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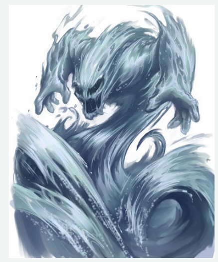
Wet-weather modelling

Why and how should we tame the beast?



L. Benedetti and P. A. Vanrolleghem

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Why?

- Discharge of untreated wet weather flows can negatively affect ecology and public health
  - Ecology: low DO and high ammonia
  - Public health: disinfection requirements
  - Other components are site specific
- Even after addressing inflow and infiltration issues, wet weather flows can still exceed plant's treatment capacity
- Well established dry weather flow management approaches are not applicable

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Why?

New WEF publication

- *Facility Wet Weather Design and Operation*

and in particular:

Chapter 9: Modeling for Wet Weather

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Topics

"Why do we have to tame the beast?"
Regulatory, design and operational aspects of WW; support provided by modelling in design and operation (Julian Sandino, Stefan Weijers)

"What is making the beast angry?"
Modelling WW influent aspects: flows, loads, and variability (Cristina Martin)

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Topics

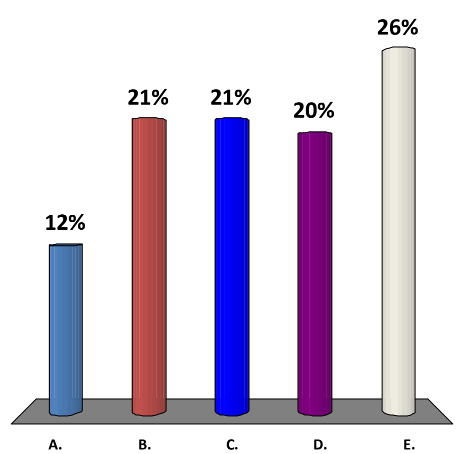
"What are the aspects of the beast's anger?"
Modelling WW impact on plant behaviour: mixing, settling, aeration, etc. (Peter Vanrolleghem)

"How do we tame the beast? The hard way"
Modelling design options for WW mitigation (Jose Jimenez)

"How do we tame the beast? The soft way"
Modelling control options for WW mitigation (Oliver Schraa)

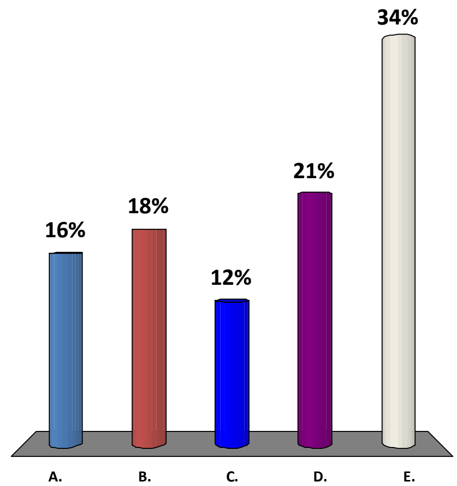
Which of the following topics in WW management can be **adequately handled by current modelling practice**?

A. infuence regulatory approach
B. improve generation of influent characteristics
C. simulate unit process performance
D. find optimal wet weather solutions (build+control)
E. integrate with sewer and receiving water models



Which has **highest priority**?

A. infuence regulatory approach
B. improve generation of influent characteristics
C. simulate unit process performance
D. find optimal wet weather solutions (build+control)
E. integrate with sewer and receiving water models



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Which has **highest cost**?

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B. improve generation of influent characteristics
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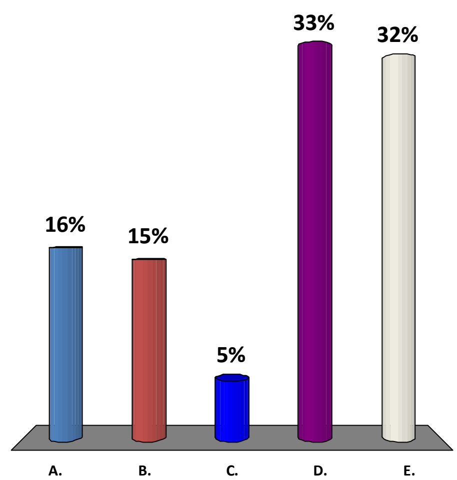
E. integrate with sewer and receiving water models



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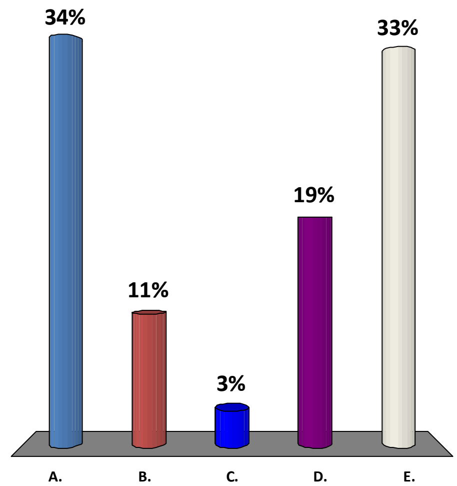
Which is the **most difficult**?

A. infuence regulatory approach
B. improve generation of influent characteristics
C. simulate unit process performance
D. find optimal wet weather solutions (build+control)
E. integrate with sewer and receiving water models



Extract/Summary of Presentations

- **Regulation**
- Influent
- Processes
- Design / Operation

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Regulation

- Wet weather conditions "temporally" affect
  - raw wastewater
  - receiving water body water quality
- How do you define appropriate protection for a changing receiving condition?
  Dynamic consenting approach

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Regulation

- Regulatory and public pressures are driving the need to address wet weather flows
- Regulatory approaches
  - in the US are "static" and do not recognize the "dynamic" nature of WW
  - in Europe there are some "dynamic" approaches (e.g. UPM3 in UK and Kallisto in NL) but not generally applied

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Extract/Summary of Presentations

- Regulation
- **Influent**
- Processes
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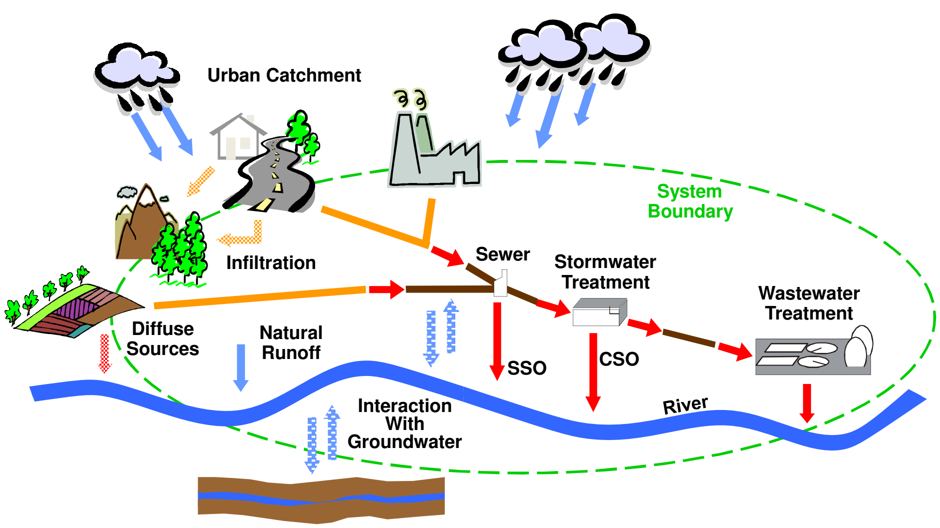
Influent



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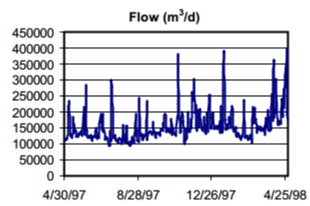
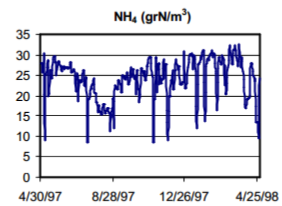
Influent

– Highly variable flows and loads
– Low predictability of the sewer behaviour
  • Difficult to model sewer transport (first-flush effect)
  • Difficult to predict the input to the WWTP





Influent

- Solutions for influent generation under wet weather conditions
  – Benchmark Influent profiles (Spanjers et al., 1998)
  – Generators based on databases (Devisscher et al., 2006)
  – Phenomenological model of BSM2 (Gernaey et al., 2011)

• The most comprehensive approach is the phenomenological model (Gernaey et al., 2011; Talebizadeh et al., 2014)

Influent

- How could we move forward the mechanistic description of the wastewater generation?
  - Including spatial stochastic generation of the **rain** events
  - Including more detailed description of the **household** wastewater generation
  - Including **soil** properties: specific moisture capacity, capillarity head, effective hydraulic conductivity, etc.
  - Including **uncertainty** description

Extract/Summary of Presentations

- Regulation
- Influent
- **Processes**
- Design / Operation

Wastewater fractionation

Wet weather induces changes in wastewater fractionation

- *Run-off*
  - *From roads, lawns, parking lots, roofs, …*
  - *Heavy metals, PHAs, oil, nutrients, pesticides, …*
- *Oxygen presence (> 1 mgO_2/L)!*
- *Dry weather plug flush-out (NH_3-peak)*
- *Resuspension of material accumulated in the sewer system (first flush)*

Unit Processes

Preliminary treatment

Primary treatment

Physical and chemical treatment

Residuals processing

Biological Treatment

Mixing

- *Flow affects mixing*
- *Number of tanks in series*
- *Computational Fluid Dynamics (CFD)*

Biological Treatment

Aeration

- *Composition affects aeration efficiency*

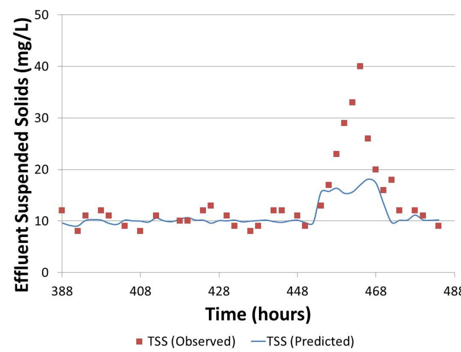
$$OTR = \alpha K_L a\left(\beta S_O^{sat} - S_O\right)$$

- *Effects on both α and β*

Biological Treatment

Secondary clarifier

- *Sludge inventory under wet weather*
- *Effluent TSS*



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Extract/Summary of Presentations

- Regulation
- Influent
- Processes
- **Design / Operation**

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Key Criteria for the Selection of WW Flow Strategy

- **Solids inventory** to be retained in the plant.
- **Biomass** to be maintained in a **healthy** state, without compromising treatment after the WW event.
- Any structure/process **overflow** to be **prevented**.
- Operating strategy to be adjusted in a **timely** manner.
- Implementation of WW operating strategy not to incur substantial additional treatment **costs**.

Strategies to deal with WW events

- Equalisation/storage
- Bypassing and use of storm tanks
- CEPT and enhanced secondary settling
- Ammonia control with swing zones to handle peak NHx load
- Step feed and control of recycles and other flows to handle peak TSS load
- Aeration tank settling (ATS)

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Discussion

Scope

- Within current regulation
(very wrong but we see end of tunnel)
- Within the fence
(also wrong, but we can go beyond)

What's done

- Influent fractionation changes in WWF
- CFD helps design and optimization
- Monitoring
- Solids inventory
- Chem dosage control (after full scale calibration)
- Tools exist to significantly improve use of existing infrastucture

What's almost done

- Secondary settling models (effluent TSS)
- Solids inventory
- Primary settling models (almost almost)
- Feasible CFD/ASM coupling
- Use of short-term flow forecast
- Integrated modelling (+sewer +river)

What's to be done

- Characterize uncertainty/variability
- Influent generators are being developed (WWF)
- Many unit processes do not have models (grit, disinfection...)
- Short HRT SRT biological treatment
- Aeration
- Mixing
- Temperature
- Micropollutants

Again: Which has **highest priority**?

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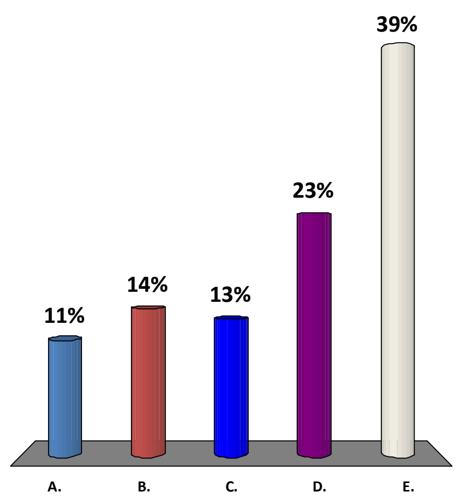

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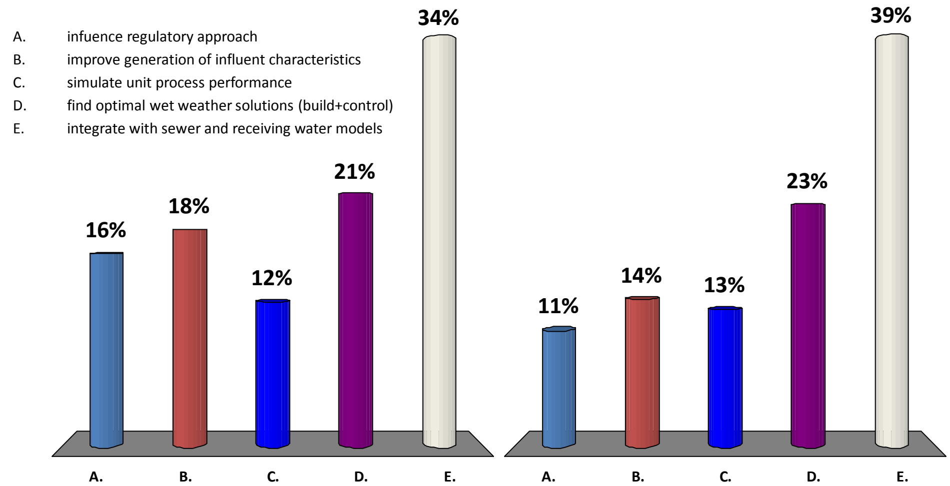
Before and After: Which has **highest priority**?



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