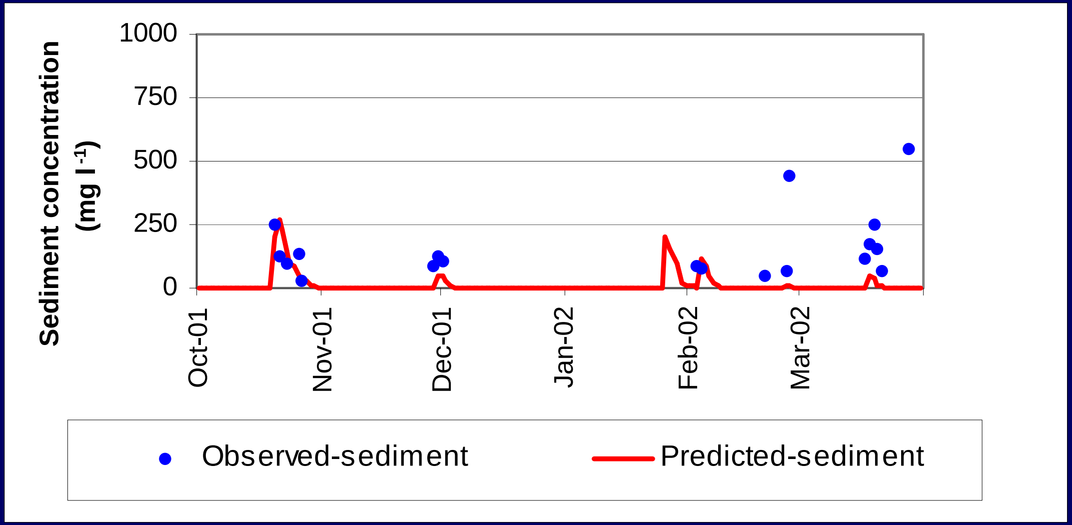
NSE – Nash & Sutcliffe Efficiency

DRMS – Daily Root Mean Square estimation criterion → Standard deviation of model prediction errors

# Comparison of predicted and observed stream flow






Comparison of predicted and observed daily sediment concentration values

## Check for Processes / components controlling water balance

| Prediction from SWAT | Compared to | Remarks |
|---|---|---|
| Crop growth | Reported observations | ok |
| Evapotranspirtaion | 30 year average values | ok |
| Soil moisture deficit | 30 year average values | ok |
| Partitioning of rainfall into Different runoff components | Discussion with soil hydrologist | ok |

# LAS modelling in SWAT

Representation of bio-solids application in SWAT

Bio-solids has a nutritional value-varies with wastewater treatment processes

– therefore bio-solids can be added as a manure in SWAT-fertiliser database

LAS in bio-solids behaves like a pesticide

- therefore bio-solids can be added as a pesticide to SWAT-Pesticide database

Properties of LAS/Bio-solids used in this study

– 3.91 % N and 4.82 % P

(from the nearest wastewater treatment plant to the study area)

– Decay properties : Varies with scenario

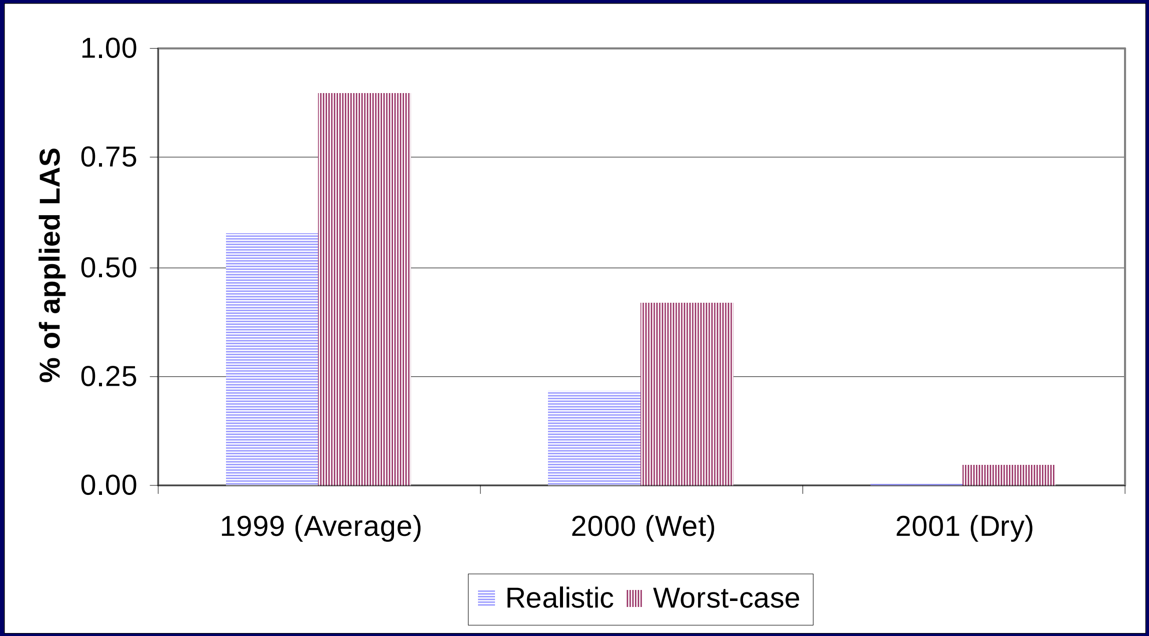
Degradation of LAS

Follows first order kinetics

# Scenarios in LAS modelling

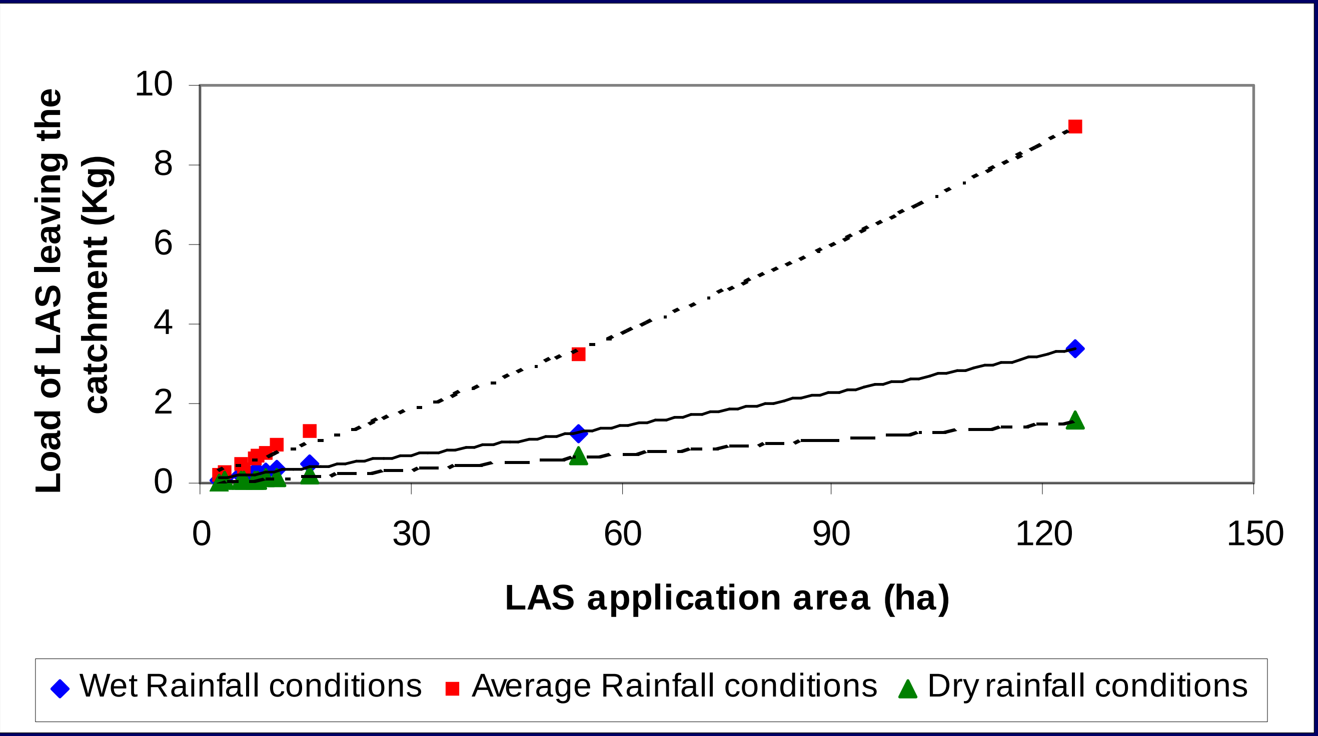
| Scenario | Half life (days) | LAS in bio-solids (g/kg) | Application rate (kg/ha) | % of nutrient demand met | Apply to |
|---|---|---|---|---|---|
| Realistic case | 7 | 5 | 2500 | 100 | All fields together and each field individually |
| Worst case | 30 | 10 | 5000 | TGD | All fields together and each field individually |

# Predicted total load of LAS for three hydrologically different cropping seasons

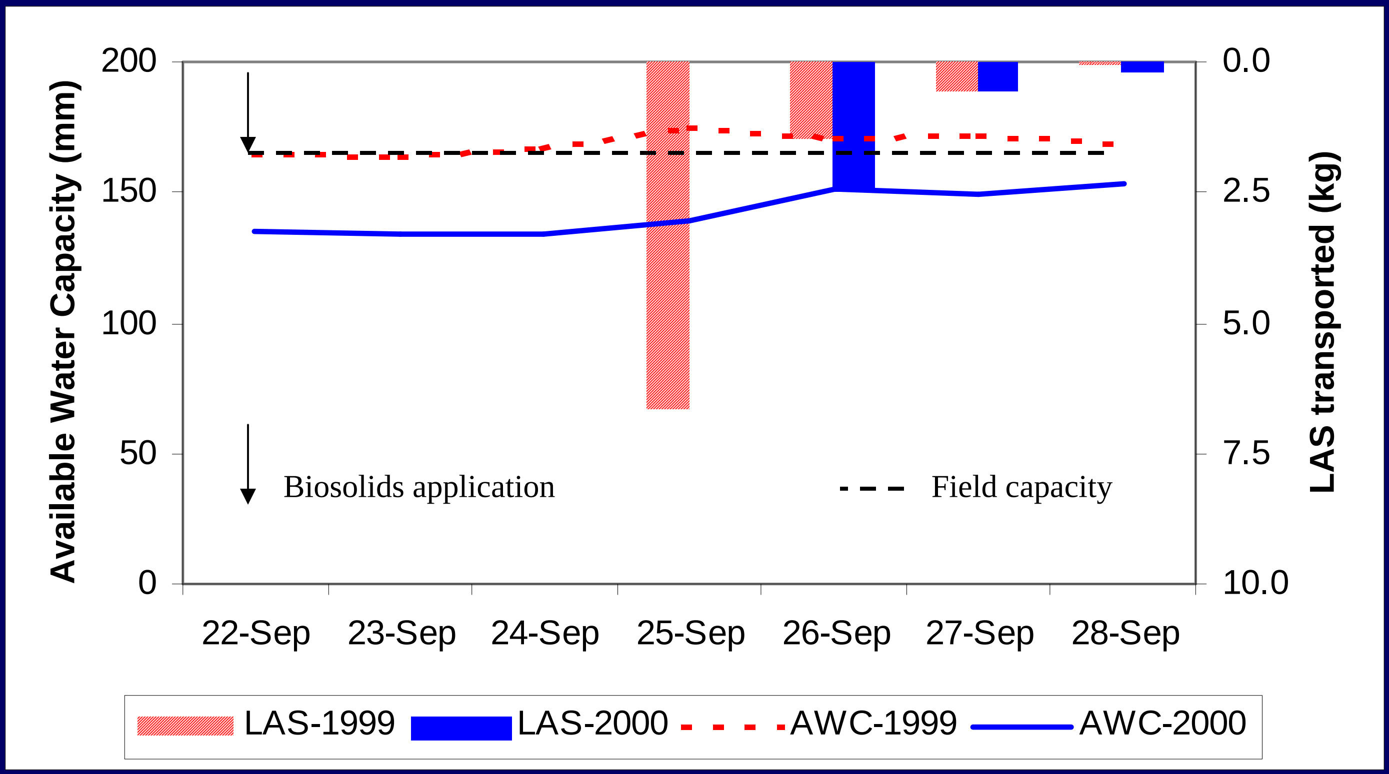



| Season | Realistic case | | | Worst case | | |
|---|---|---|---|---|---|---|
| | Applied (kg) | Load (kg) | % applied | Applied (kg) | Load (kg) | % applied |
| 1999 Winter | 1556.25 | 8.993 | 0.58 | 6225 | 55.908 | 0.900 |
| 2000 Winter | 1556.25 | 3.376 | 0.22 | 6225 | 26.113 | 0.420 |
| 2001 Winter | 1556.25 | 0.085 | 0.01 | 6225 | 3.032 | 0.050 |

Relationship between area of application and predicted load of LAS leaving the catchment for various rainfall conditions-Realistic case



# Analysis of soil water at the time of biosolids application



# Conclusions

- SWAT can be used to model the transport of LAS
- Although the scenarios examined were hypothetical, the predictions of LAS from SWAT can be reliably used owing to its successful application for pesticide modelling for the same catchment
- Total quantity of bio-solids applied, and soil water content at the time of bio-solids application have biggest control over LAS transport
- Transport of LAS from bio-solids application will not impair water quality

# ACKNOWLEDGEMENTS

1. Unilever (Mick Whelan) – Technical Support
2. ADAS (Simon Groves) – Collecting data
3. British Atmospheric Data Centre – Access to weather data


**More information on LAS can be found in**

**http://www.heraproject.com/RiskAssessment.cfm**