

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

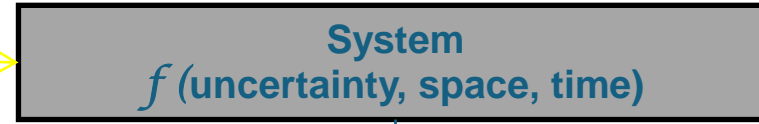
Based on solution of differential equation describing specific natural process (hydrodynamic equations, advection-dispersion equations)

Stochastic models

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

Rainfall Runoff Processes and Analogy Methods

INPUT



OUTPUT

Hydrological Model

Deterministic

Stochastic

Uncertainty?

Conceptual

Distributed

Spatially independent

Spatially correlated

Spatial resolution?

Stationary

Non stationary

Temporally independent

Temporally correlated

Temporal resolution?

Simulation model – governing equations

Simulation of water related processes in:

Spatial domain (X,Y,Z coordinates)

Temporal domain (T -time)

Mass conservation law

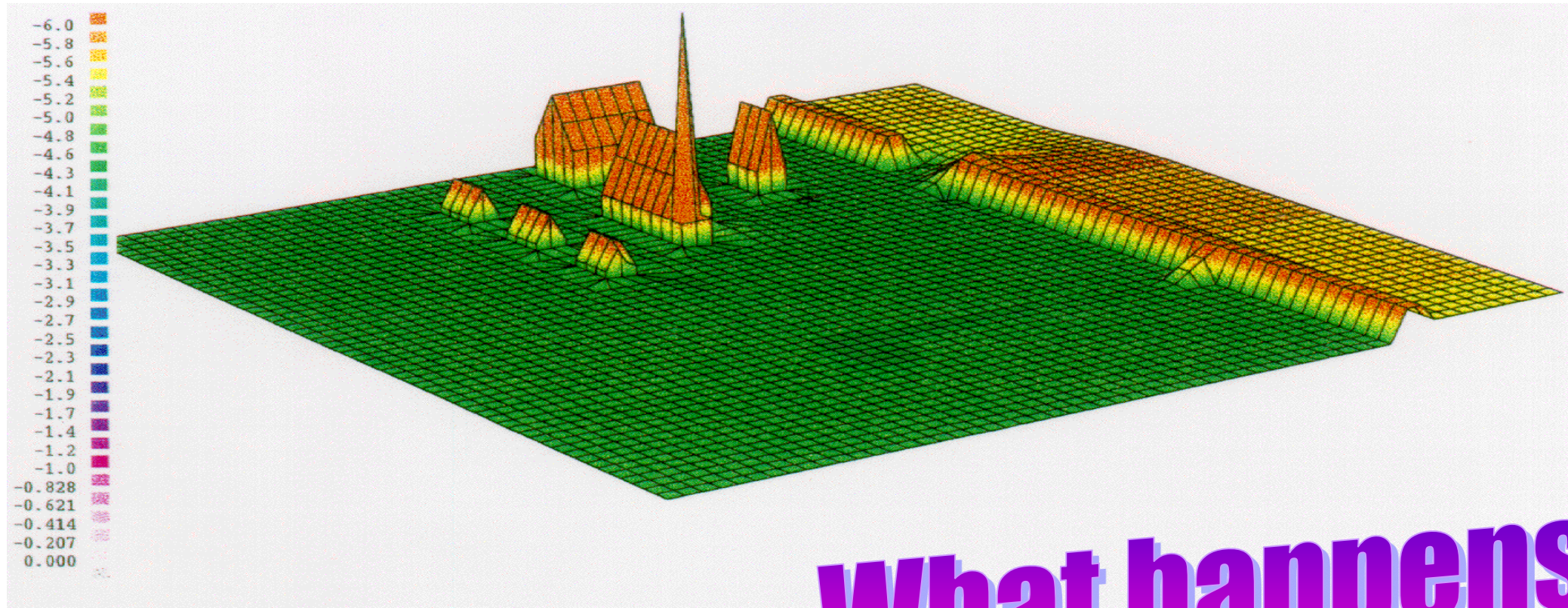
$$\frac{\partial Q}{\partial x} + b_x \frac{\partial H}{\partial x} = 0$$

Momentum conservation law

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(\frac{Q^2}{A} \right)}{\partial x} + gA \frac{\partial H}{\partial x} + gA i_E = gA i_0$$

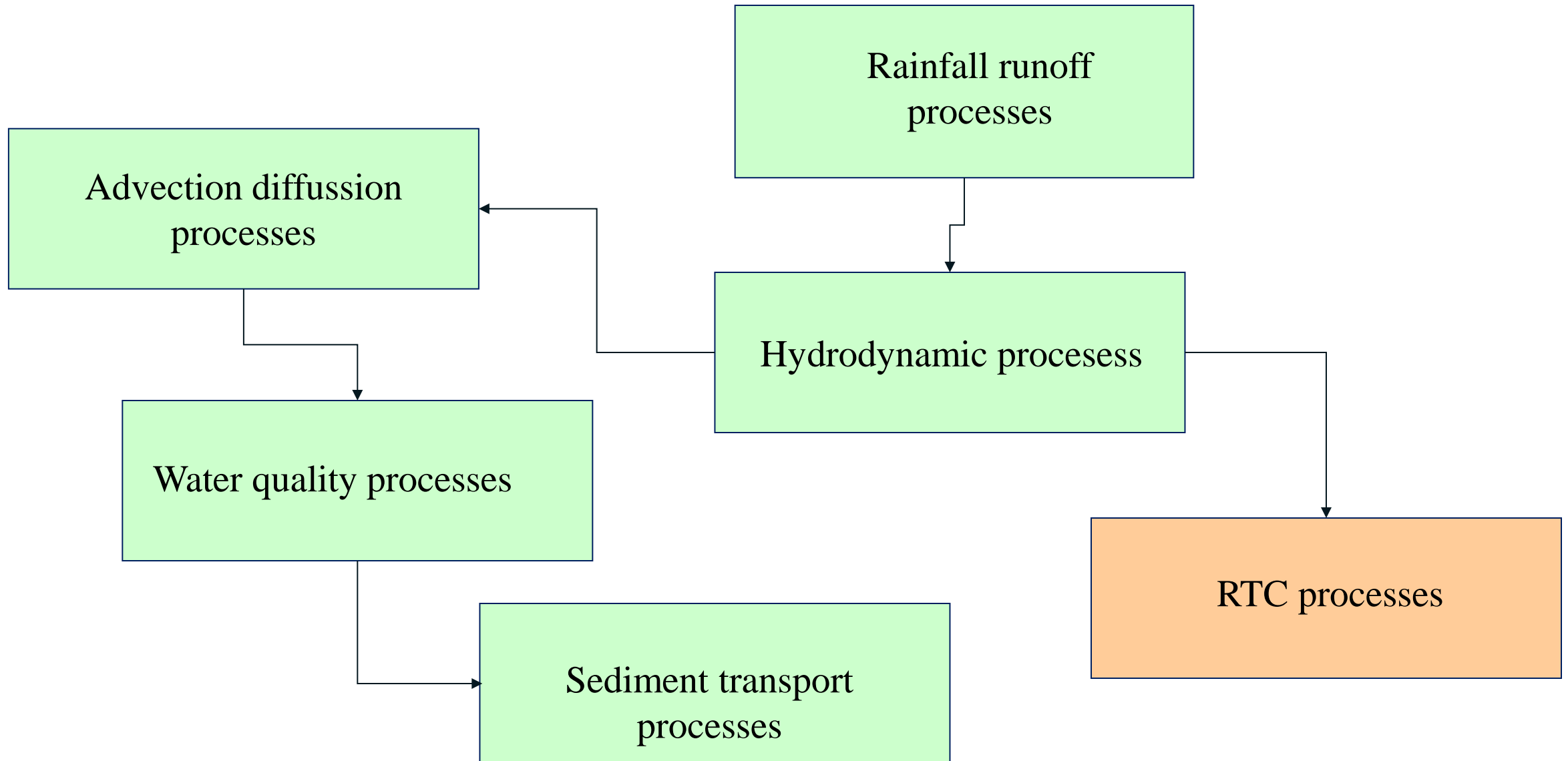
Simulation Model - as virtual reality

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

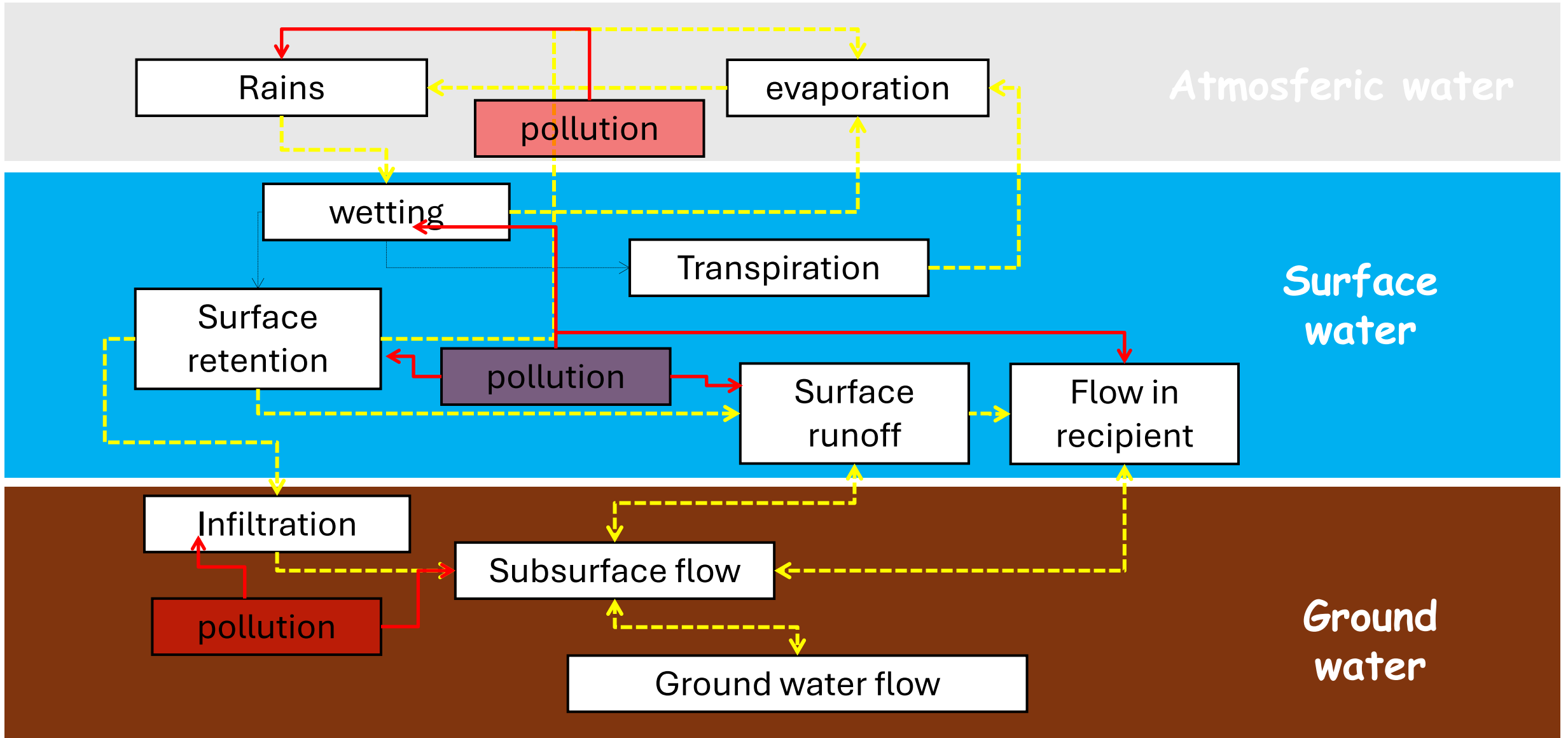


What happens, if...

Modular structure of Simulation Model



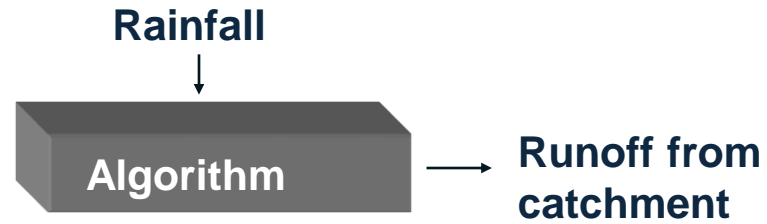
Rainfall Runoff Processes



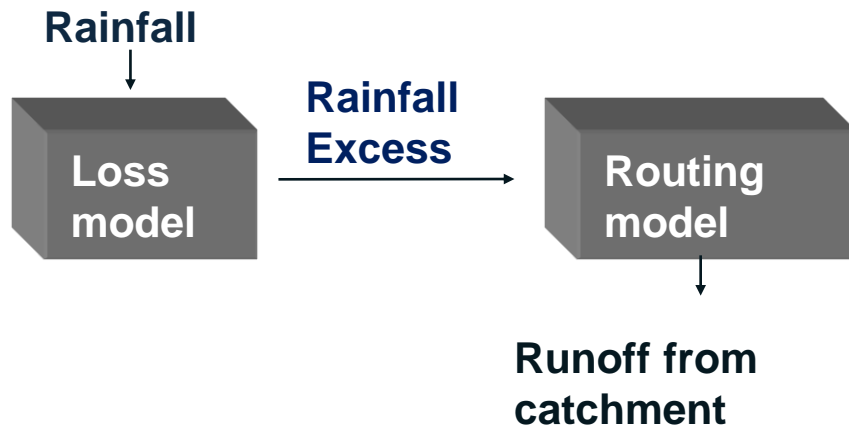
Physical, Chemical a Biological Proceses

Schematization of Rainfall Runoff Processes

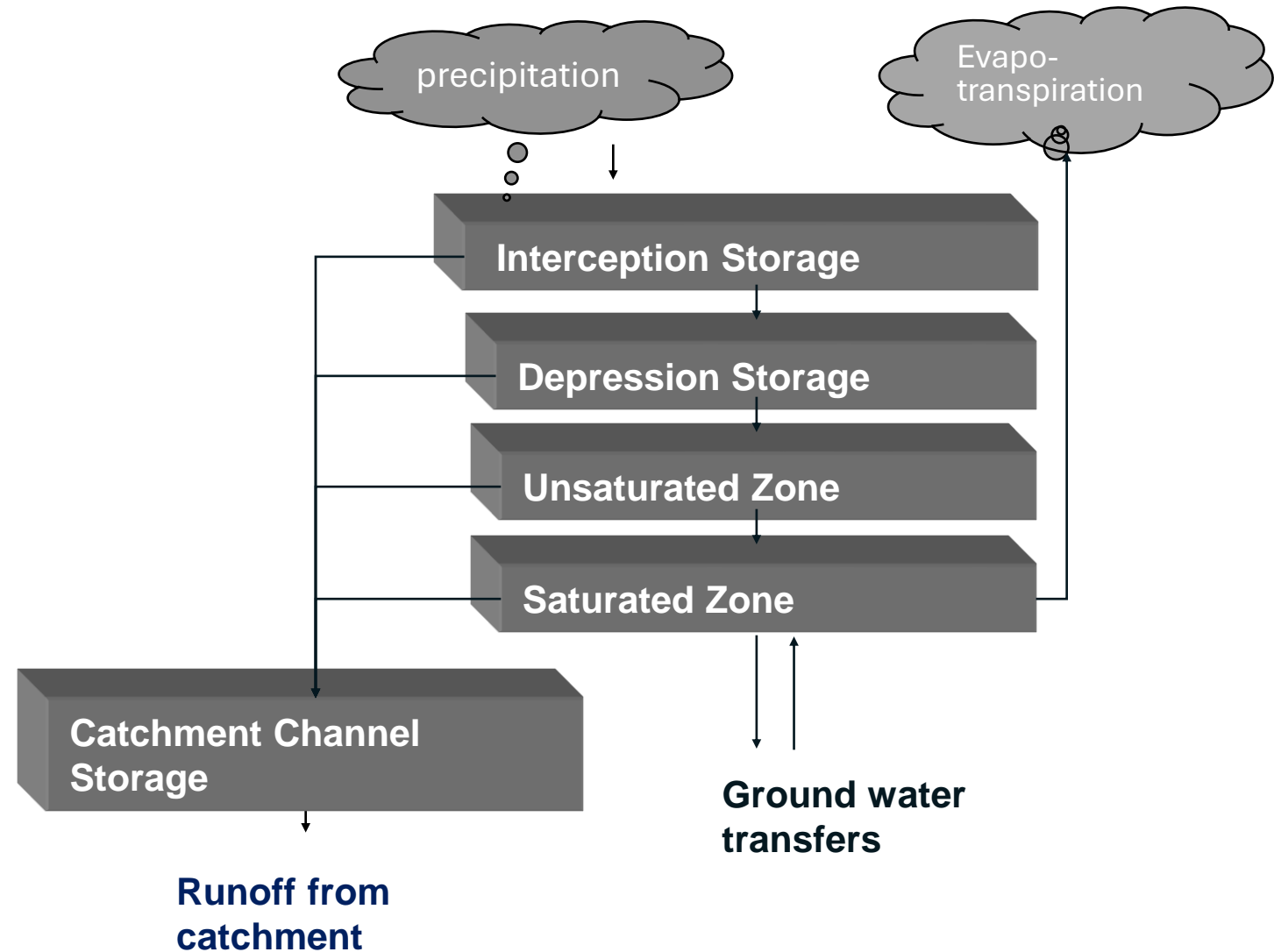
„Black Box“ models (izohyet, method,...),



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

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(\frac{Q^2}{A} \right)}{\partial x} + gA \frac{\partial y}{\partial x} + gA i_E = gA i_0$$

Advection – diffusion equation

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

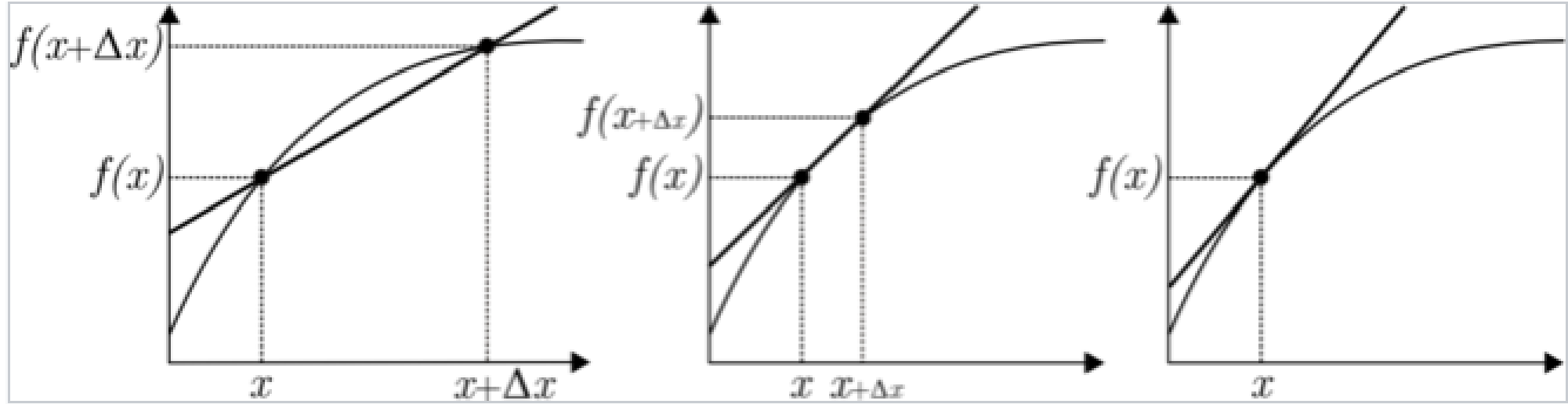
Governing equations II.

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

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

$U = \text{velocity}$

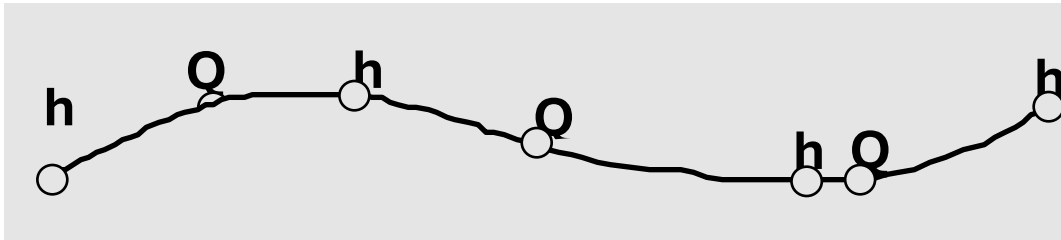
$\Delta t = \text{time step}$

$\Delta x = \text{mesh size}$

$$dT/dX = Cn/U=1$$

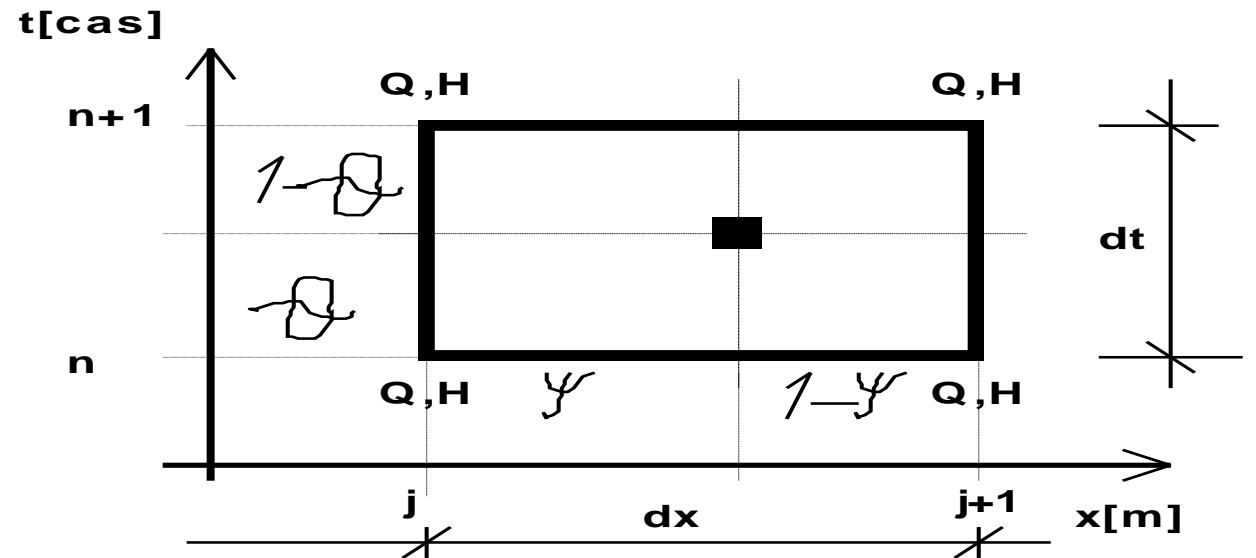
Numerical Methods

- Finite difference method
- Finite 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

MIKE URBAN - [Untitled]

File Edit EPANET Simulation Model Results View Tools Window Help

Collection System

- MOUSE
 - MOUSE Nodes
 - MOUSE Links
 - MOUSE Weirs
 - MOUSE Orifices
 - MOUSE Pumps
- SWMM5

MOUSE Nodes

m_RESLI	msm_RESLI	msm_RESLI	msm_RESLI	msm_RESLI
2611	0000010450	8.038499852	592.0187034	1.22794
2607	0000010460	8.024998440	591.7687964	1.07962
2541	0000010470	9.689225230	591.6457039	1.36381
2477	0000010520	2.814462306	602.3785915	0.91261
2473	0000010530	0.032056137	600.4144191	0.85776
2486	0000010540	6.191602470	597.2838761	1.33506
2488	0000010550	9.675548514	591.5189992	1.48877
2483	0000010720	2.488136880	602.6471740	0.98183
2455	0000010740	0.165007570	599.5427065	1.67922
2447	0000010790	2.899670953	617.7752097	0.98596
2457	0000010850	4.883851706	601.0336395	0.41291
2464	0000010890	4.837933132	602.2000518	0.77291
2461	0000010920	1.372569313	601.0336395	0.72091
2515	0000010930	1.369853426	600.1230780	0.81751
2518	0000010940	1.343365483	598.5796484	0.76541

MOUSE Longitudinal Profile

Property Value

Link ID	0014020520
Type	CRS
Up Level	537.130000
Down Level	536.960000
Length	
Diameter	2.250000
Width	
Height	
Cross Section	EGG_1*150/225
Topography ID	
Material ID	Concrete (Normal)
Description	
Time	5/5/2002 4:15:00
Link Water Level	538.192
Link Discharge	1.280
Link Velocity	1.180

Time Series (Active)

Time	Node Water Level [m]
68	5/5/2002 5:35:00.0
69	5/5/2002 5:40:00.0
70	5/5/2002 5:45:00.0
71	5/5/2002 5:50:00.0
72	5/5/2002 5:55:00.0
73	5/5/2002 6:00:00.0
74	5/5/2002 6:05:00.0
75	5/5/2002 6:10:00.0
76	5/5/2002 6:15:00.0
77	5/5/2002 6:20:00.0
78	5/5/2002 6:25:00.0
79	5/5/2002 6:30:00.0
80	5/5/2002 6:35:00.0

X,Y: 42920.125, 50574.098 Map Scale: 5291.46189

Model Build process

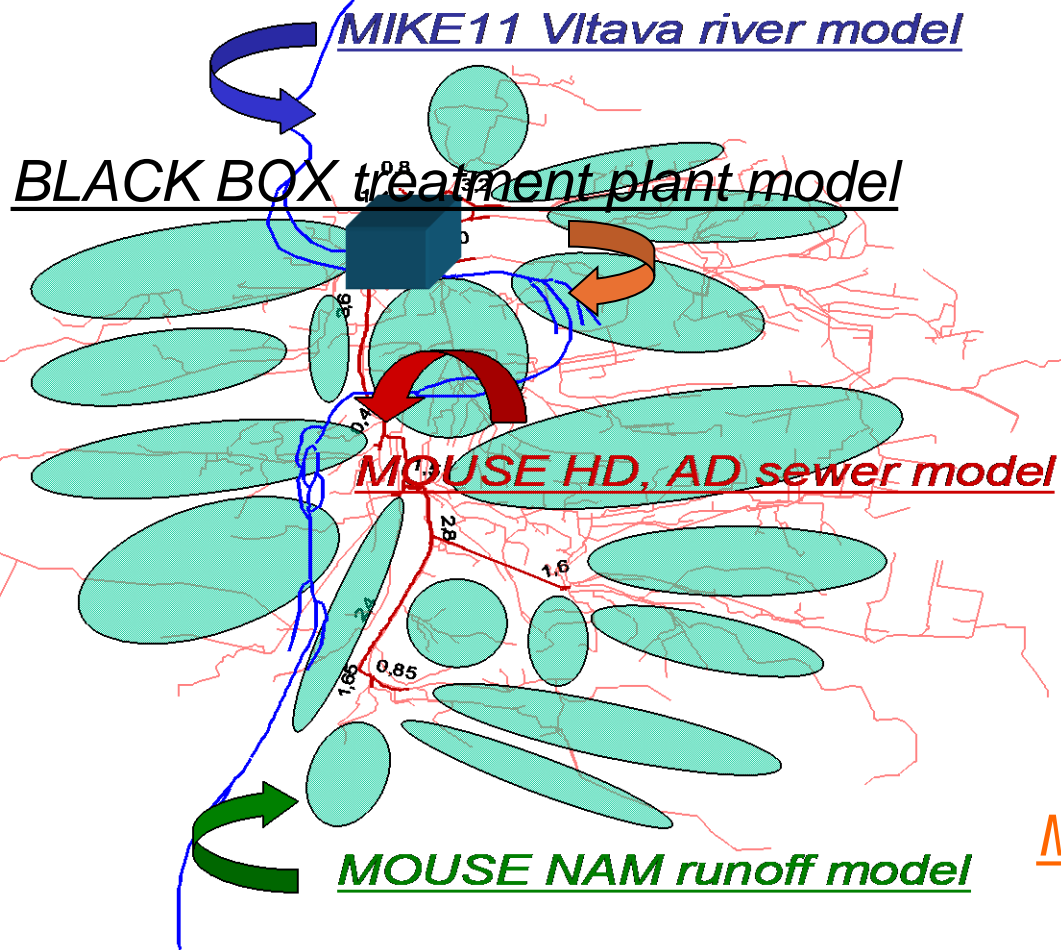


Model Build Process

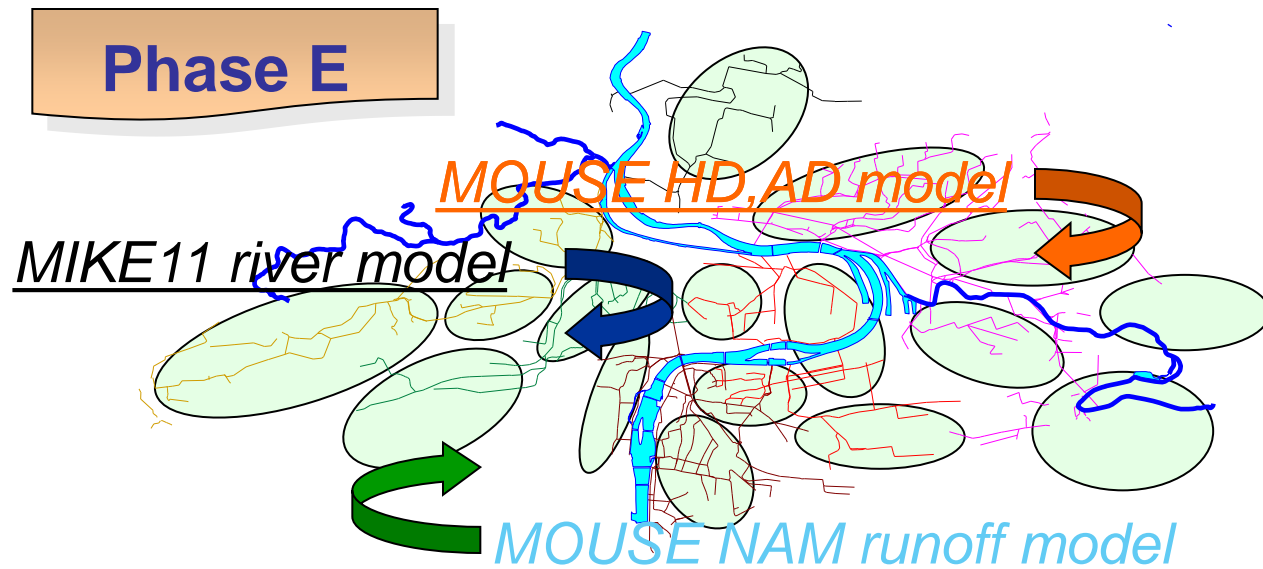
- 1. Model formulation** (governing equations, key parameters)
- 2. Model schematization** (simulation scale)
- 3. Monitoring definition**
- 4. Data collection**
 - a. Topological Digitization of paper data (or import from GIS)
 - b. Setting up the attribute data (DN, material, slope,...)
 - c. Verification of topology
- 5. Surveys**
 - a. Manhole survey, CSO survey, reservoir survey, 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

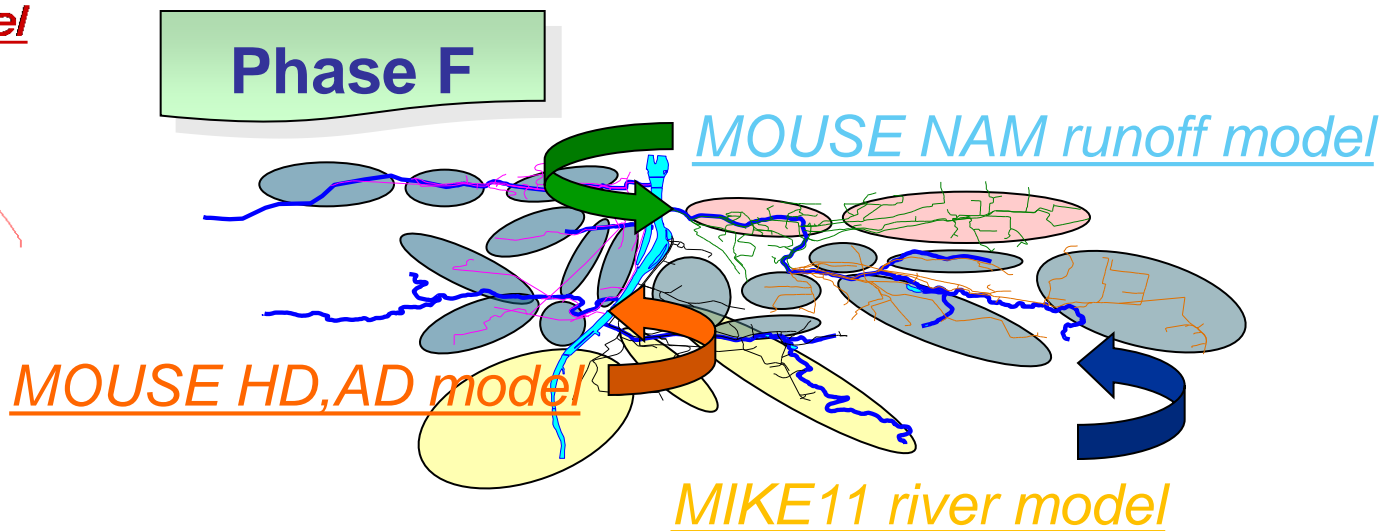
Phase C+D



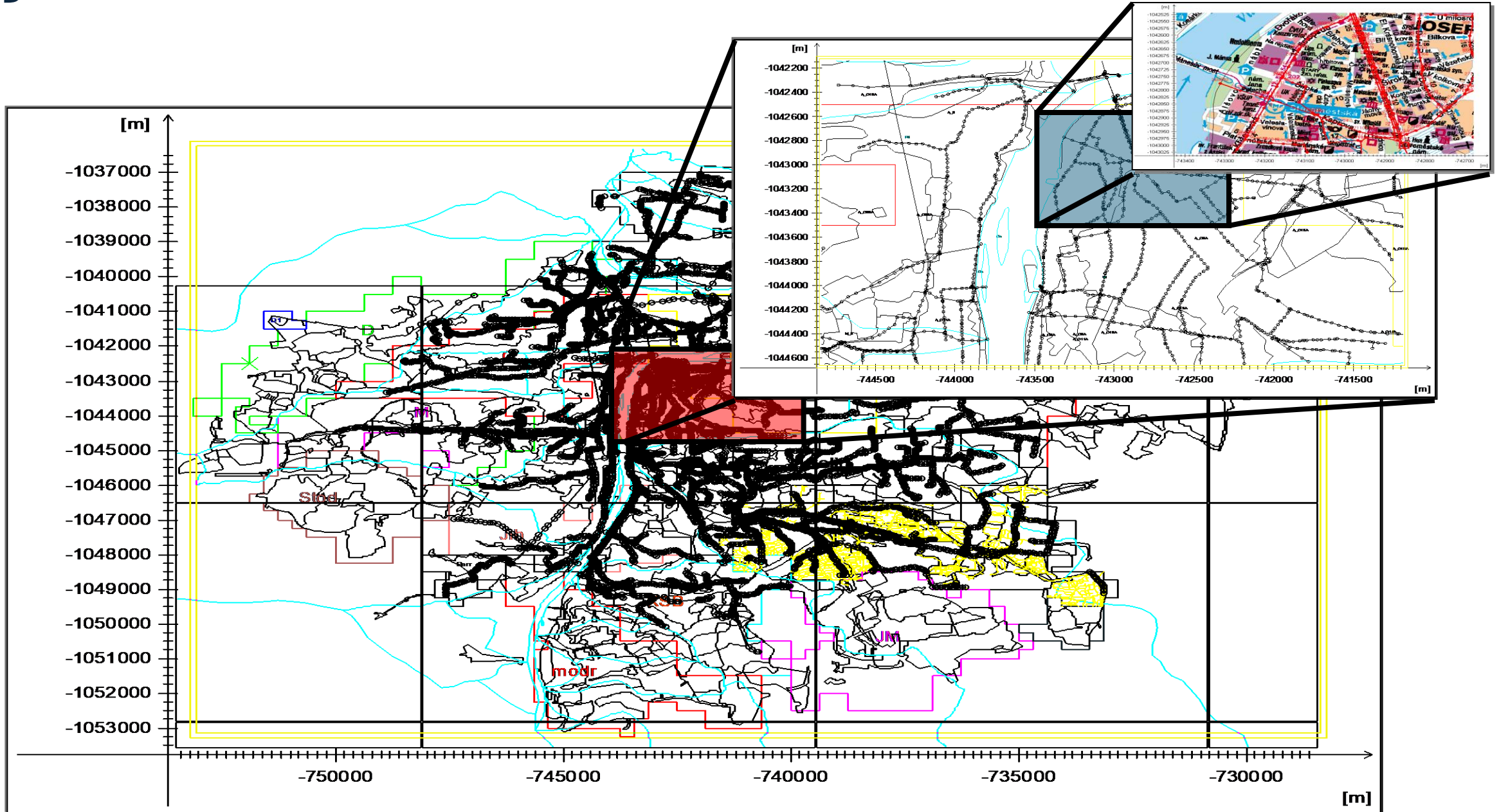
Phase E



Phase F



System schematization



Surveys

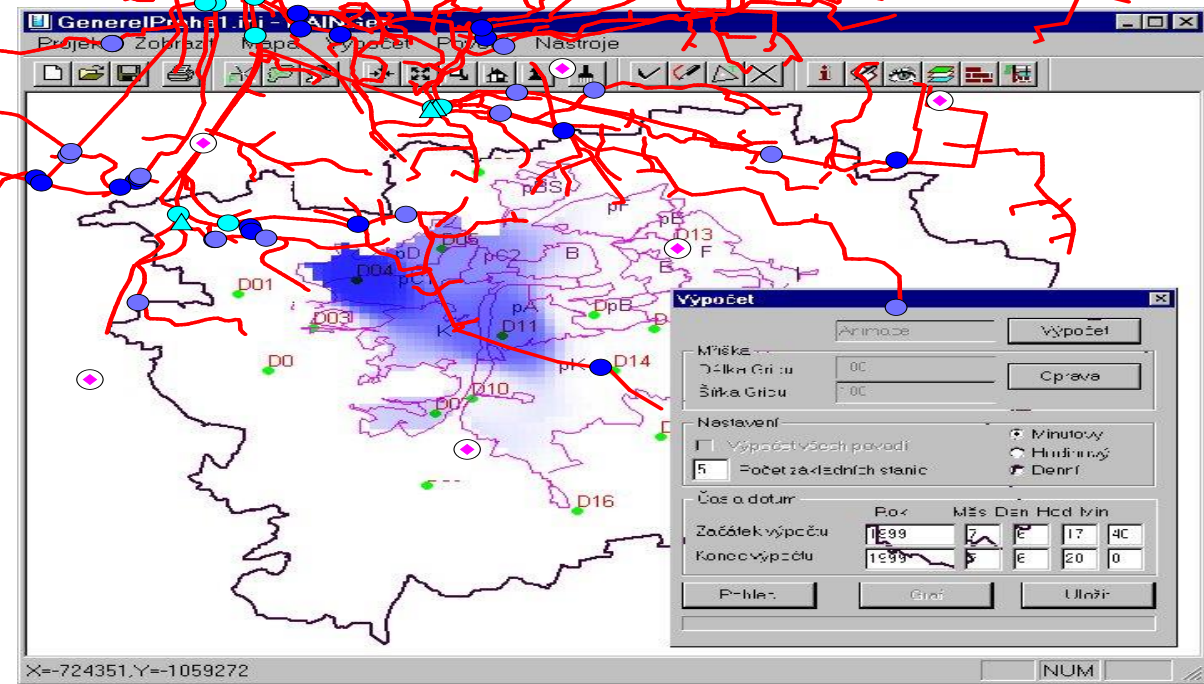
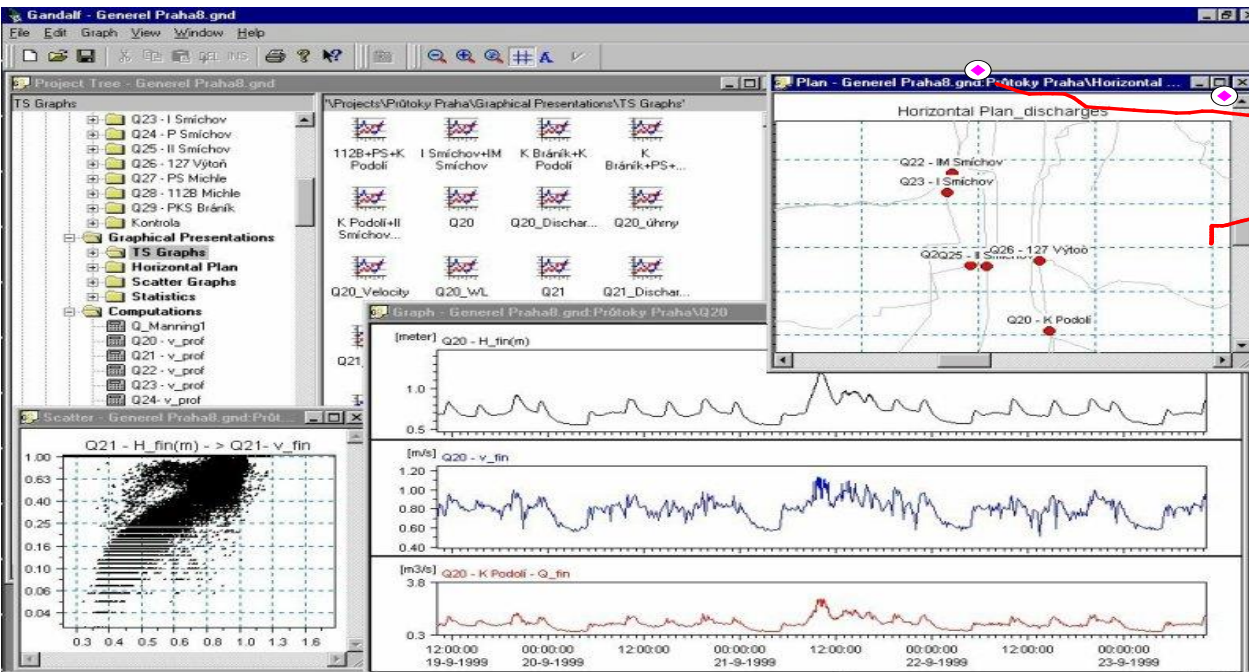
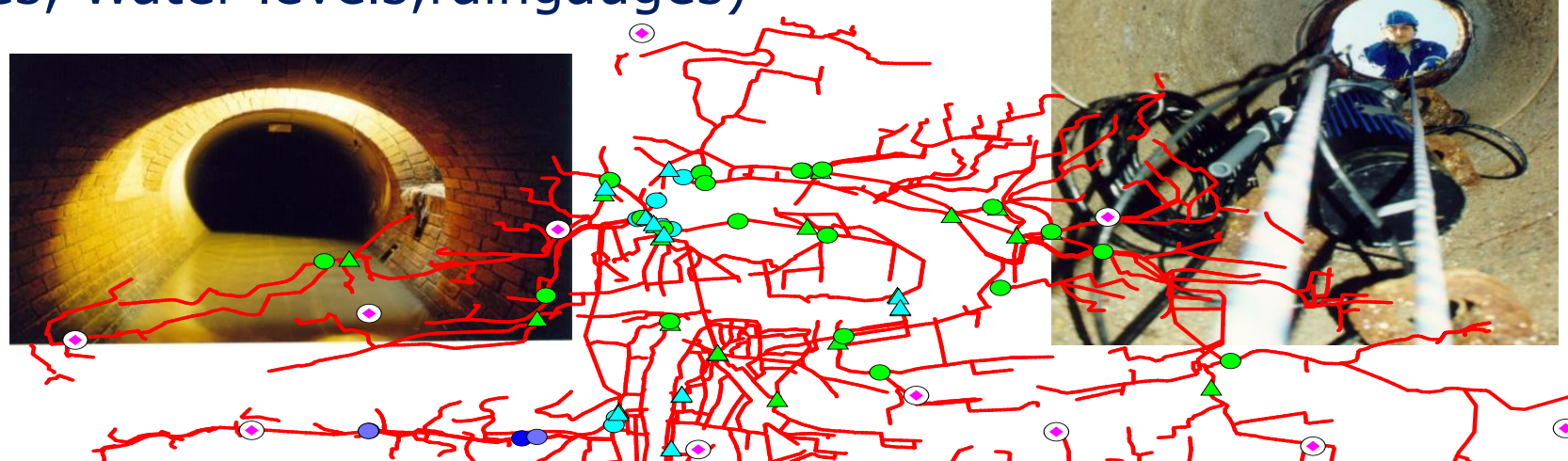
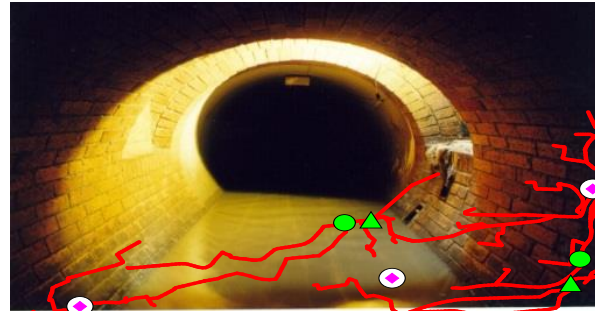
Flow survey (flows, pressures, Water levels, raingauges)

Geodetic survey

WQ sampling survey

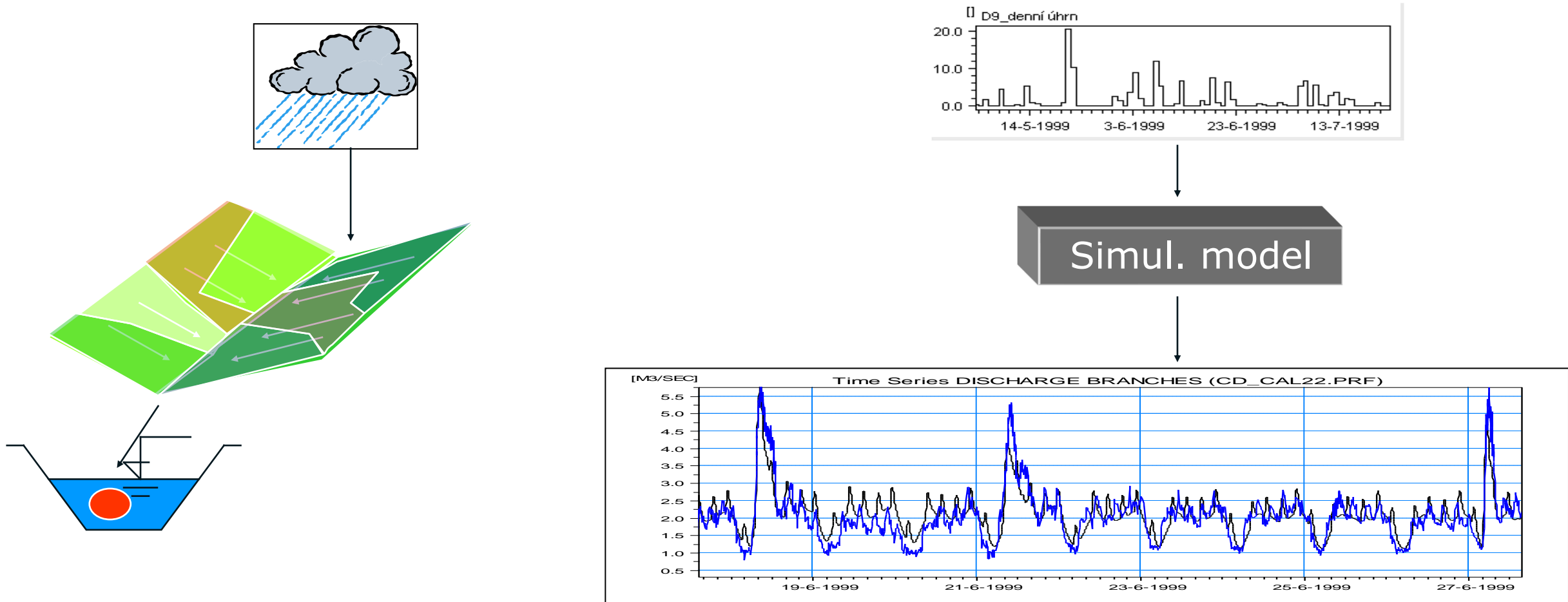
Structures survey

Impermeability survey



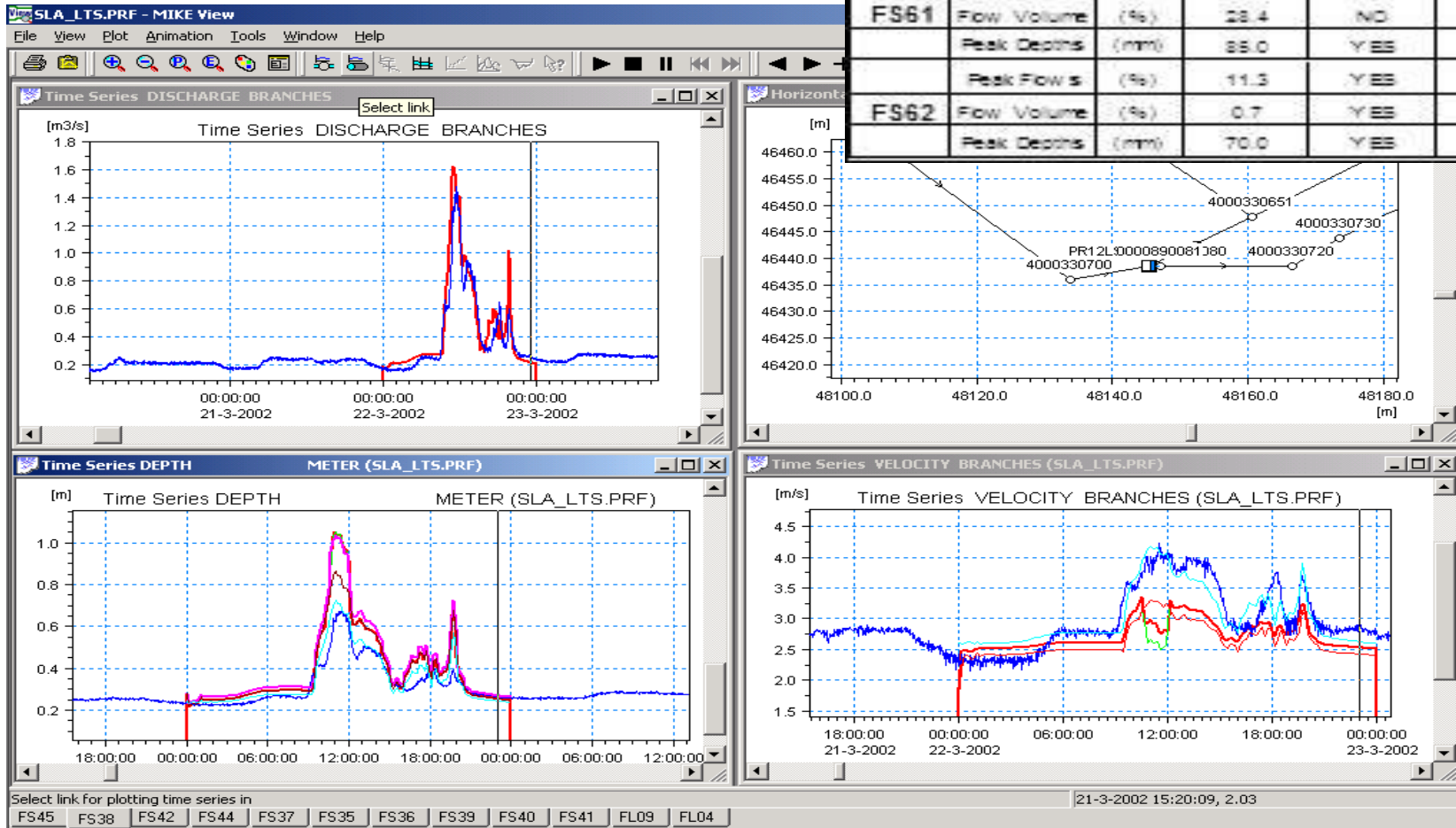
Model Calibration

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



Calibration details

- Dry weather flow
- Wet weather flow



KEY		NS		NS		NS		NS	
1000	No observed data recorded	1000	Recorded depth & velocity errors (resulting in criteria non-compliance)	1000	Average within criteria - considered verified	1000	Average not within criteria due to recorded errors (or no data) - model acceptable	1000	Average not within criteria - see individual comments for parent & model limitations
1000	See individual event comments for reasons for non-compliance	1000	Average within criteria - considered verified	1000	Average not within criteria due to recorded errors (or no data) - model acceptable	1000	Average not within criteria - see individual comments for parent & model limitations	1000	Average not within criteria - see individual comments for parent & model limitations
1000	Recorded velocity errors (resulting in criteria non-compliance)	1000	Average within criteria - considered verified	1000	Average not within criteria due to recorded errors (or no data) - model acceptable	1000	Average not within criteria - see individual comments for parent & model limitations	1000	Average not within criteria - see individual comments for parent & model limitations
1000	Recorded depth errors (resulting in criteria non-compliance)	1000	Average within criteria - considered verified	1000	Average not within criteria due to recorded errors (or no data) - model acceptable	1000	Average not within criteria - see individual comments for parent & model limitations	1000	Average not within criteria - see individual comments for parent & model limitations
Ref	Comparative analysis	Event A	Within Criteria?	Event B	Within Criteria?	Event C	Within Criteria?	Average	Within Criteria?
	Peak Flow s (%)	13.0	YES	-8.0	YES	-18.4	NO	-3.8	YES
FS61	Flow Volume (%)	28.4	NO	15.1	YES	1.9	YES	15.1	YES
	Peak Depth (mm)	85.0	YES	34.0	YES	20.0	YES	46.3	YES
	Peak Flow s (%)	11.3	YES	13.0	YES	-38.1	NO	-4.6	YES
FS62	Flow Volume (%)	0.7	YES	-1.5	YES	-27.4	NO	-9.4	YES
	Peak Depth (mm)	70.0	YES	43.0	YES	5.0	YES	39.3	YES

- Discharge
- Water level
- Velocity

Model Verification

