Integrated modeling of the urban wastewater system: Back to the future

Peter A. Vanrolleghem
model*EAU* – Université Laval
Québec City, CAN

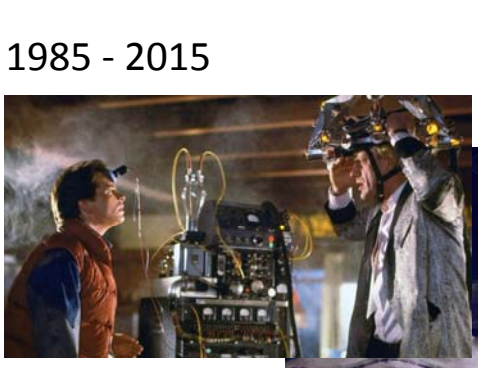
UNIVERSITÉ LAVAL

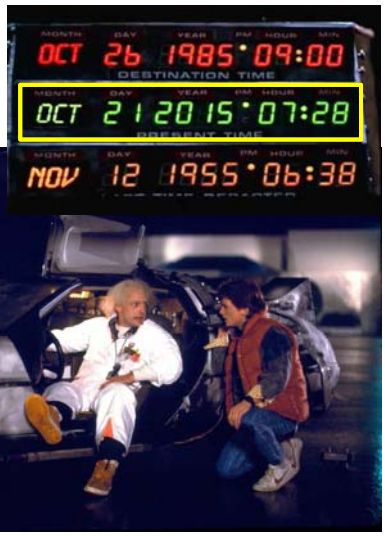
modelEAU

weftec 2015 the water quality event™ TECHNICAL SESSION

Back to the future

- 1985 - 2015





1955

Stream Pollution

EFFECT OF SEWAGE–BORNE PHOSPHORUS ON ALGAE *

By John J. Curry and S. L. Wilson

Respectively, Chief Engineer, Connecticut State Water Commission, Hartford, Conn., and Biologist, Connecticut Agricultural Experiment Station, New Haven, Conn.

When Lake Zoar was first formed by Stevenson Dam on the Housatonic River in Connecticut there was no algae problem. However, as the years passed algae in the lake increased and by 1947 they were so plentiful that a serious nuisance was created for the property owners around the lake. At the time it was thought the most offensive part of the problem was the aquatic weeds and some efforts were made to determine the most suitable method of control. In 1949, the Housatonic Valley Clean Waters League, Inc., requested the Connecticut Benoit and in July, 1954, a research study was authorized.

Physical Aspects

Lake Zoar was formed behind a run-of-the-river hydroelectric plant built by the Connecticut Light and Power Company in 1919 and the drainage area of the Housatonic River at this point is about 1545 sq. mi. This company also operates a pump storage facility at Lake Candlewood. Although Lake Candlewood is not on the Housatonic River proper, the water in the lake is Housatonic River water pumped to it for storage. (Figure 1)

Phosphorus Removal

The removal of soluble phosphates from sewage treatment plant effluents through the use of alum and lime is to be studied in a pilot plant constructed with a special legislative appropriation. It is hoped that algae can be controlled by reducing the phosphorus in the water.

1975

- Bruce Beck (Cambridge, UK)

Water Research Vol. 10, pp. 575 to 595. Pergamon Press 1976. Printed in Great Britain.

DYNAMIC MODELLING AND CONTROL APPLICATIONS IN WATER QUALITY MAINTENANCE

M. B. Beck*

Control Division, University Engineering Department, Cambridge, U.K.

(*Received* 4 *October* 1975)

Abstract—The purpose of this paper is to develop and illustrate a unified, systematic approach to problems of water quality management. In order to achieve this a water quality system is defined as the following group of component features: the abstraction, purification, and supply of potable water from a river; consumer effluent, rainfall-runoff from an urban land surface, and the sewer network; the wastewater treatment plant; the river itself. A systems analysis approach to the study of the dynamic and control aspects of the system is discussed, with particular reference to the practical limitations of instrumentation and technology. In an attempt to blend the theory with the practice recent studies on the dynamic modelling and control of parts of the water quality system are reviewed. Special attention is paid to the practical application of techniques of system identification and parameter estimation. Finally, piecing together several individual results, it is possible to give a good indication of the manner in which control studies should be directed in the near future.

Sewer Network

Water Resource Recovery Facility

Distribution Network

Receiving Water Body

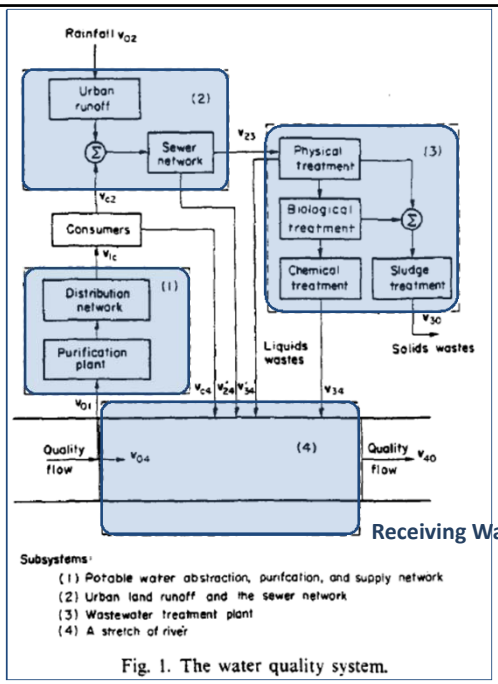


Fig. 1. The water quality system.

1985

- Willi Gujer (eawag, Switzerland)

ANHANG: Gujer et al. (1982), *gwa*, 62(7), 298-311.

Von der Kanalisation ins Grundwasser – Charakterisierung eines Regenereignisses im Glattal

EAWAG, 8600 Dübendorf, in Zusammenarbeit mit der Abt. Stadtentwässerung des Tiefbauamtes der Stadt Zürich

Bericht:
W. Gujer, V. Krejci, R. Schwarzenbach, J. Zobrist

Für alle diese Phänomene, die typisch sind für Regenereignisse, interessieren sich mit unterschiedlicher Gewichtung verschiedene am Gewässerschutz beteiligte Fachleute. Nur selten gelingt es aber, einen umfassenden Überblick über die Zusammenhänge und Auswirkungen dieser Phänomene zu erhalten.

Verschiedene Forschungsprojekte der EAWAG befassen sich mit Teilaspekten des generellen Problemkreises «Gewässerschutz bei Regenereignissen». Gemeinsam decken diese Projekte den ganzen Bereich, von der Quelle der Schmutzstoffe bis zur Senke respektive zum Abfluss aus einem ganzen Einzugsgebiet eines Fliessgewässers. Es war daher naheliegend, dass die verschiedenen Arbeitsgruppen in einer gemeinsamen Aktion versuchten, ein Regenereignis im Detail so zu untersuchen, dass für ausgewählte Schmutzstoffe Ursprung, Verhalten und Auswirkungen auf die Wasserzusammensetzung in einem

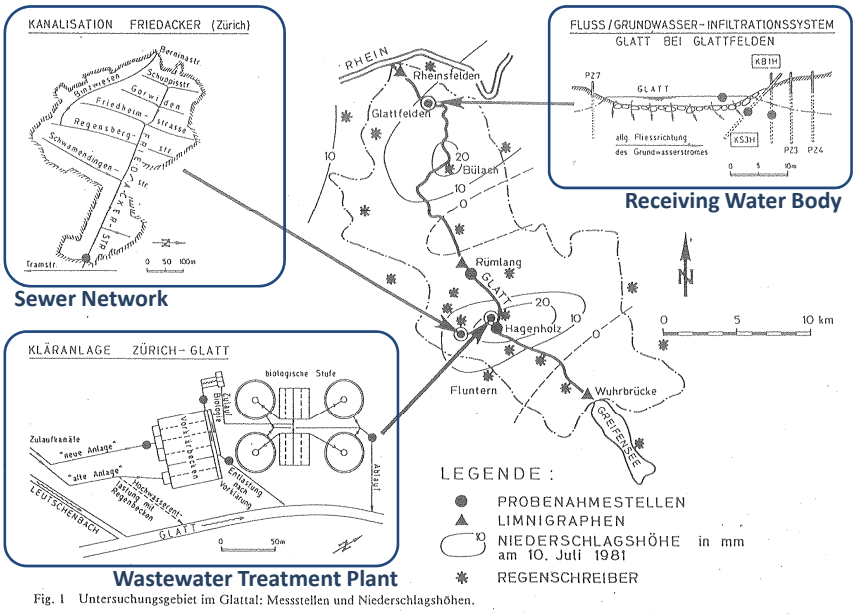


Fig. 1 Untersuchungsgebiet im Glattal: Messstellen und Niederschlagshöhen.

1995

- Peter Vanrolleghem (BIOMATH, Belgium)

WEF Specialty Conference on Urban Wet Weather Pollution:
Controlling sewer overflows and stormwater runoff. Quebec City, Canada, June 16-19 1996.

EVALUATION OF DESIGN AND OPERATION OF THE SEWAGE TRANSPORT AND TREATMENT SYSTEM BY AN EQO/EQS BASED ANALYSIS OF THE RECEIVING WATER IMMISSION CHARACTERISTICS

Peter A. Vanrolleghem
Department of Applied Mathematics, Biometrics and Process Control (BIOMATH)
University of Gent, Coupure Links 653, B-9000 Gent, Belgium

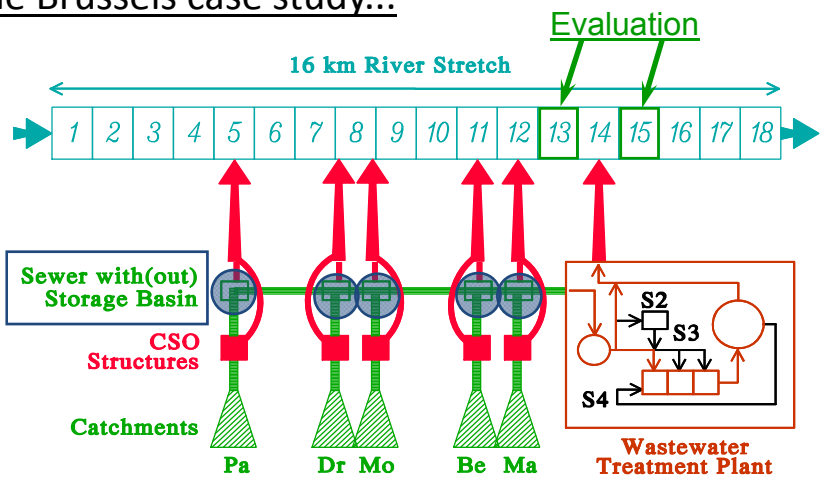
Chantal Fronteau and Willy Bauwens
Laboratory of Hydrology, University of Brussels, Pleinlaan 2, B-1050 Brussels, Belgium

INTRODUCTION

It is evident to all those involved in urban water management that three important units need to be considered to assess the performance of an urban drainage system: the sewer, the treatment plant and the receiving

1995

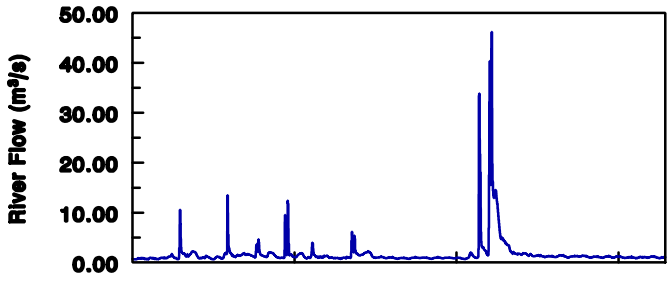
The Brussels case study...



1995

Effect of 2 design options (BAS/CSO) on River Water Quality

River flow at end of summer

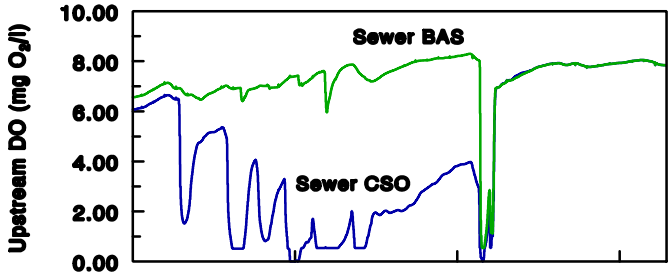


One big and several small rain events in summer '86

1995

River Water Quality (oxygen)

Downstream of CSO, upstream of WRRF

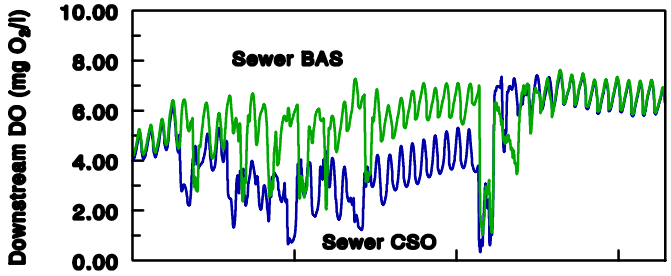


Clear beneficial effect of retention basins (BAS) in sewer !

1995

River Water Quality (oxygen)

Downstream of CSO, downstream of WRRF



Beneficial effect of basins is reduced due to lower efficiency of WRRF by increased loading from basins

2005

- Eveline Volcke (Ghent Univ., Belgium)

WATER RESEARCH 40 (2006) 2817–2828

Available at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/watres

ELSEVIER

Continuity-based model interfacing for plant-wide simulation: A general approach

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[b]Department of Biochemical Engineering, Delft University of Technology, Julianalaan 67, NL-2628 BC Delft, The Netherlands
[c]ModelEAU, Département de génie civil, Pavillon Pouliot, Université Laval, Qué., Canada G1K 7P4

ARTICLE INFO

Article history:

ABSTRACT

In plant-wide simulation studies of wastewater treatment facilities, often existing models

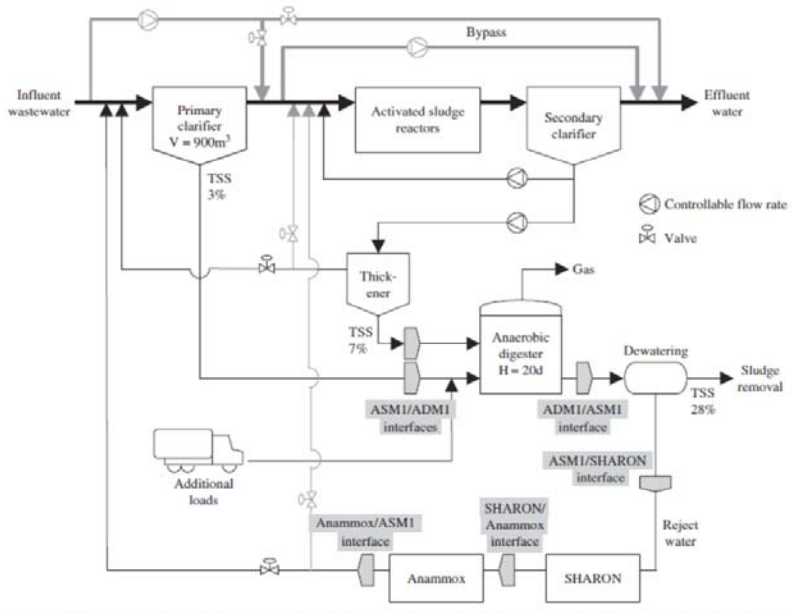
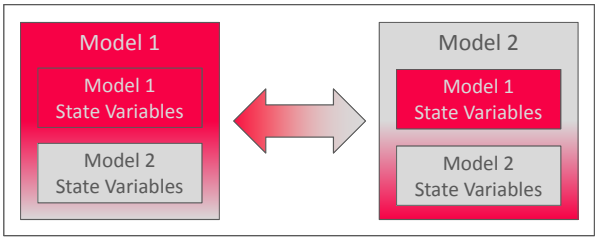


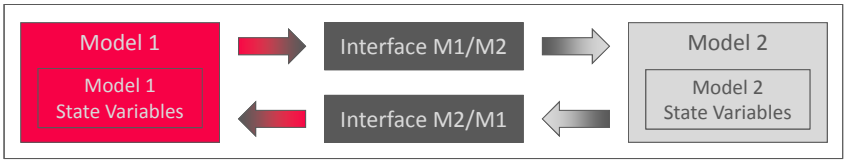
Fig. 2 – Extended benchmark plant with anaerobic sludge digestion and reject water recirculation, adapted from Jeppsson et al. (2006). The location for inclusion of the SHARON and Anammox process is indicated, as well as the model interfaces.

2005

Supermodel approach



Interfaces approach



2005

- Peter Vanrolleghem (model*EAU*, Canada)

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Environmental Modelling & Software 20 (2005) 427–442

Environmental Modelling & Software

www.elsevier.com/locate/envsoft

Modelling and real-time control of the integrated urban wastewater system

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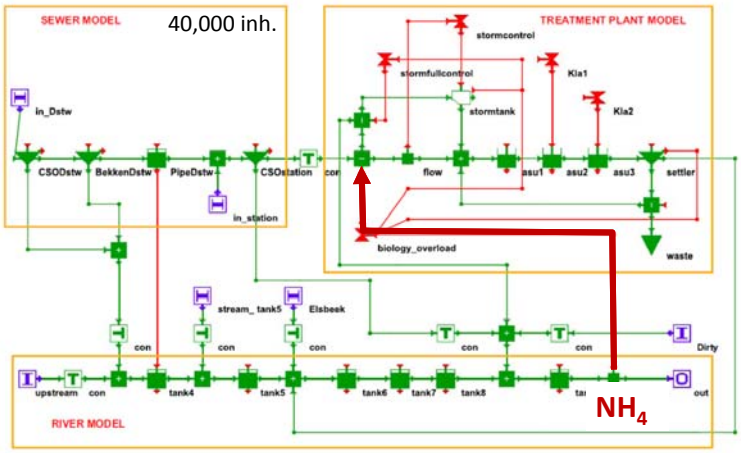
BIOMATH, Department for Applied Mathematics, Biometrics and Process Control, Ghent University, Coupure Links 653, B-9000 Gent, Belgium

Abstract

In the European Union, the Water Framework Directive (WFD) enforces a good ecological and chemical status of all surface waters. In-stream (immission) concentrations and populations need to comply with certain standards. In order to deal with this new

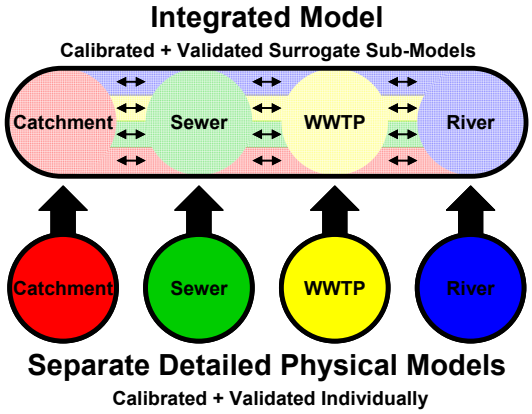
2005

Water quality based real-time control (NH_4)



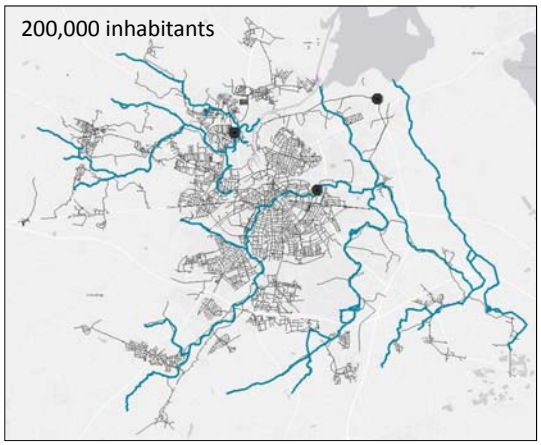
2005

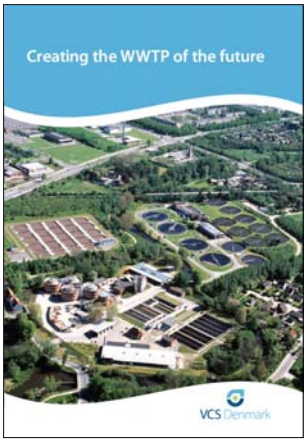
Integration using surrogate sub-models



2015

- Lorenzo Benedetti (VCS-Odense, DK)





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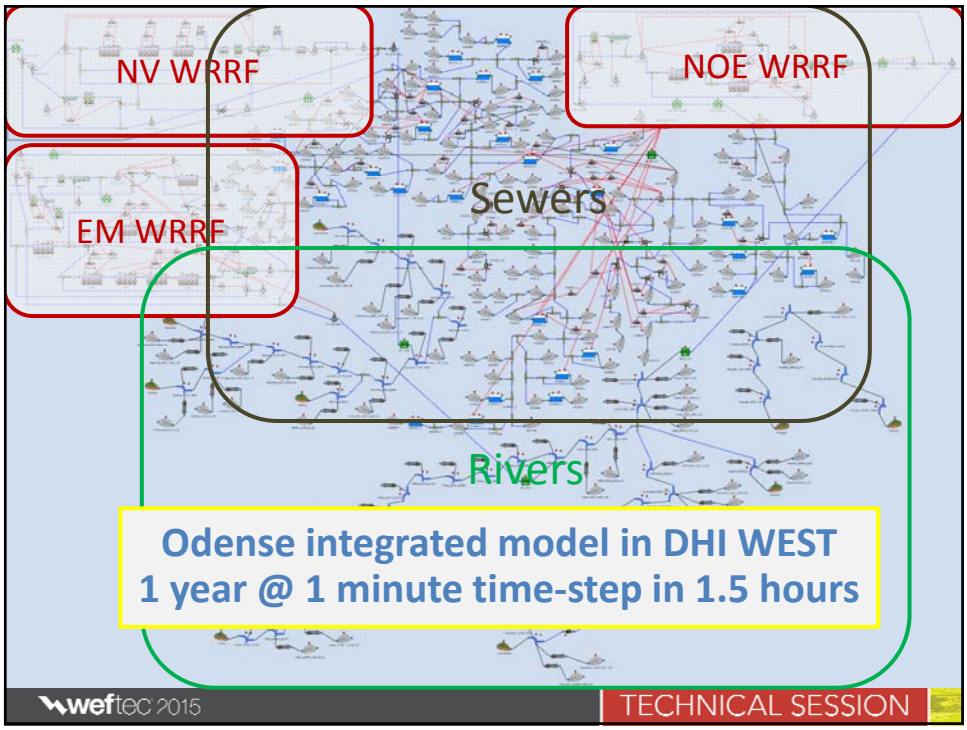

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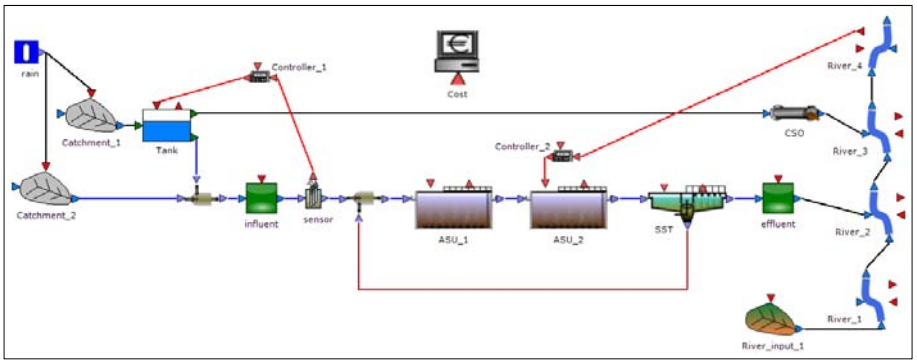
2015

What Odense's 3-headed beast boils down to:



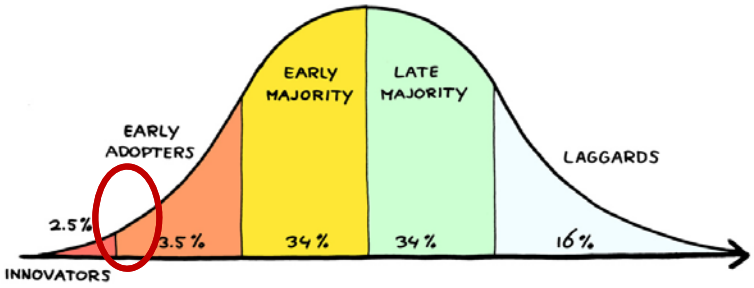
2015

- Develop an alternative wet weather plan which:
  - satisfies the Danish regulator,
  - delivers long term environmental benefit; and
  - supports the most efficient use of VCS investment
- Demonstrate leadership & innovation in wet weather planning
  - New integrated modeling technology
  - Wet weather water quality design criteria (UPM)

2015

- Integrated modeling: Case studies → Applications

  Slow uptake in practice, but there is significant progress



Modeling - Definitions

- System

  Part of reality that is separated from its environment on the basis of a purpose defined by the researcher

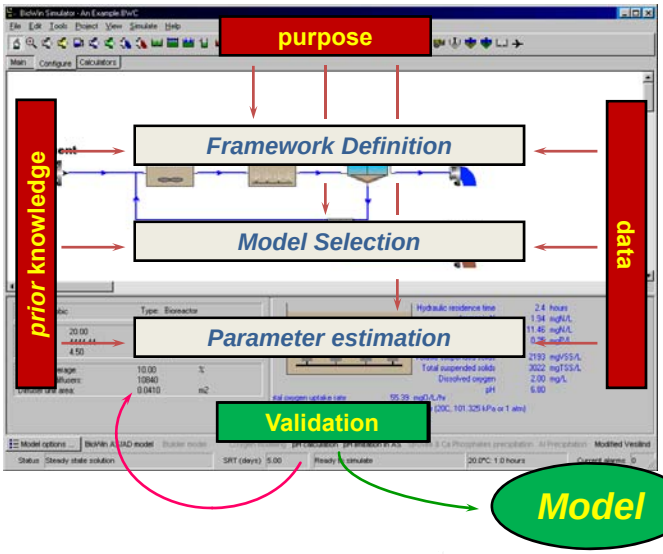
- Model

  An approximate description of a part of reality considering only those aspects that are of interest

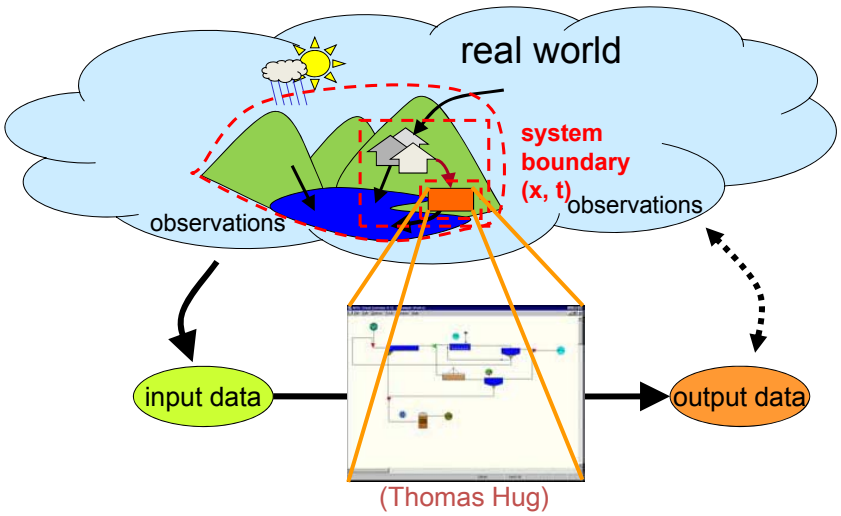
- Simulation

  = Virtual Experimentation: Manipulation of a model to gain insight in the "behaviour" of the real system

Model building

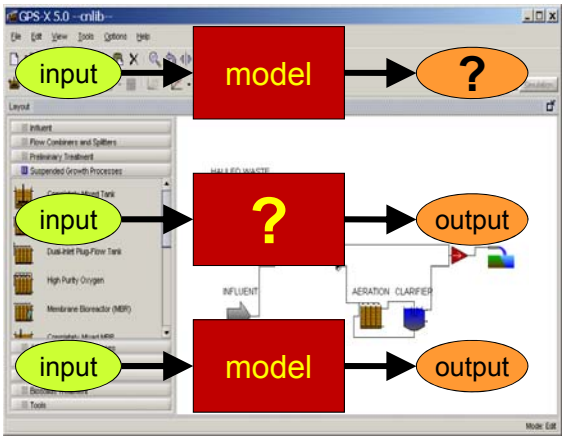


Model building



(Thomas Hug)

Objectives of model use



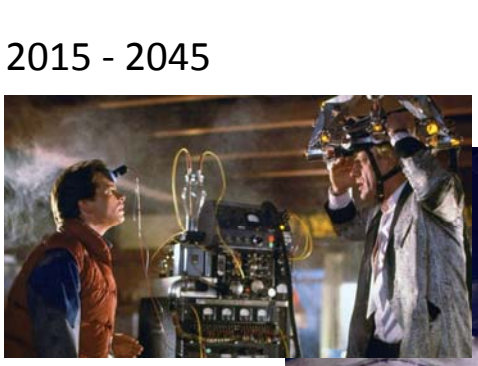
… predict

… understand

… communicate

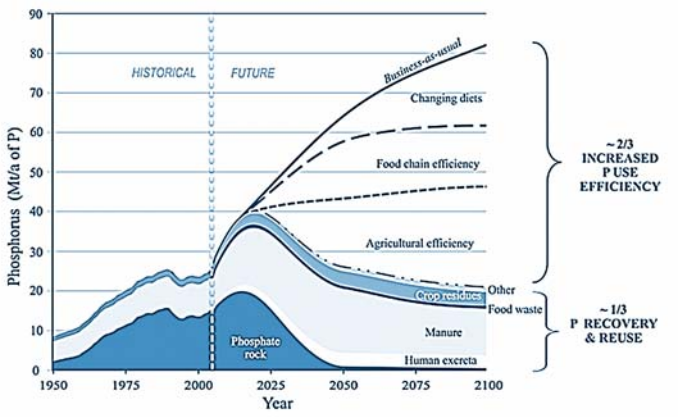
Back to the future

- 2015 - 2045



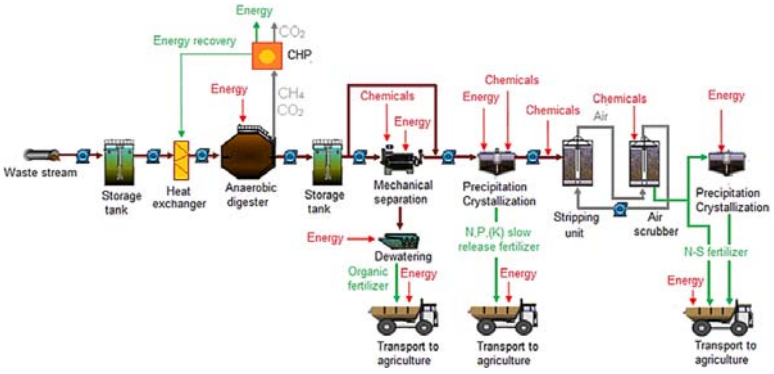
2045

- Resource depletion (e.g. phosphate)



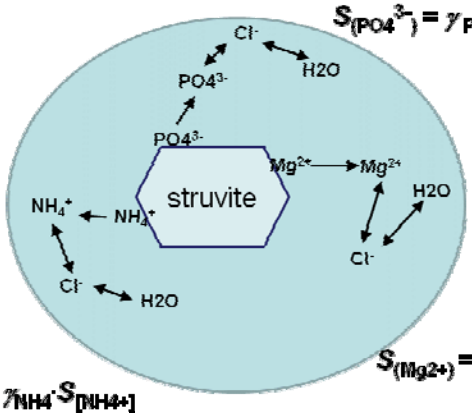
2015

- Céline Vaneeckhaute (model*EAU*)
  Modeling of resource recovery processes



2015

- Céline Vaneeckhaute (2015) Integration of physico-chemical models



$S_{(PO4^{3-})} = \gamma_{PO4} \cdot S_{[PO4^{3-}]}$

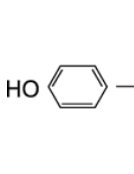
$S_{(Mg2+)} = \gamma_{Mg} \cdot S_{[Mg2+]}$

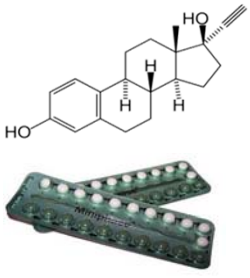
$S_{(NH4+)} = \gamma_{NH4} \cdot S_{[NH4+]}$

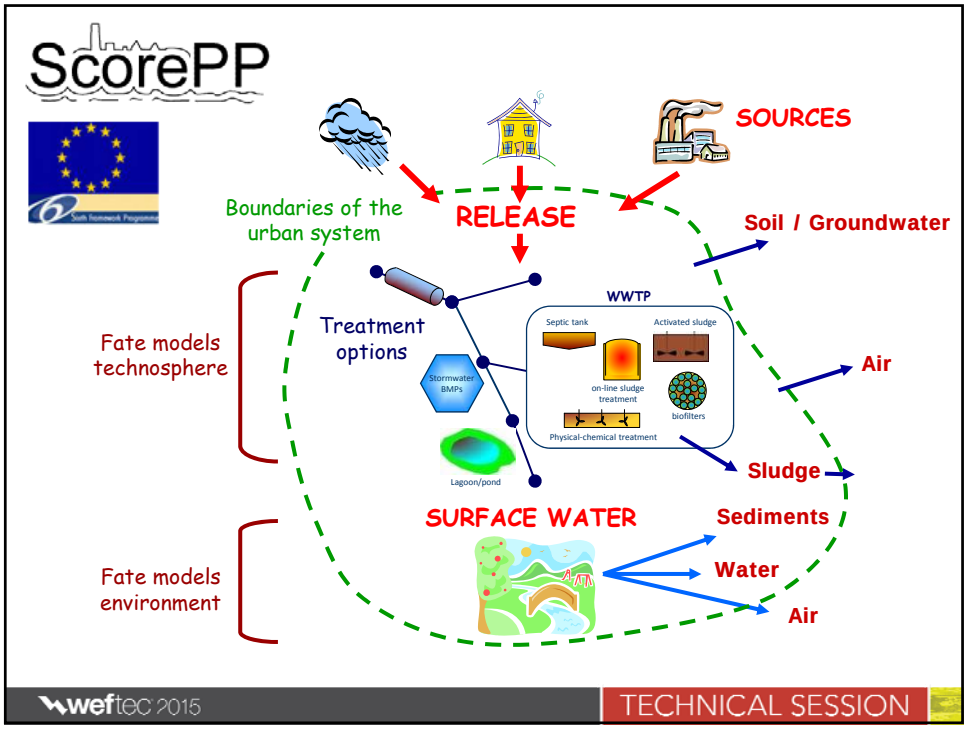
2025

- Micropollutant modeling

*Joanne Parrott






ScorePP
SOURCES
Boundaries of the urban system
RELEASE
Soil / Groundwater
Fate models technosphere
Treatment options
WWTP
Septic tank
Activated sludge
Stormwater BMPs
on-line sludge treatment
biofilters
Physical-chemical treatment
Lagoon/pond
Air
Sludge
SURFACE WATER
Sediments
Water
Air
Fate models environment
wefTEC 2015
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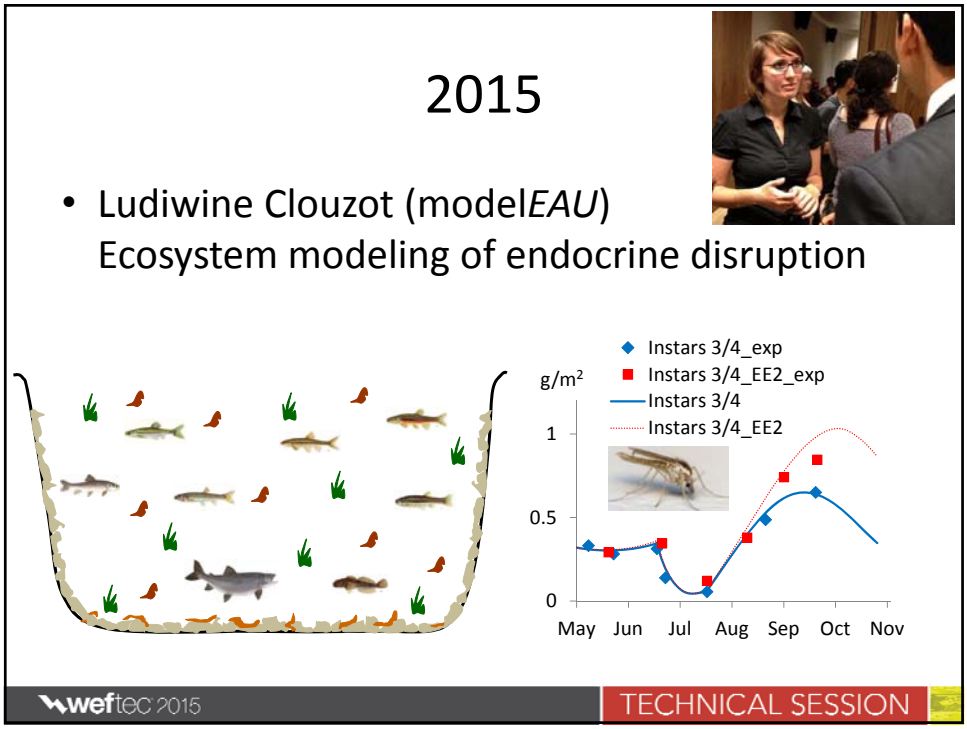
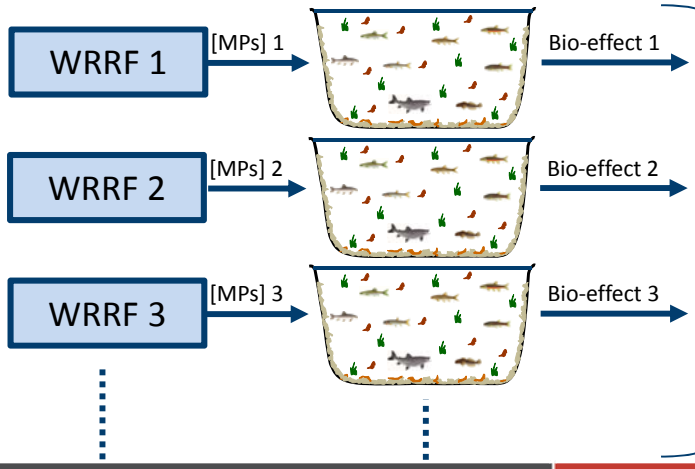

2015
• Ludiwine Clouzot (model*EAU*)
Ecosystem modeling of endocrine disruption
Instars 3/4_exp
Instars 3/4_EE2_exp
Instars 3/4
Instars 3/4_EE2
g/m²
1
0.5
0
May
Jun
Jul
Aug
Sep
Oct
Nov
wefTEC 2015
TECHNICAL SESSION

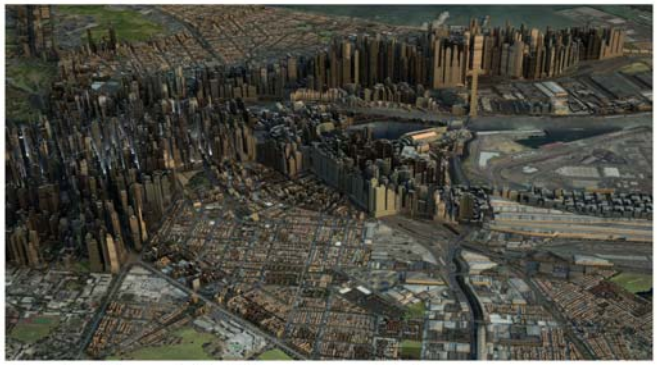
2025

Ecological benchmarking of WRRFs



2045

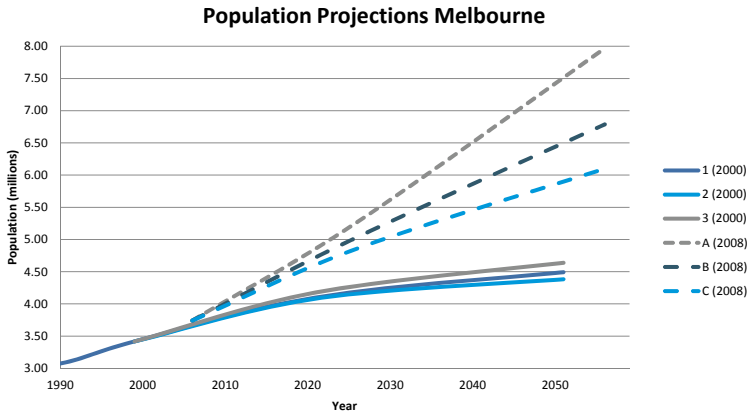
- Christian Urich (Monash Univ, AUS)
  Modeling the evolution of urban water systems



Monash Architecture Studio: Melbourne a future Manhattan

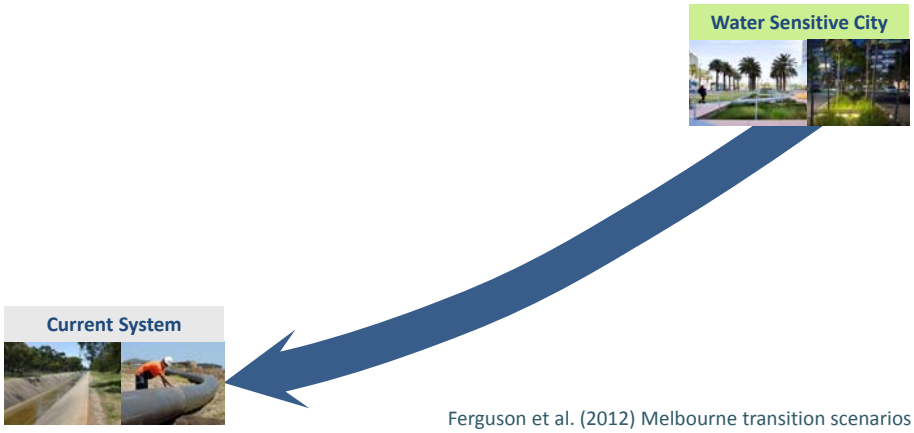
2045

- Decision-making under deep uncertainty



2045

- Backcasting from future vision



Ferguson et al. (2012) Melbourne transition scenarios

2045

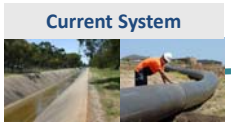
- Planning should

Use windows of opportunities

Respond to surprises

Avoid "lock-in" effects

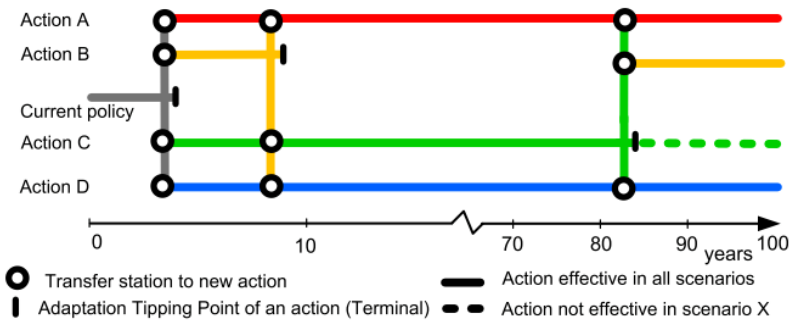
Address vulnerabilities



Ferguson et al. (2013) A strategic program for transitioning to a water sensitive city

2045

- Adaptation pathways (robust adaptation)
  No regret decisions (keep your options open)



2045

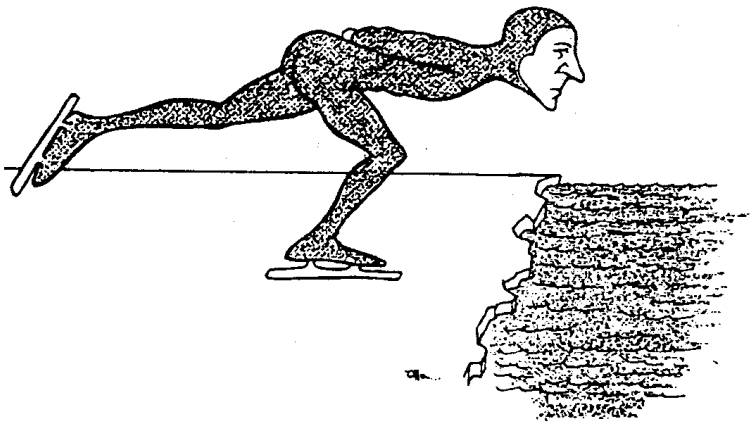
- Data collection is quite different
  - Explorative
  - **Collaborative**

The big jump forward

Integronsters – ugly constructions

adapted from Voinov and Shugart (2013)

Don’t extrapolate too far



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