Magic of the simulation modeling

Computational Hydraulics

Modelling Technology Definitions

Simulation model

- Concept
  - mathematical model (basic equations)
  - physical model – scaled models in laboratory
- Program
  - software (code) executable
- Simulation tool
  - real world virtual copy

Simulation Models

Tools capable in mirroring the behavior of natural (water) system by means of interpretation of dominant system processes at defined system space

Conceptual models

Based on use of analogy of specific natural process with analogical (conceptual) process (method of non-linear reservoir)

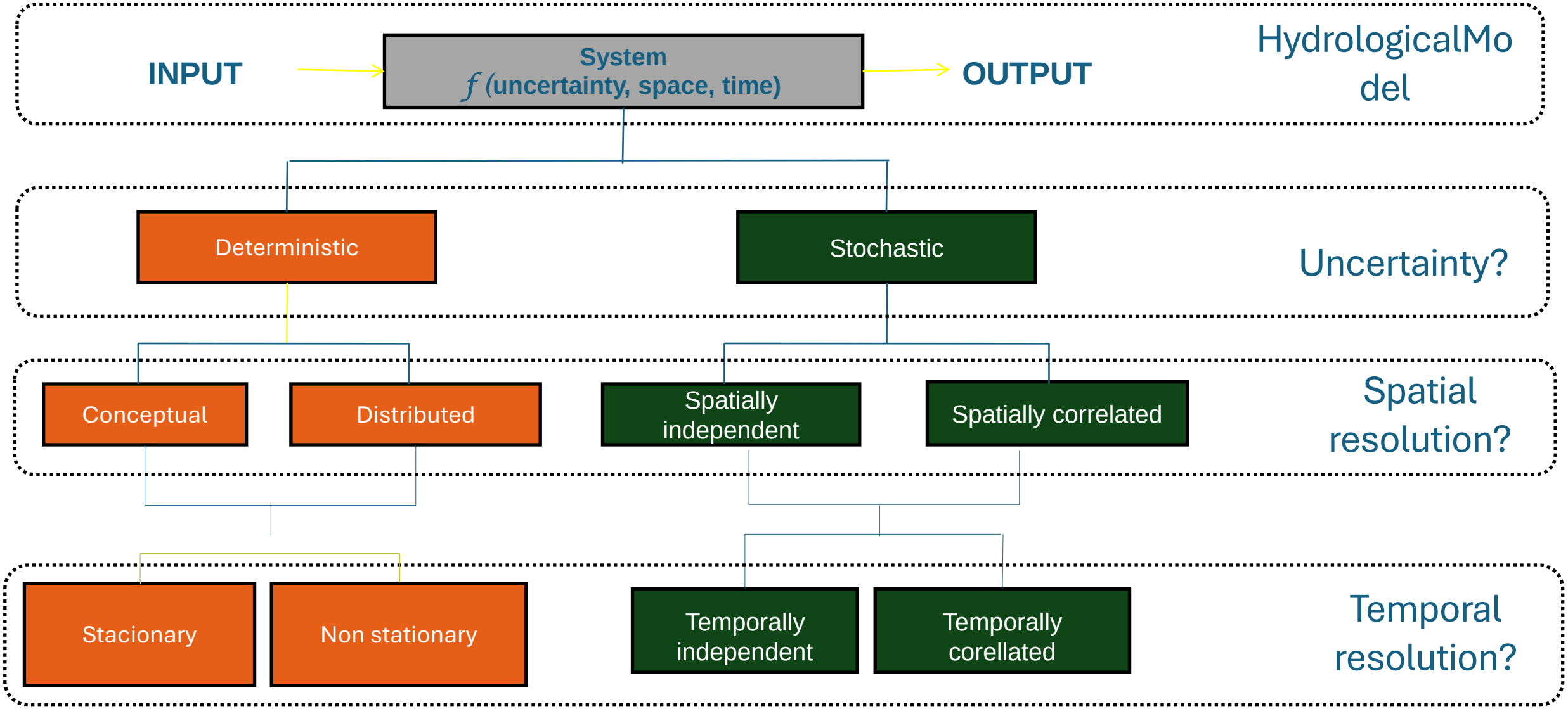
Distributed (deterministic) models

Based on solution of differential equation describing specific natural process (hydrodynamic equations, advection-dispersion equations)

Stochastic models

Based on solution of specific natural process by means of statistics and probability methods

Rainfall Runoff Processes and Analogy Methods



Simulation model – governing equations

Simulation of water related processes in:

Spatial domain (X,Y,Z coordinates)

Temporal domain (T -time)

Mass conservation law

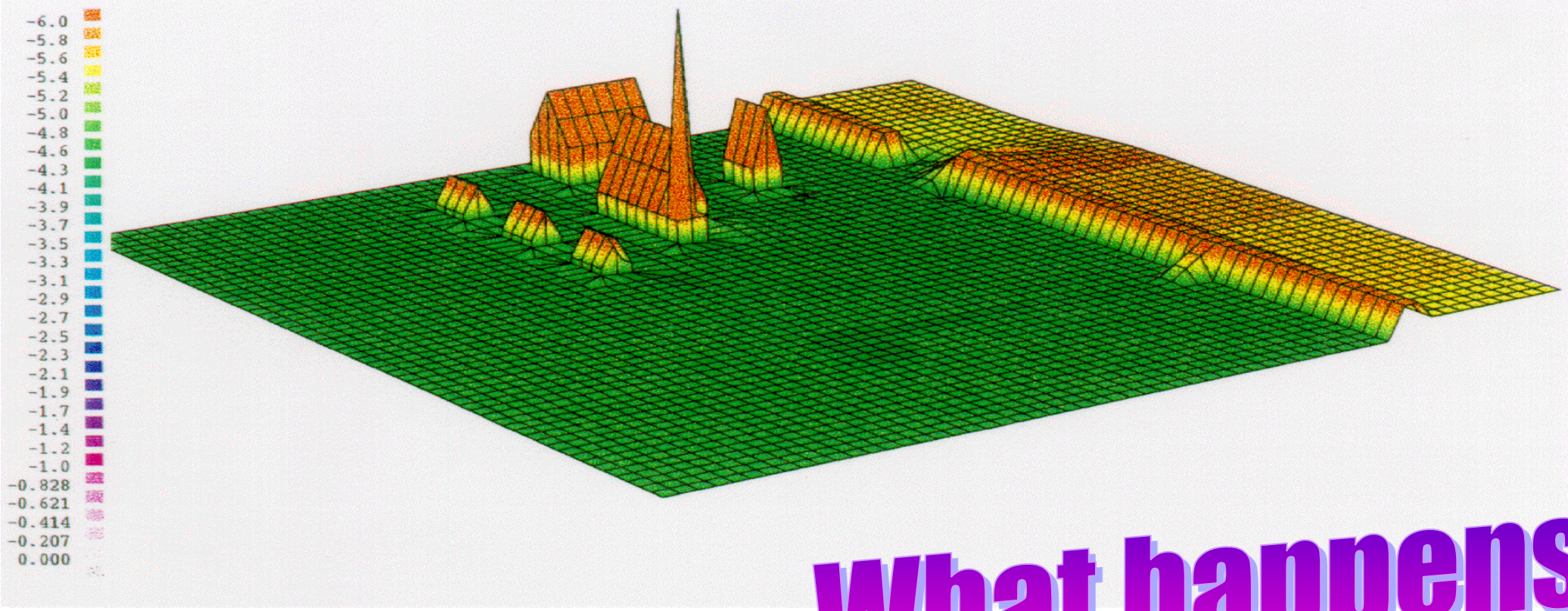
$$\frac{\partial Q}{\partial x} + b_x \frac{\partial H}{\partial x} = 0$$

Momentum conservation law

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(\frac{Q^2}{A} \right)}{\partial x} + gA\frac{\partial H}{\partial x} + gAi_E = gAi_0$$

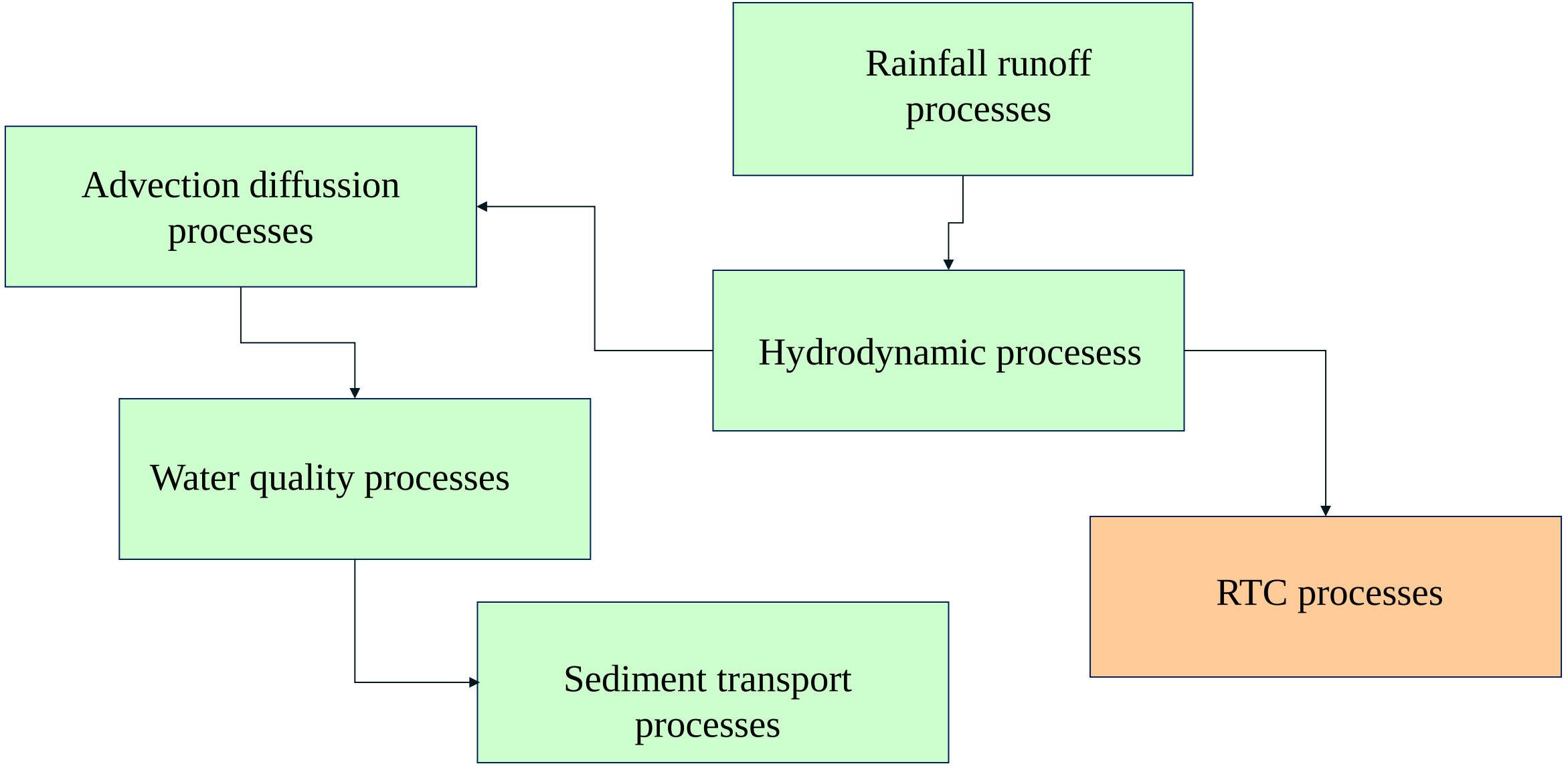
Simulation Model - as virtual reality

Simulation model represents a Virtual Copy of the real world including its Structure and functions (processes) involved

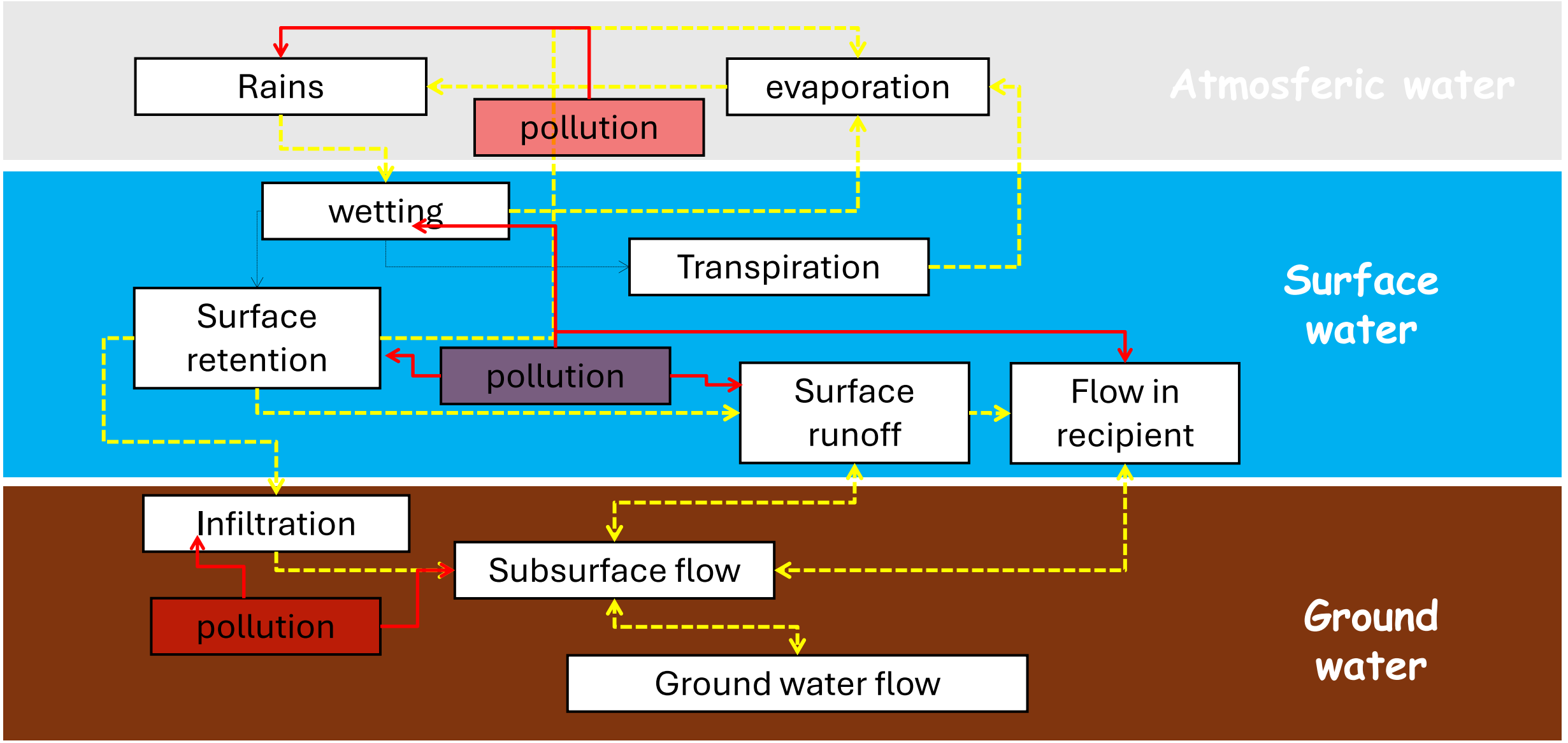


What happens, if...

Modular structure of Simulation Model



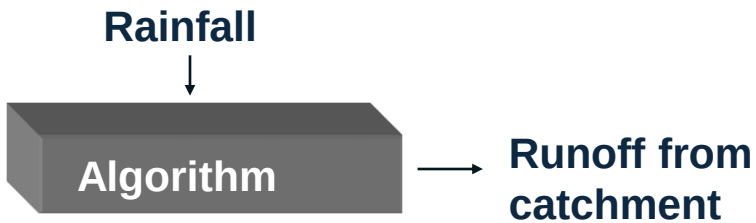
Rainfall Runoff Processes



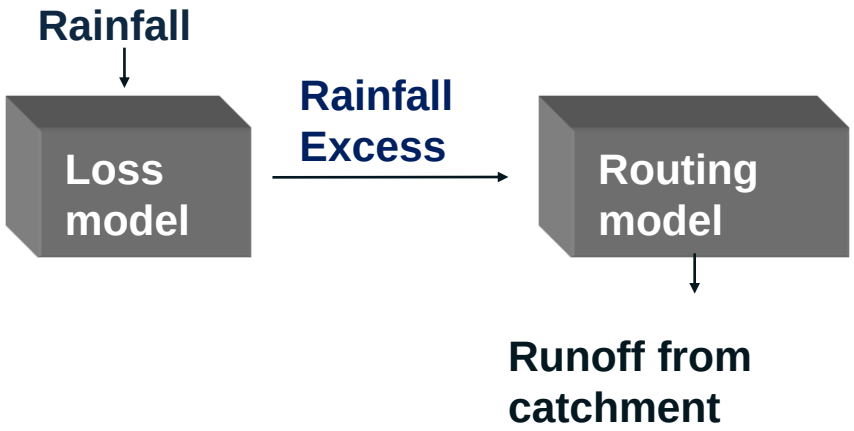
Physical, Chemical a Biological Proceses

Schematization of Rainfall Runoff Processes

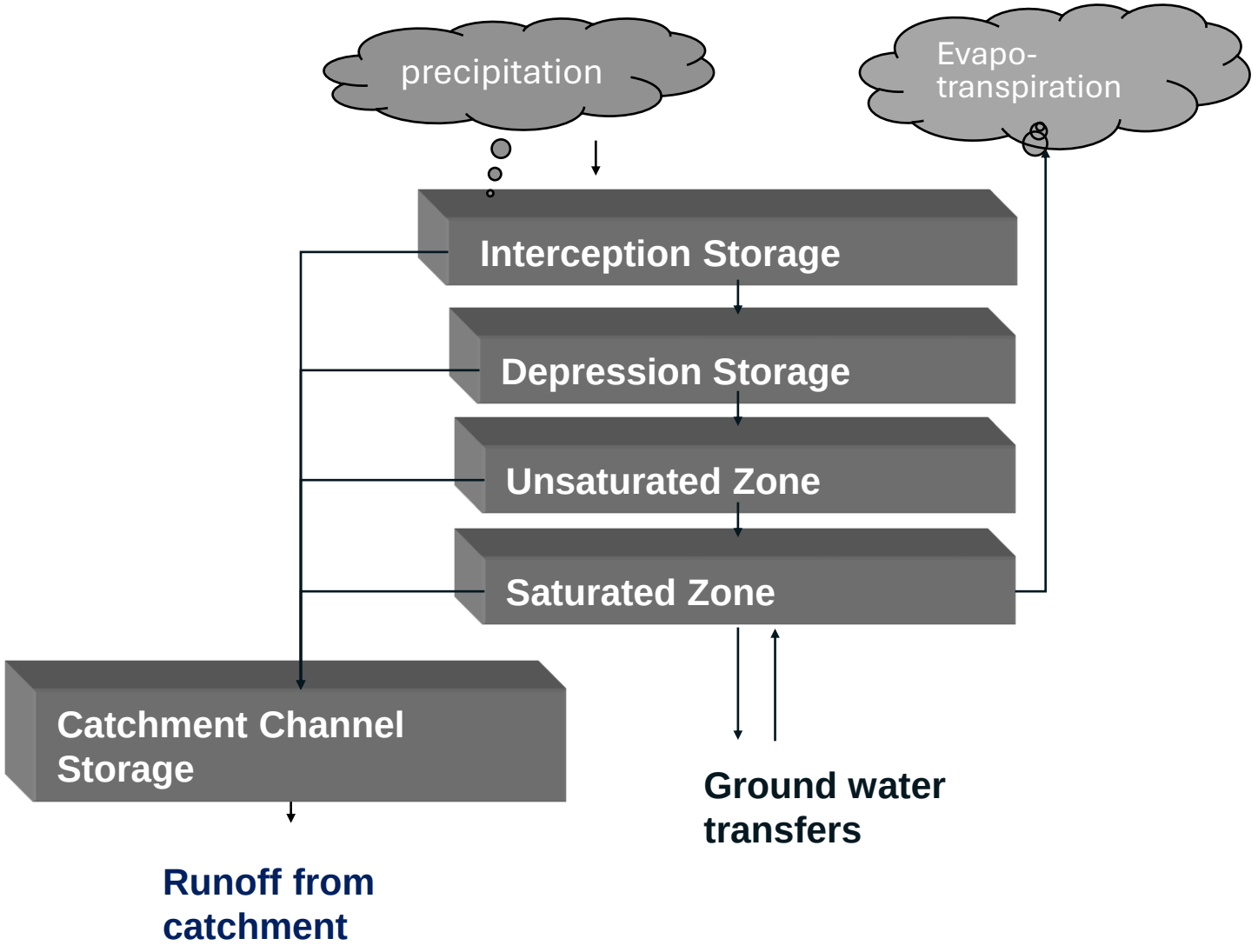
„Black Box“ models (izohyet, method,…),



Loss routing models (unit hydrograph,...)



Physical process models (non/linear reservoir model...)



Governing equations I.

Mass balance (continuity) equation

$$\frac{\partial Q}{\partial x} + b_x \frac{\partial H}{\partial x} = 0$$

Momentum (Bernoulli) equation

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(\frac{Q^2}{A} \right)}{\partial x} + gA\frac{\partial y}{\partial x} + gAi_E = gAi_0$$

Advection – diffusion equation

$$\frac{\partial F}{\partial t} + v\frac{\partial F}{\partial x} = D\frac{\partial^2 F}{\partial x^2}$$

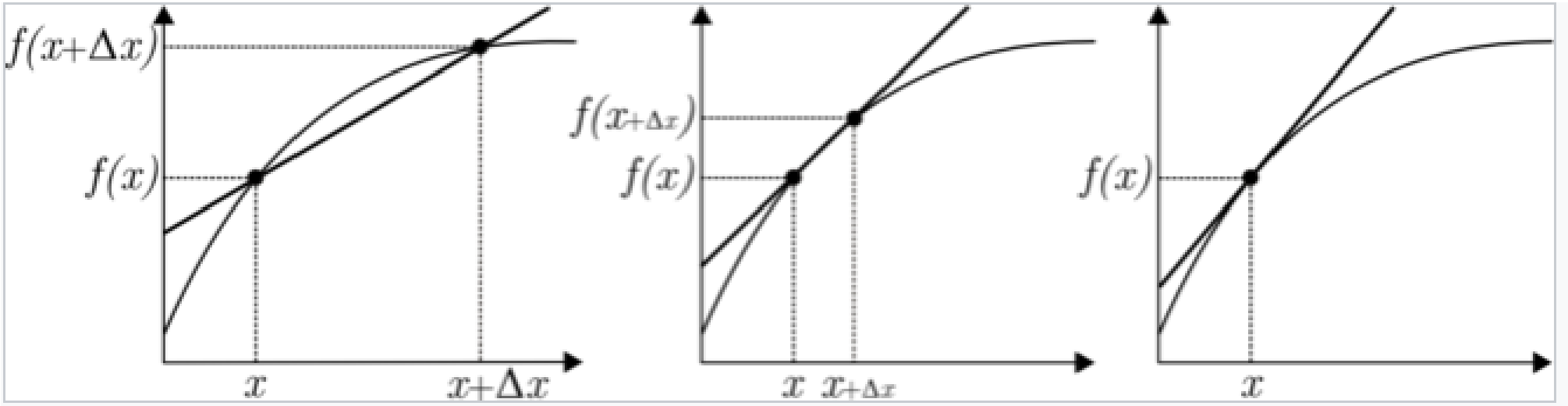
Governing equations II.

Subsurface flow (Richard's) equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\psi)\left(\frac{\partial \psi}{\partial z} + 1\right)\right]$$

K is the hydraulic conductivity,
ψ is the pressure head,
z is the elevation above a vertical datum,
θ is the water content, and
t is time

Diferential and difference



Courant number $Cn = U\frac{\Delta t}{\Delta x}$

$U = velocity$
$\Delta t = time\ step$
$\Delta x = mesh\ size$

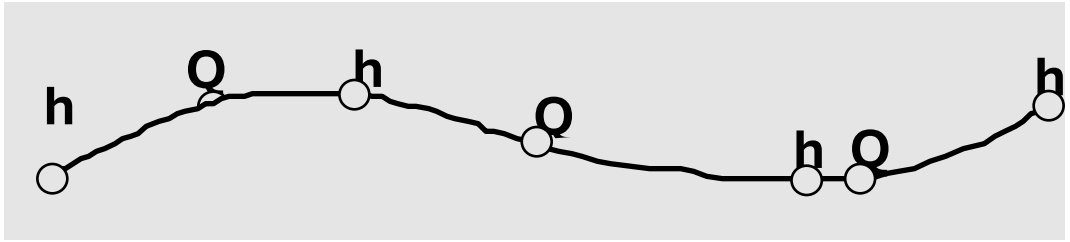
dT/dX = Cn/U=1

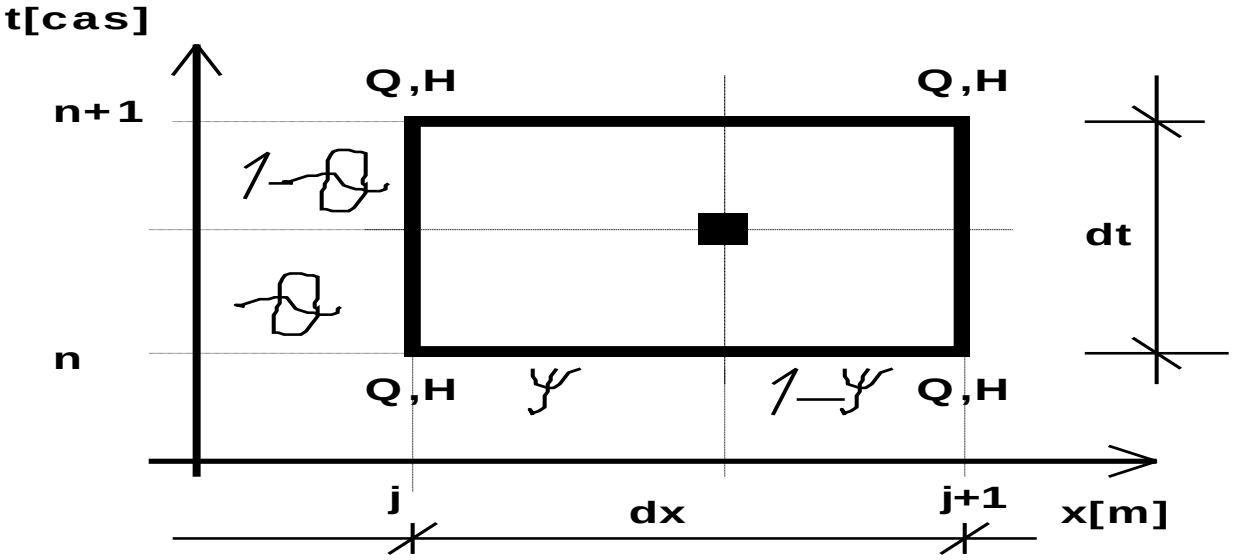
Numerical Methods

- Finite difference method
- Finete elements method
- Finite volume method
- …

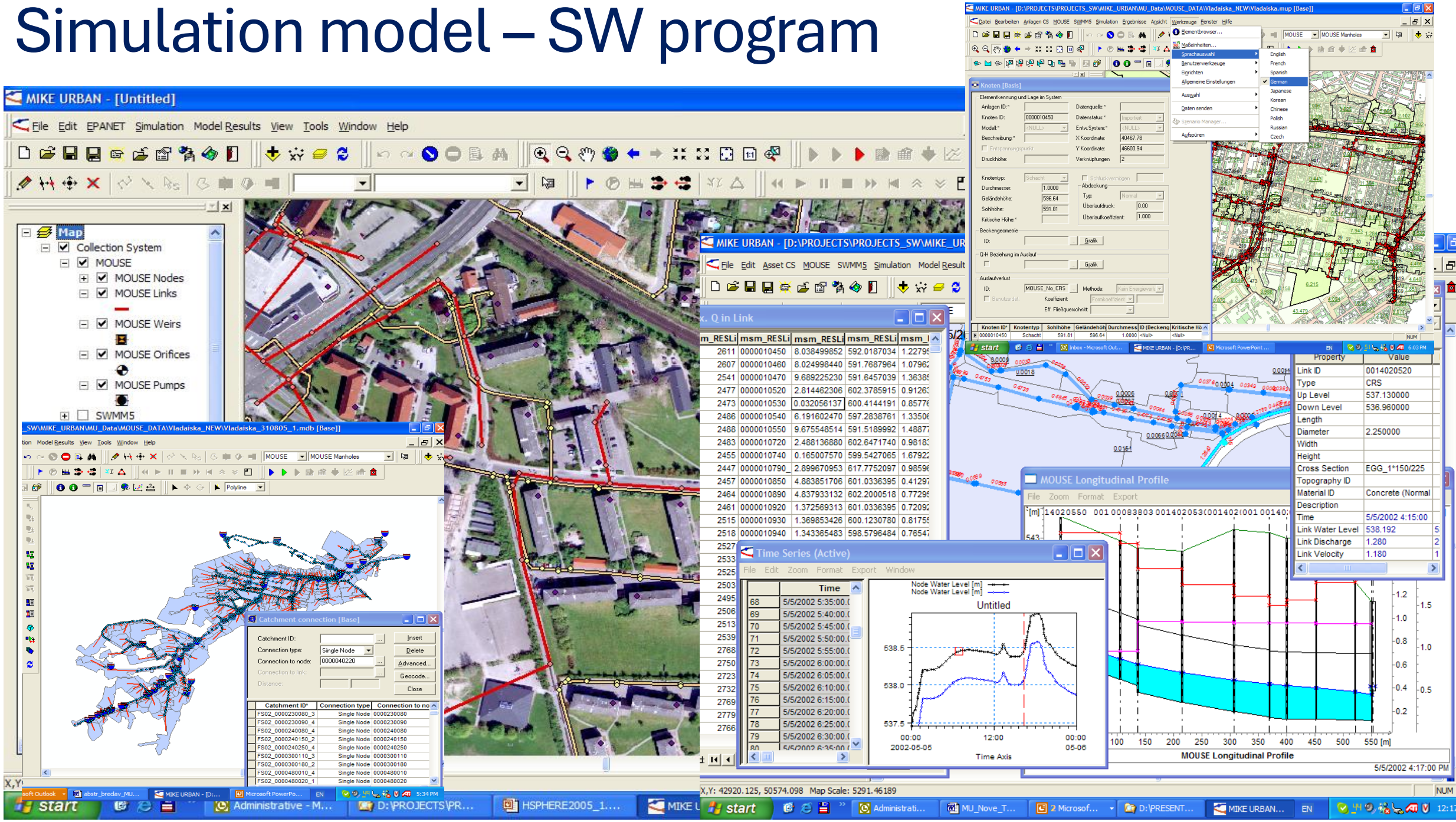
$$\frac{\partial Q}{\partial x} = \theta \frac{Q_{j+1}^{n+1} - Q_j^{n+1}}{\Delta x} + (1-\theta)\frac{Q_{j+1}^{n} - Q_j^{n}}{\Delta x}$$

$$\frac{\partial Q}{\partial t} = \psi \frac{Q_{j+1}^{n+1} - Q_{j+1}^{n}}{\Delta t} + (1-\psi)\frac{Q_{j}^{n} - Q_{j}^{n}}{\Delta t}$$





Simulation model – SW program



Model Build process

Model Build Process

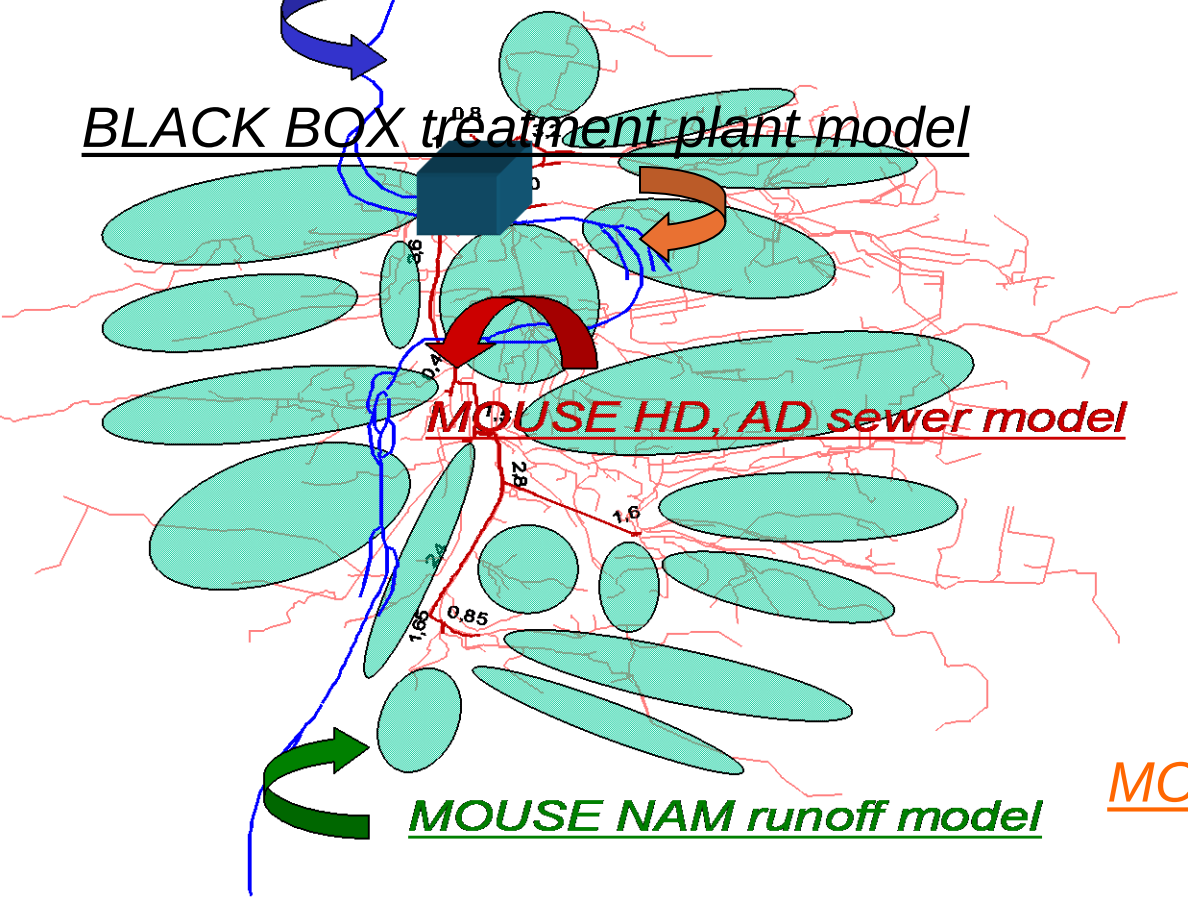
1. **Model formulation** (governing equations, key parameters)
2. **Model schematization** (simulation scale)
3. **Monitoring definition**
4. **Data collection**
   a. Topological Digitization of paper data (or import from GIS)
   b. Setting up the attribute data (DN, material, slope,…)
   c. Verification of topology
5. **Surveys**
   a. Manhole survey, CSO survey, reservoir survay, etc.
   b. Flow survey (discharge, water level, precipitation, pressure, WQ,…)
   c. CCTV survey
   d. Impermeable area survey
   e. Industrial water survey
   f. Other surveys
6. **Model development**
   a. Update of basic data based on surveys
   b. Setting up boundary and initial conditions
7. **Model calibration and verification**
8. **Model use**

Model formulation, system conceptualisation

Phase C+D

MIKE11 Vltava river model

BLACK BOX treatment plant model



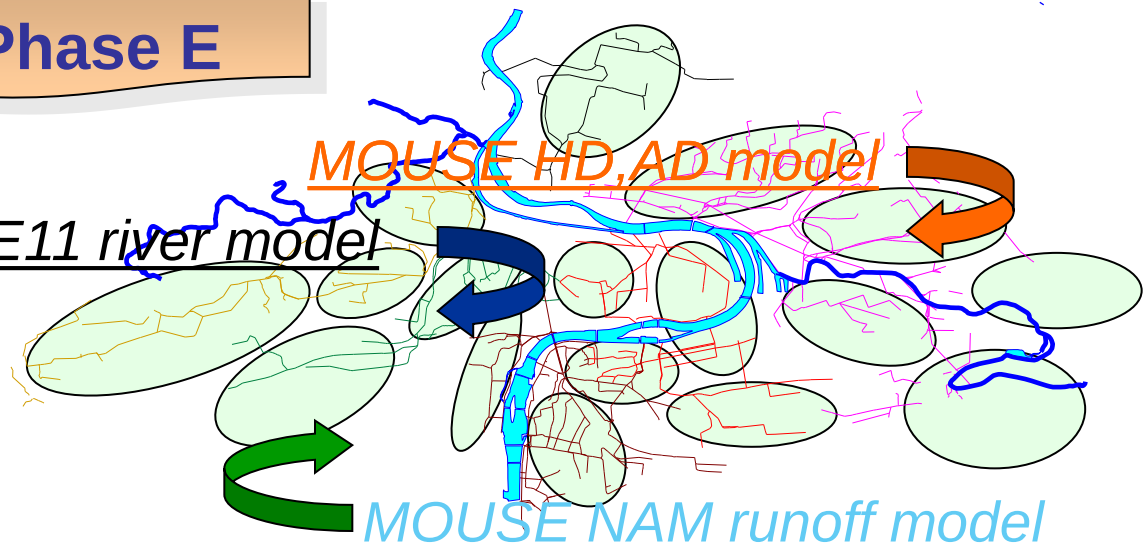
MOUSE HD, AD sewer model

MOUSE NAM runoff model

Phase E

MOUSE HD,AD model

MIKE11 river model

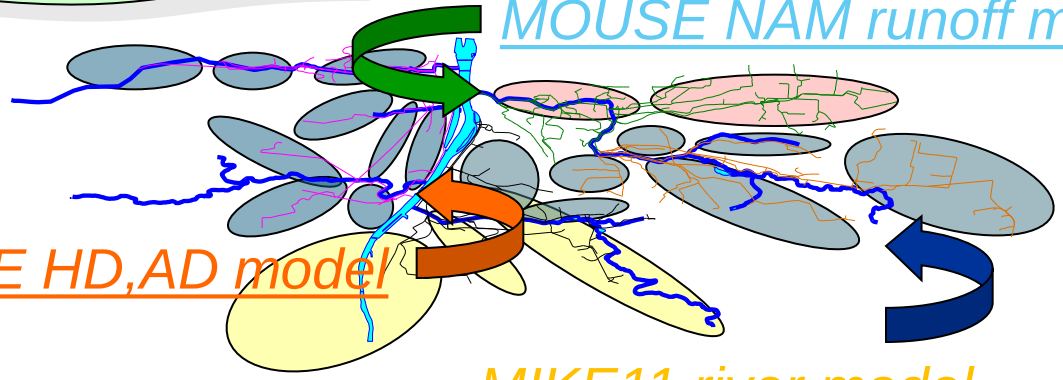


MOUSE NAM runoff model

Phase F

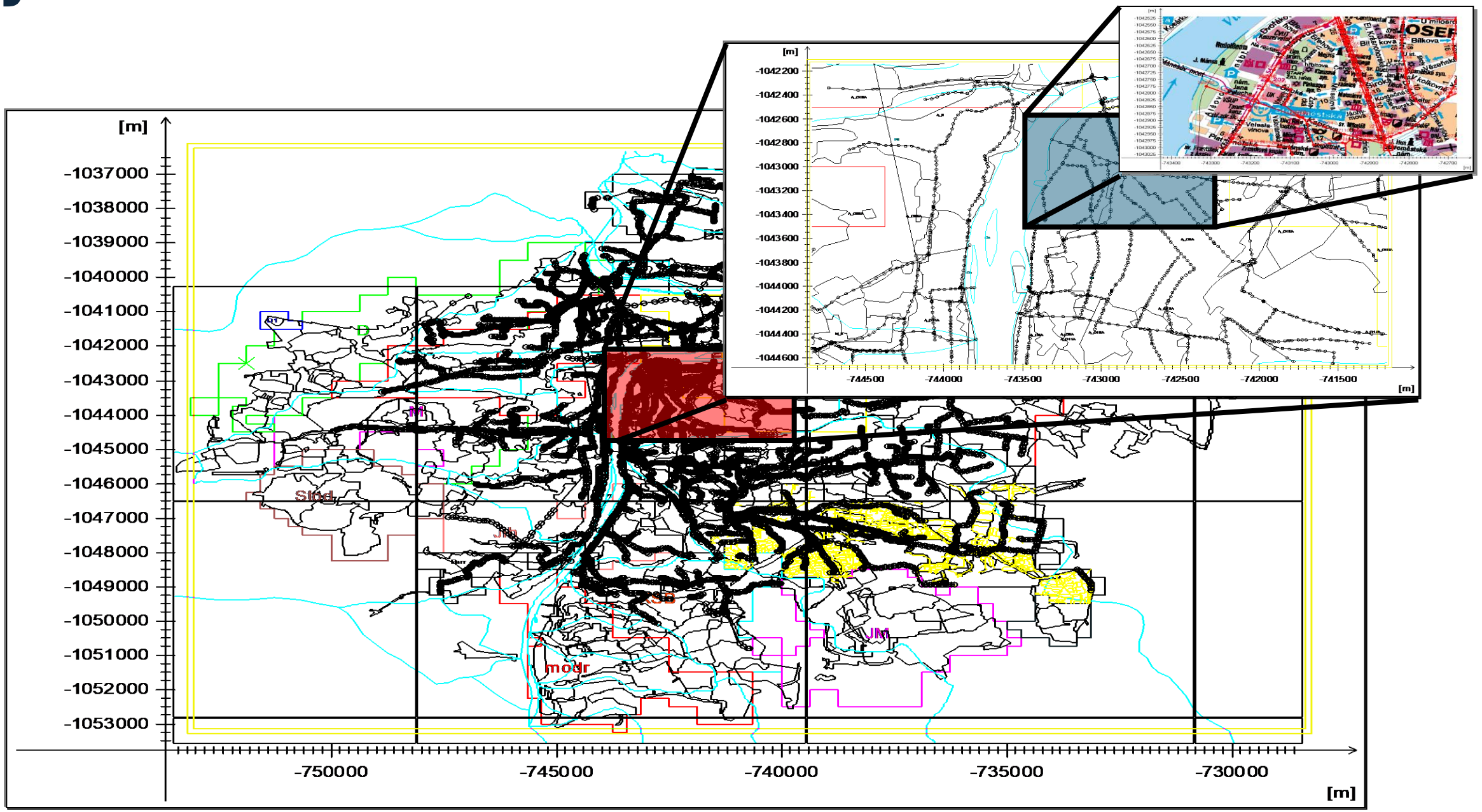
MOUSE NAM runoff model

MOUSE HD,AD model



MIKE11 river model

System schematization



Surveys

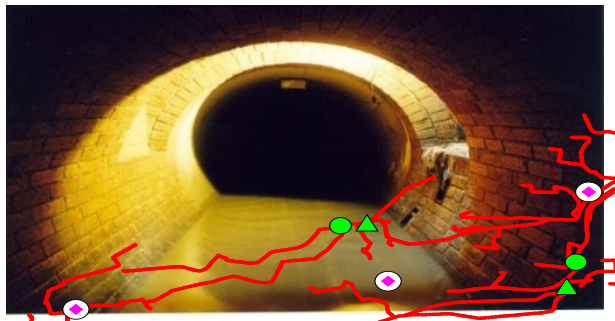
Flow survey (flows, presures, Water levels,raingauges)

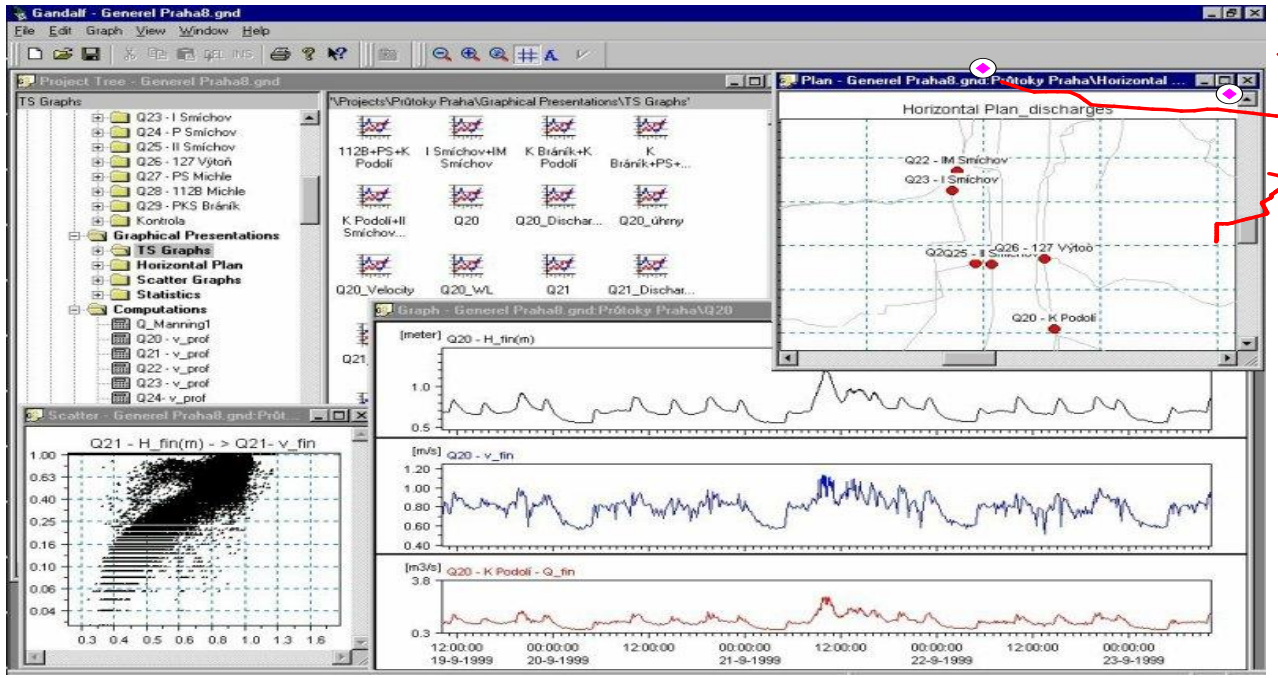
Geodetic survey

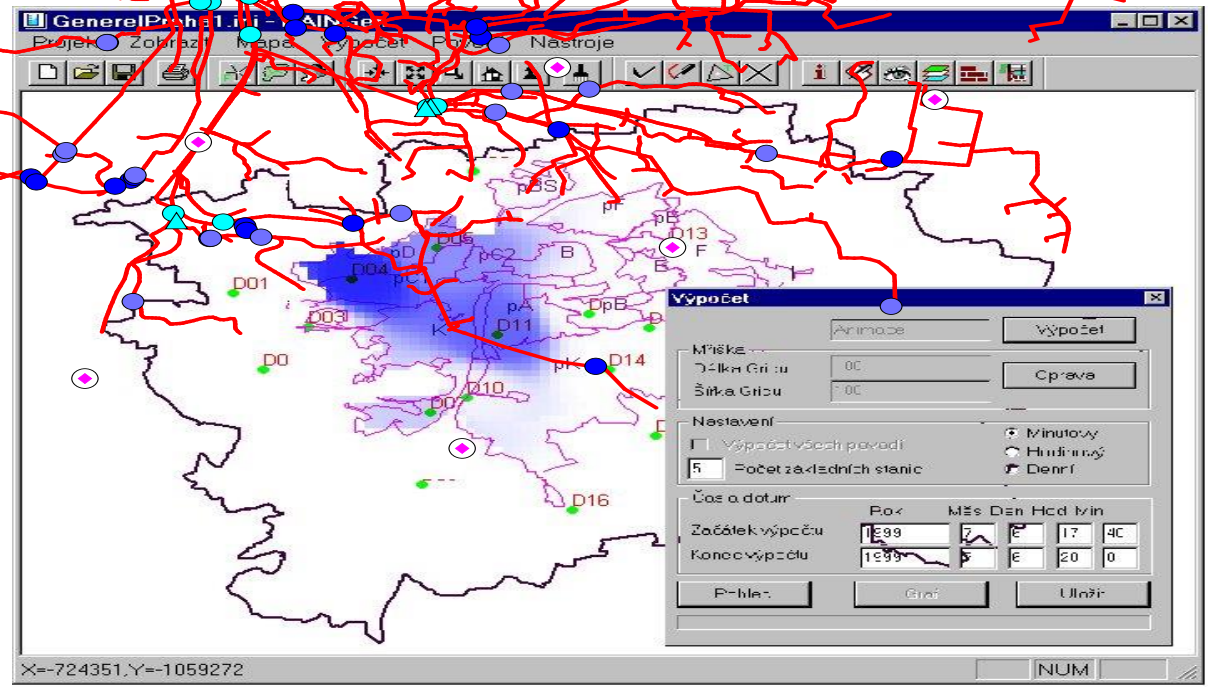
WQ sampling survey

Structures survey

Impermeability survey

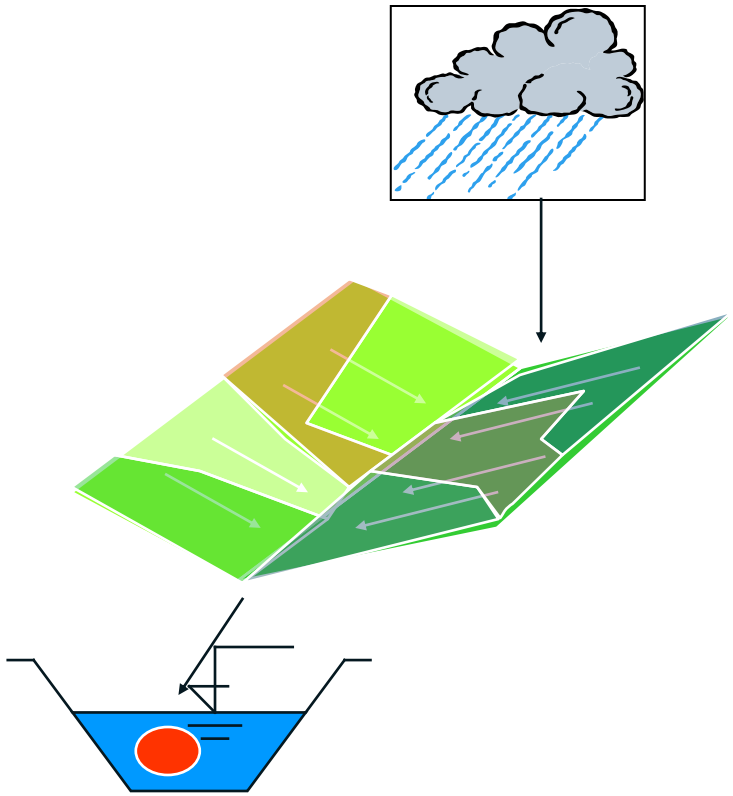


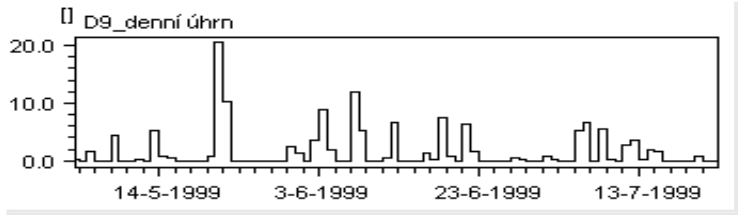




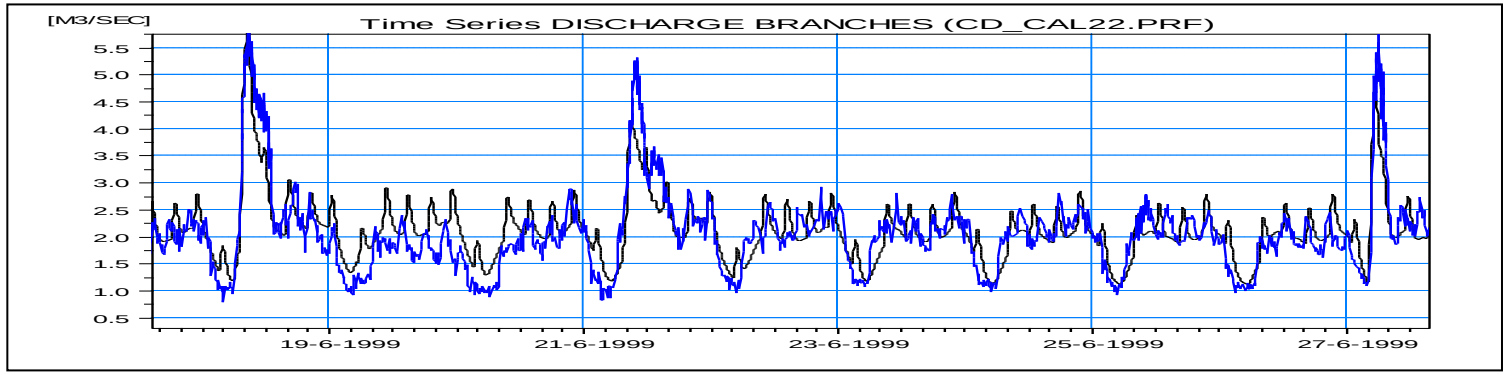
Model Calibration

Setting up the model parameters to provide the same response to the external input as in reality





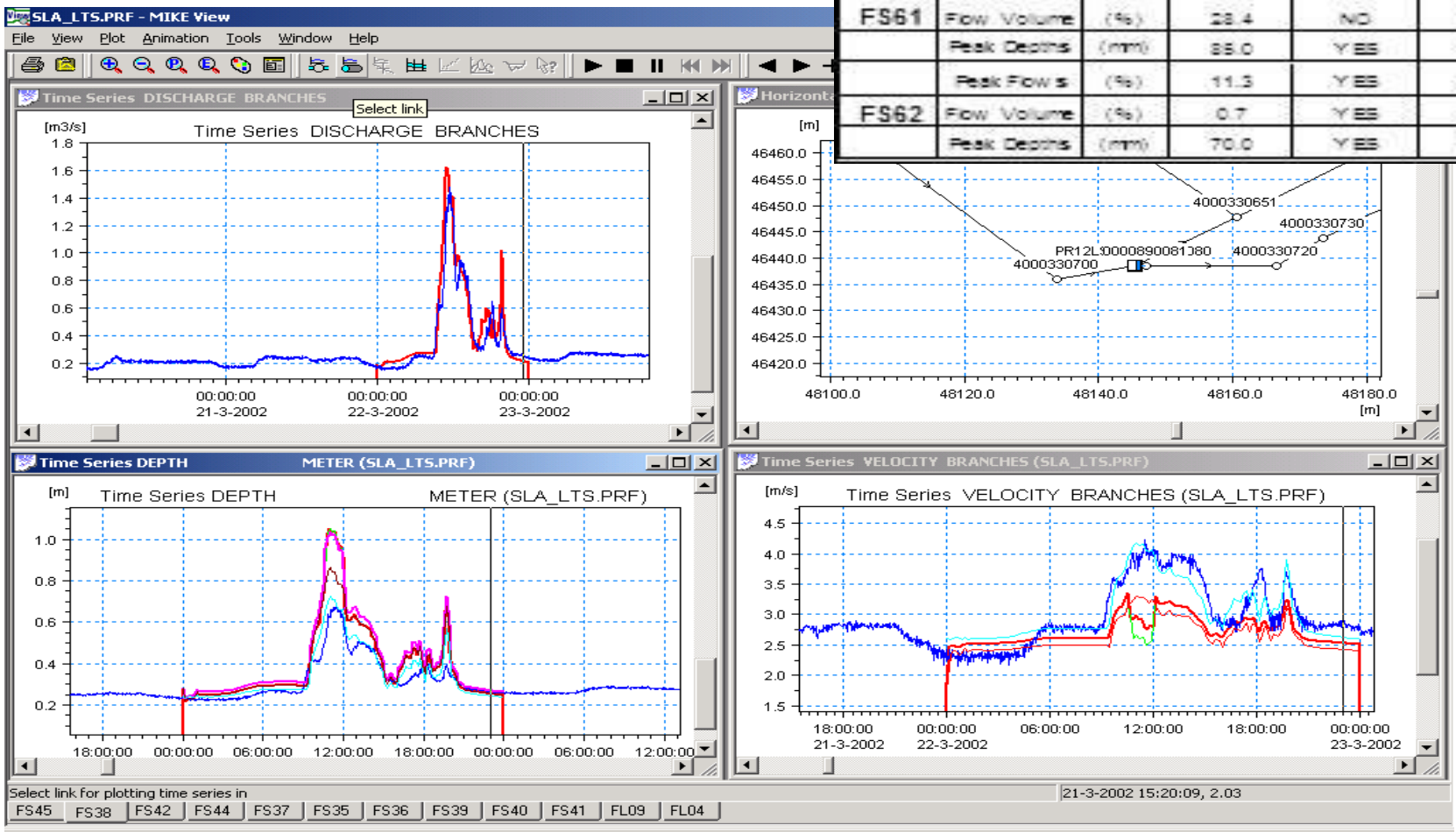
Simul. model



Calibration details

- Dry weather flow
- Wet weather flow

KEY				NS	Not surcharge conditions				
	No observed data recorded				Recorded depth & velocity errors (resulting in criteria non-compliance)				
	See individual event comments for reasons for non-compliance				Discharge within criteria - considered verified				
	Recorded velocity errors (resulting in criteria non-compliance)				Discharge not within criteria due to recorded errors (or no data) - model acceptable				
	Recorded depth errors (resulting in criteria non-compliance)				Discharge not within criteria - see individual comments for potential model limitations				
Ref	Comparative analysis		Event A	Within Criteria?	Event B	Within Criteria?	Event C	Within Criteria?	Average	Within Criteria?
FS61	Peak Flows	(%)	13.0	YES	-6.0	YES	-18.4	NO	-3.8	YES
	Flow Volume	(%)	28.4	NO	15.1	YES	1.9	YES	15.1	YES
	Peak Depths	(mm)	86.0	YES	34.0	YES	20.0	YES	46.3	YES
FS62	Peak Flows	(%)	11.3	YES	13.0	YES	-38.1	NO	-4.6	YES
	Flow Volume	(%)	0.7	YES	-1.5	YES	-27.4	NO	-9.4	YES
	Peak Depths	(mm)	70.0	YES	43.0	YES	5.0	YES	39.3	YES



- Discharge
- Water level
- Velocity

Model Verification