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BIOMATH

Department of Applied Mathematics, Biometrics and Process Control

Pivoting
from "Emission" to "Immission"

On the importance of the integral approach of the water cycle

Peter A. Vanrolleghem et al.

Université Laval, Québec, April 15 2004

RUG-Biomath, Coupure 653, 9000 Gent, Belgium (e-mail Peter.Vanrolleghem@rug.ac.be)

Opening note

- "Immission" is not existing in the English language !
- But there is improvement on its way:
  van Dale (thé Dutch thesaurus English <=> Dutch)
  already translates "immissie" to "immission"
  but doesn't know "immission" yet…
- Alternative terms in the English language:
  - Ambient quality
  - Receiving water quality
- "Emission" on the other hand is a very known word …

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Content

- Pivoting of legislation (EU - USA)
- Consequences for urban wastewater management
- A possible approach:
  - a vision for 2015
  - difficulties
- First steps in that direction (3 case studies):
  - Wastewater transport and treatment infrastructure Brussel
  - Immission based Real-time Control approach in Tielt
  - GREAT-ER water quality management of Rupel basin

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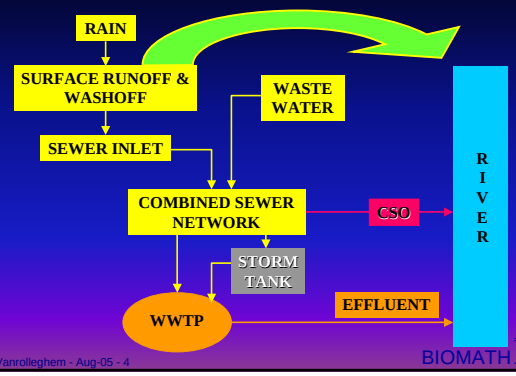
The integrated urban wastewater system



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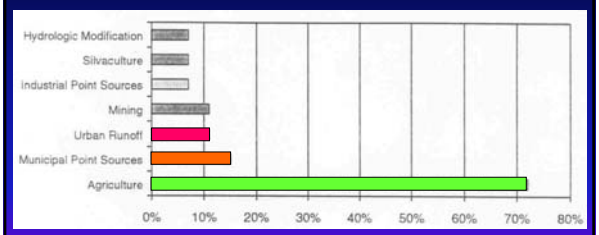
Contributions to negative impacts on river water quality 1990-1991 (US EPA, '94)



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EU-WFD / US-TMDL

- EU Water Framework Directive (WFD)
  - °2000 (in preparation since 1996)
  - Many directives (°1975) are integrated in it
  - No concrete specifications (yet), not (yet) coherent Working Groups are working on this
  - Achieve "Good Status" and "No deterioration" biological, morphological, physico-chemical
  - Basin-oriented (Rhine, Donau, Seine…)
  - Stakeholder participation
  - Strict time schedule

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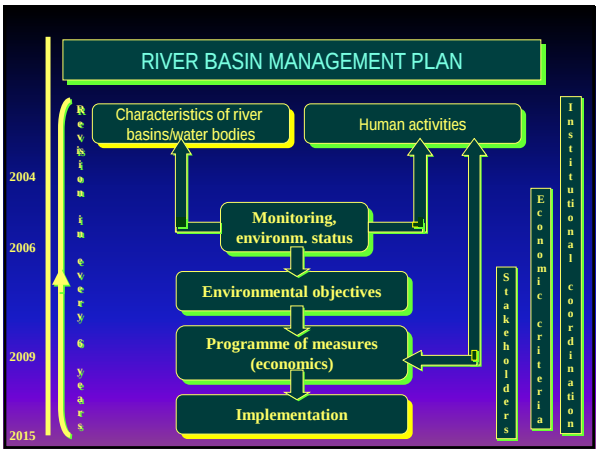

EU-WFD tijdsschema

- 2003 - National legislation & district councils
- 2004 - Analysis of impacts & economical implications
- 2006 - Monitoring programs
- 2008 - Draft River Basin Management Plan (RBMP) & consultation of the public
- 2009 - RBMP published
- 2015 – Reaching environmental objectives

6 yearly cycle when objectives are not reached

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US-TMDL

- Part of Clean Water Act (1972)
- TMDL = Total Maximum Daily Load
  - Calculated amount of pollution that can be emitted into a receiving water body that will not endanger imposed water quality standards
  - Licensing agency determines acceptable pollution
  - Assignment of acceptable pollution to point and diffuse pollution (stakeholder participation in 1970 !)
  - Considers seasonal variations and safety margins
  - must allow future growth (sustainability in 1970 !)
  - basin-based

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US-TMDL

- During first 30 years of Clean Water Act: mainly technolocally based standards/laws for point pollution are implemented
- Water quality focused laws (immission !) are not prosecuted until the end of the '90s
- Environmental organizations sue the US-EPA at the end of the '90s
- Convictions in California in 2000 ==> TMDL-fever

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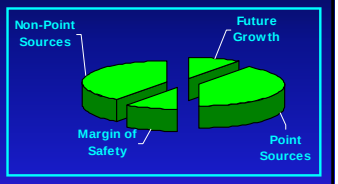
US-TMDL

- Essential components:
  - TMDL
  - Assignment of pollution (incl. municipal pollution load and agriculture)
  - Safety margin (conservative)
  - Vision on the future
- Implementation plan
- Monitoring programme



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US-TMDL

- The future of TMDL:
  - TMDL is re-determined based on “best science today”
  - Monitoring as input to readjust TMDL’s
  - “Pollutant trading” between e.g. industry/agriculture is allowed if the trade is verifiable
  - Markets for “pollutant trade” are being created
  - Aerial deposition and long range transport will also be considered
  - Interrelations between air, water- and solid waste are being acknowledged

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Consequences for water management

- Scale:

1 treatment plant or 1 sewer system

➢

Integrated approach on river basin level
(extends beyond organisations, borders)

⇒ Reorganisation (other players, e.g. agriculture)
⇒ Introduction of Geographical Information Systems

Consequences for water management

- Quality criteria:

Chemical indicators (NO_3, COD, P_{tot})

➢

Ecological quality
(bio-diversity, biotic index)

⇒ Knowledge building (even more multi-disciplinary)
⇒ Other (technical) management efforts needed

Vision for 2015

- Integrated data- & information management
  - GIS-systems
  - Knowledge bases (models, rules)
- Negotiations between “Stakeholders”:
  - Water quality managers
  - Agriculture & Industry (Pollutant trading ?)
  - Population & Authorities
- Integrated operational management
  - Much more information - Automatic Measurement Stations
  - Many more control handles - Real-time control

Difficulties

- Requirement for a multitude of disciplines
- Relation physico-chemistry --> ecology
- Large need for data/knowledge
- Current models are not adequate
  - not compatible for different subsystems
  - procedure for model building is too demanding/inflexible
  - different simulators needed
  - calculation times are too long
- Uncertainty remains large, but remains unknown
- Number of control handles for management is large

Difficulties ==> EU WFD R&D

- Ecology - Definition of “Good Status”
- Economical analyses
  - cost-efficiency
  - taxes
  - pricing policy
  - cost recuperation
- Social impacts
- Planning and planning tools
- EU 5th and 6th R&D Framework programme

Difficulties

- Requirement for a multitude of disciplines
- Relation physico-chemistry --> ecology
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Relation Physico-chemistry / Ecology

- Black box approach
  - RIVPACS (UK, multi-linear regression)
  - Neural networks

We are hardly there !

Trained with water quality data

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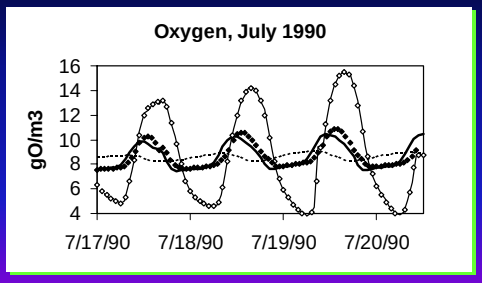
River Water Quality Model No. 1 RWQM1

Peter A. Vanrolleghem et al.

IWA Scientific and Technical Report No. 12

RUG-Biomath, Coupure 653, 9000 Gent, Belgium (e-mail Peter.Vanrolleghem@rug.ac.be)

RWQM1 for Glatt river (Switzerland)



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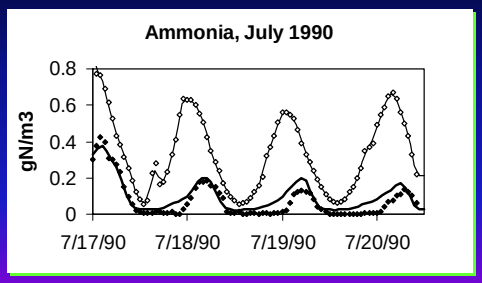
RWQM1 for Glatt river (Switzerland)



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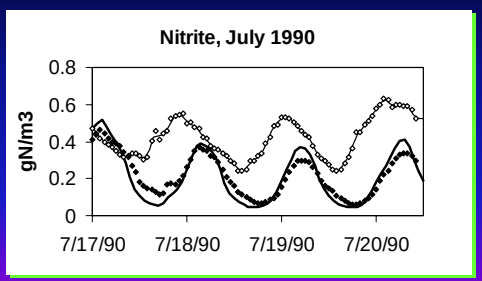

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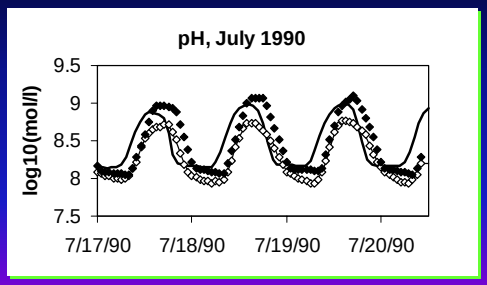

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Integrated modelling: Compatibility

- Models for sewer system, treatment plant and river are not really compatible
  - BOD <--> COD based models
  - NH_4 --> NO_3 <--> NH_4 --> NO_2 --> NO_3
- The aim of RWQM1 was to be compatible with the industry-standard Activated Sludge Model No. 1
- Not completely compatible, but already much better than ASM - Qual2E

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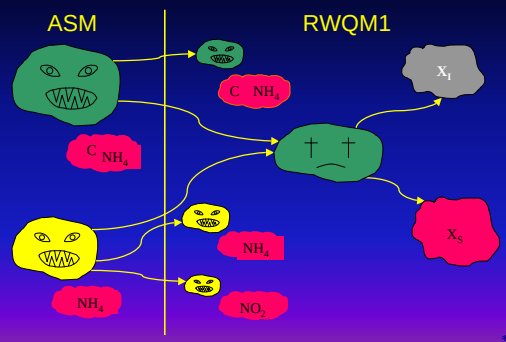
Integrated modelling: Connector



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Integrated modelling: Simulators

- Manual sequential simulation
  - file transfers
  - file formats
  - no interaction between subsystems possible
- SYNOPSIS (Schuetze, 1998)
  - Coupling routines between Sewer/WWTP simulators
- Integrated Catchment Simulator (ICS)
  - connects MOUSE, STOAT & MIKE11 simulators
  - organises communication between simulators
  - too much overhead ==> slow

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Integrated Modelling: WEST-IUWS

- Integrated Urban Wastewater System in WEST®
- WEST® (Hemmis NV, Kortrijk, Belgium)
  - state-of-the-art simulator (comparable to SIMBA, GPS-X)
  - open (implement your own models)
  - hierarchical modelling
  - parameter estimation routines
  - contains state-of-the-art models for WWTP
  - contains RWQM1 for river modelling
  - contains KOSIM-model for sewer system

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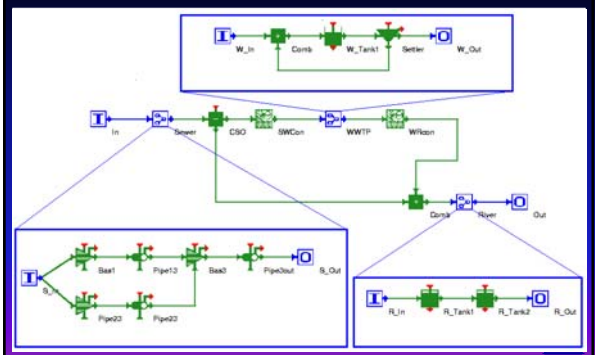
Integrated Modelling: WEST-IUWS



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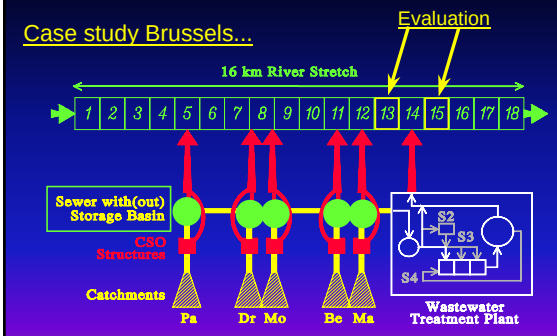
Integrated Urban Water Management

Case study Brussels...



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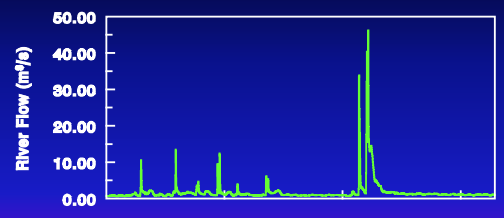
Effect of 2 design options on River water quality



One large and different small rain events in the summer of 1986

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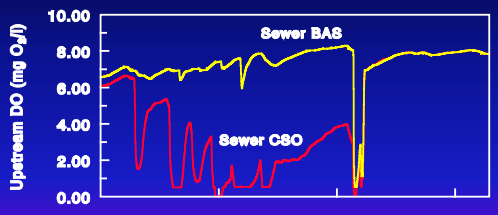
River water quality (dissolved oxygen)

Downstream of CSO, Upstream of WWTP



Clear positive effect of storage basins (BAS) in sewer system !

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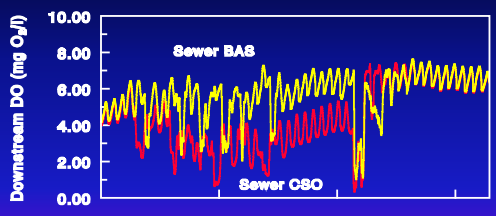
River water quality (dissolved oxygen)

Upstream CSO, Downstream WWTP



Positive effect of basins is reduced due to the lower WWTP-efficiency under the increased loading coming from the basins

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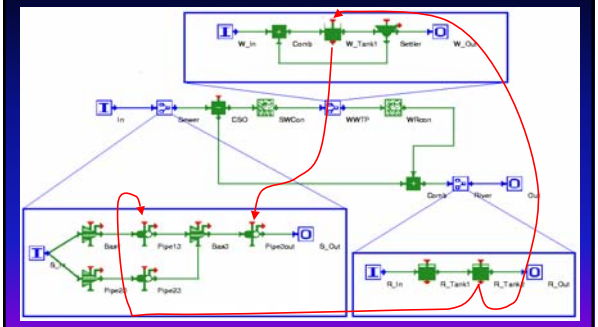
Integrated Urban Water Management: RTC



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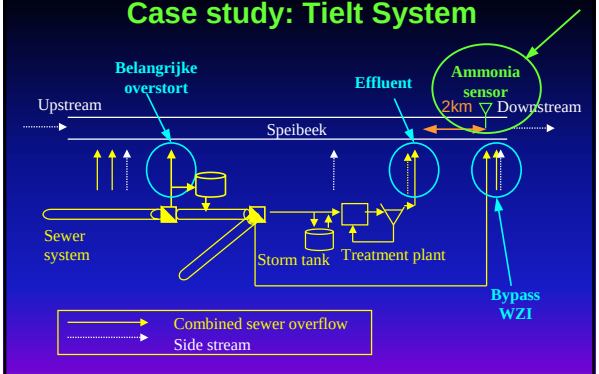
Case study: Tielt System



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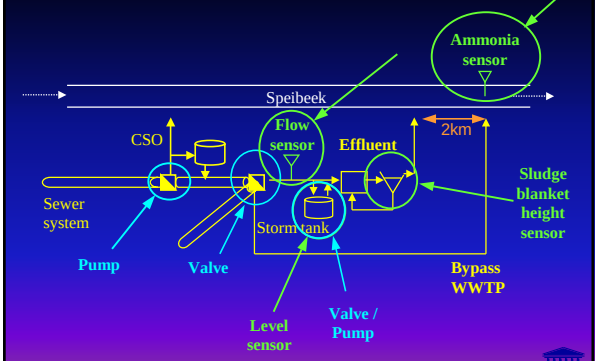
Case study: Description of control



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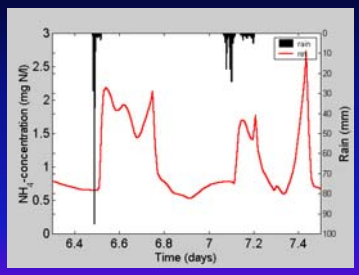
Immission-based control: Results



Referentie

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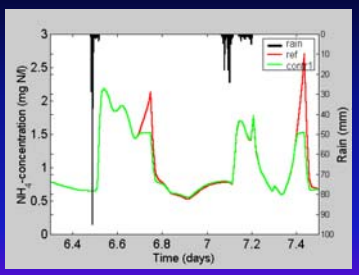
Immission-based control: Results



Control actions only at WWTP

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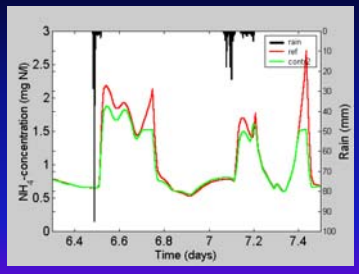
Immission based control: Results



Control actions both at WWTP and sewer system

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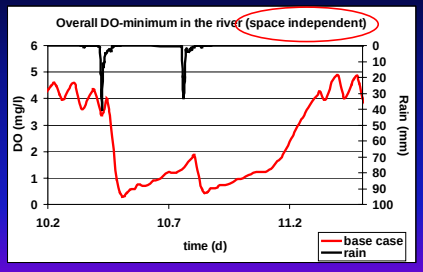
Immission based control: Results

Evaluation of secondary objectives (oxygen)



BIOMATH

Immission based control: Results

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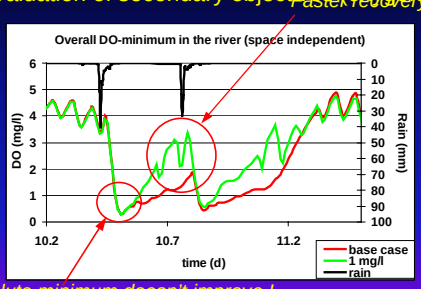

Absolute minimum doesn't improve !

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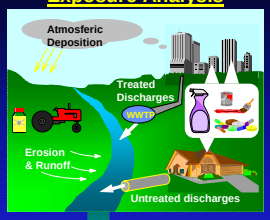
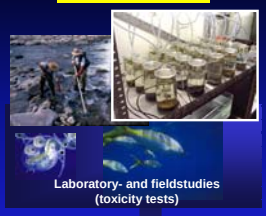
GREAT-ER

Ecological risk assessment

Exposure Analysis



Effects Analysis



Predicted Environmental Concentration (PEC)

Predicted No Effect Concentration (PNEC)

YES/NO, potential risk

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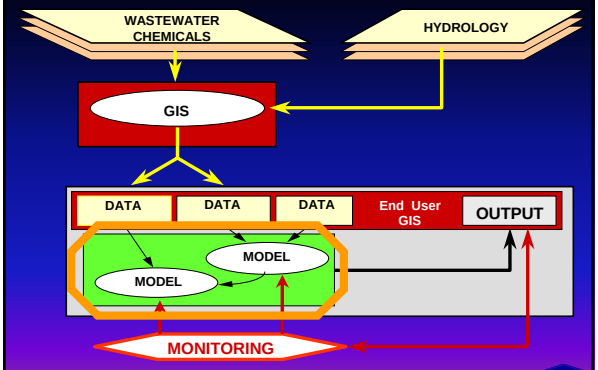
GREAT-ER: overview



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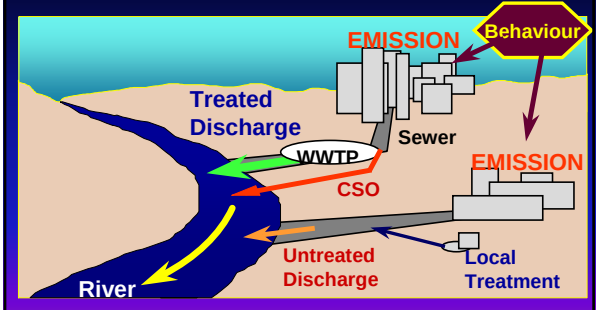
Deterministic Model + Monte Carlo



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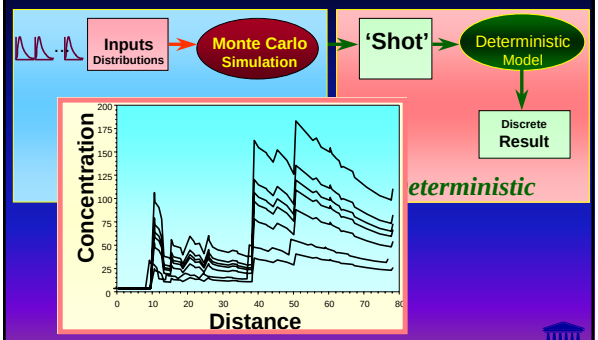
Uncertainty analysis: Monte Carlo



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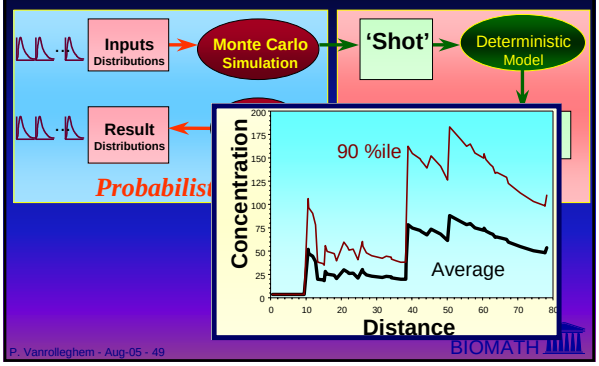

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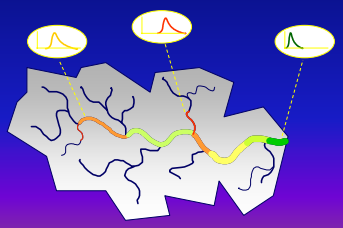
Data analysis

- direct GREAT-ER **simulation results**

Geo-referenced concentration distributions



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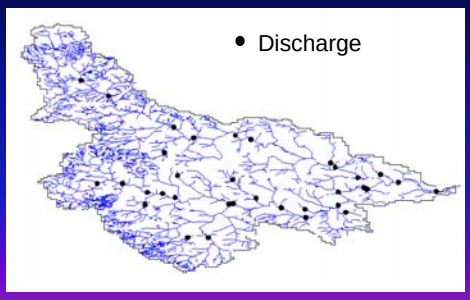
GREAT-ER Validation

River basin in Yorkshire (UK)



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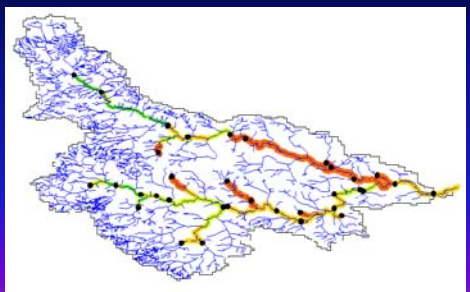
GREAT-ER Validation

Concentrations in river stretches



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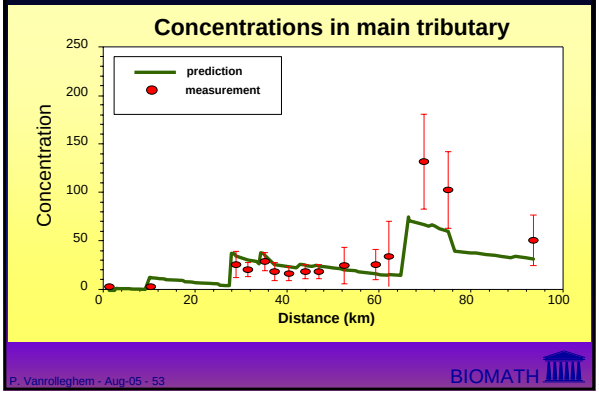

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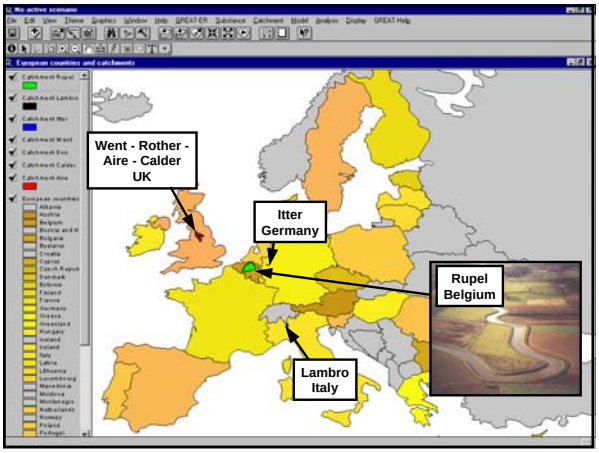
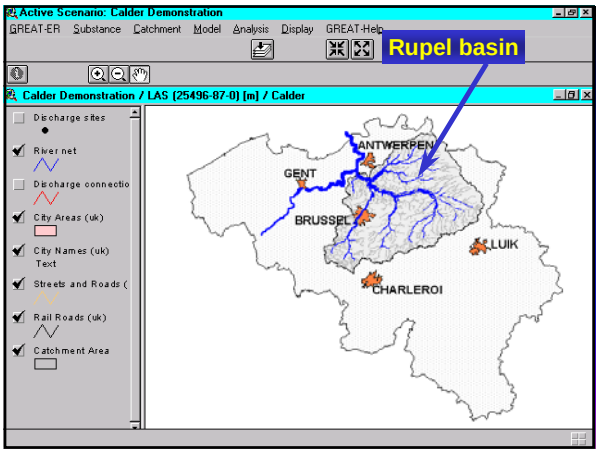
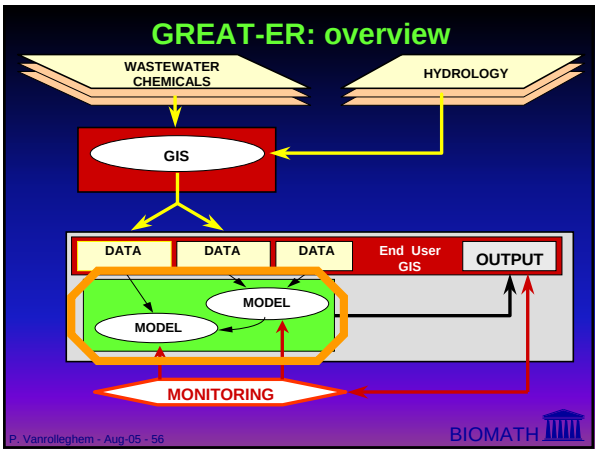



Active Scenario: Calder Demonstration
GREAT-ER Substance Catchment Model Analysis Display GREAT-Help
Rupel basin
Calder Demonstration / LAS (25496-87-0) [m] / Calder
Discharge sites
River net
Discharge connectio
City Areas (uk)
City Names (uk) Text
Streets and Roads (
Rail Roads (uk)
Catchment Area
ANTWERPEN
GENT
BRUSSEL
LUIK
CHARLEROI


GREAT-ER: overview
WASTEWATER CHEMICALS
HYDROLOGY
GIS
DATA
DATA
DATA
End User GIS
OUTPUT
MODEL
MODEL
MONITORING
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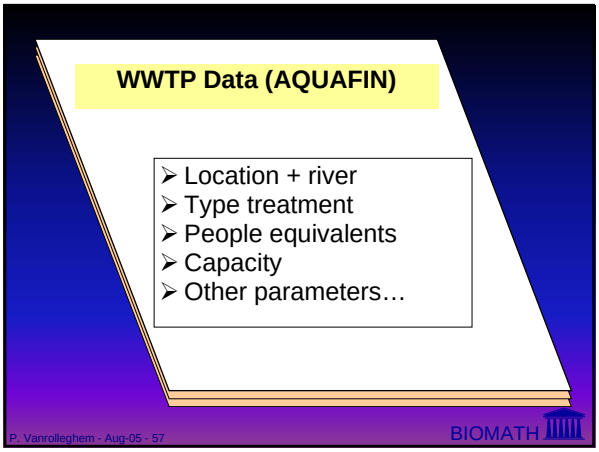
WWTP Data (AQUAFIN)
Location + river
Type treatment
People equivalents
Capacity
Other parameters…
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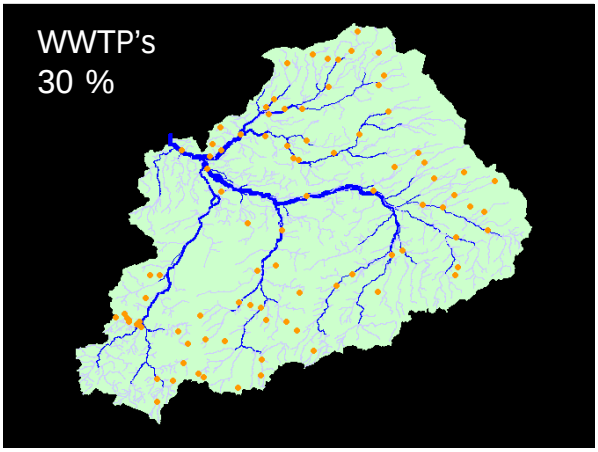
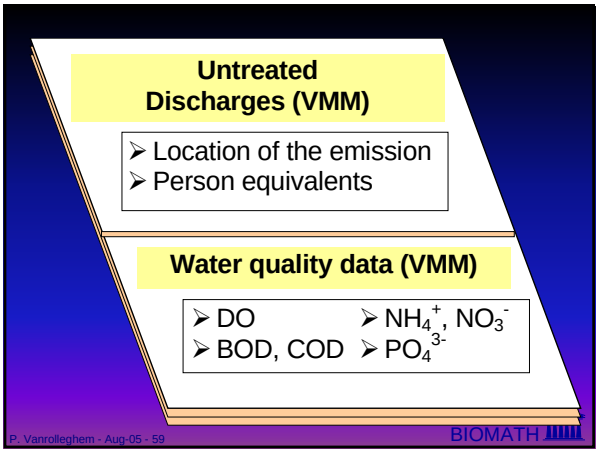
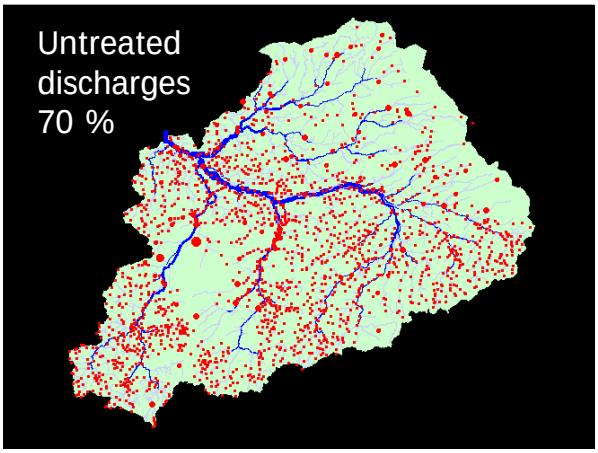

WWTP's
30 %


Untreated Discharges (VMM)
Location of the emission
Person equivalents
Water quality data (VMM)
DO
BOD, COD
NH4+, NO3-
PO43-
P. Vanrolleghem - Aug-05 - 59
BIOMATH


Untreated discharges
70 %

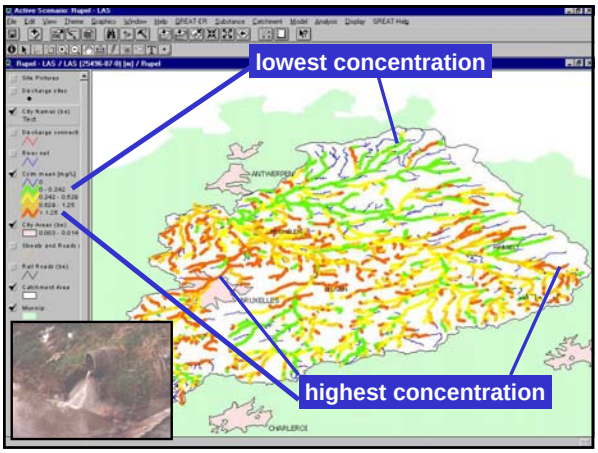
Hydrological Data (AMINAL + AWZ)

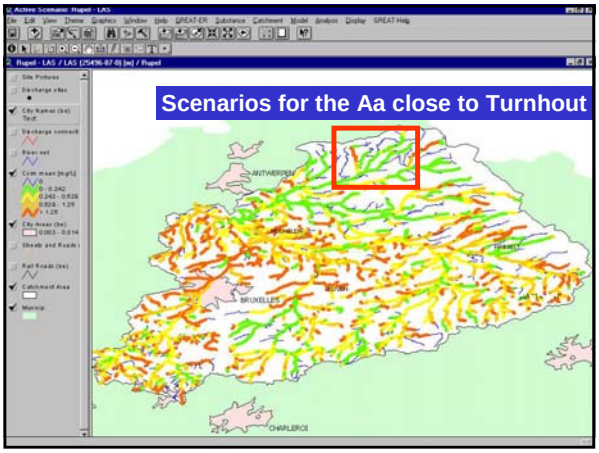
Measuring stations:
- Flow rate time series
- Depth
- Width
- Velocity

} indirect

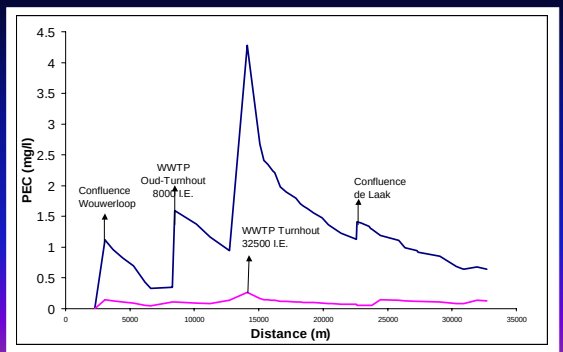
Digital river network:
- Location on map

BIOMATH

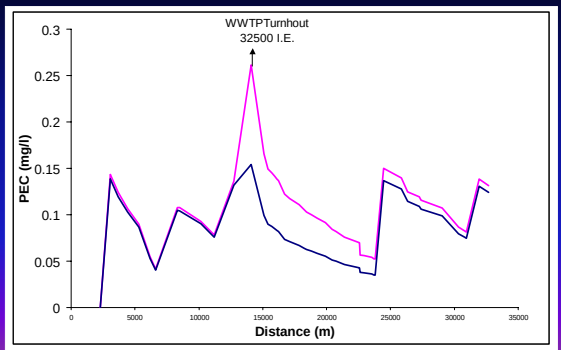




Scenario 1: No treatment



Scenario 2: Trickling Filter <-> Activated Sludge



Take home

- Pivoting of legislation (EU - USA)
- Consequences for urban wastewater management
- A possible approach:
  - a vision for 2015 (GIS, knowledge, pollutant trading)
  - difficulties

BIOMATH

Difficulties

- Requirement for a multitude of disciplines
- Relation physico-chemistry --> ecology
- Large need for data/knowledge
- Current models are not adequate
  - not compatible for different subsystems
  - procedure for model building is too demanding/inflexible
  - different simulators needed
  - calculation times are too long
- Uncertainty remains large, but remains unknown
- Number of control handles for management is large

Take home

- First steps in that direction (3 case studies):
  - Wastewater transport & treatment infrastructure Brussels
  - Immission based Real-time Control approach in Tielt
  - GREAT-ER water quality management of Rupel basin