Advances in modelling particle transport in urban storm- and wastewater systems

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Abstract: Suspended solids in sewers not only carry organic and inorganic pollution but are also the preferred vector for heavy metals, hydrocarbons, many hydrophobic micropollutants and pathogens that are preferentially attached to them. Their behaviour in sewer systems has thus been object of many studies, but, unfortunately the predictive power of the available models remains limited due to the complexity of the processes that determine their transport, sampling and measurement. This contribution summarizes 10 years of research at Université Laval that took advantage of the ViCAs measurement set-up that allows for characterizing the wastewater particles' settling velocity distribution (PSVD) to come up with a conceptual modelling framework of storm and wastewater transport systems in which mass balances are made of particle classes, each with a characteristic settling velocity. The models have been calibrated and validated for stormwater basins, combined sewer retention tanks, primary clarifiers and complete combined sewer systems, from sewer catchment to stormwater basins outlets, sewer overflows and primary clarifier effluents. The ViCAs experimental set-up is simple to build and work with, and has intrinsic quality control indicators that allow evaluating the quality of the obtained PSVD's.

Keywords: Conceptual sewer model; particle settling velocity distribution, ViCAs,

1. INTRODUCTION

Urban stormwater composition changes a lot from the moment it hits the ground to its discharge into the receiving water, both in combined and separate sewer systems. Water pollution can be split in soluble and particulate components, the latter often being characterized by the concentration of total suspended solids (TSS). TSS is often correlated with turbidity, which can be measured online, providing then continuous information on this aspect of water quality, and allowing development of controllers that take advantage of it. This paper focuses on particulate pollution of stormwater which is a key parameter to evaluate the stormwater's impact on the environment. Indeed, particulate material not only leads to visual pollution, but also contains considerable organic matter, leading to oxygen depletion, and nutrients, causing eutrophication. Moreover it carries adsorbed pollution (pathogens, heavy metals, hydrophobic micropollutants, ...). Despite years of efforts (Ashley et al., 2004), understanding the processes affecting particulate pollution in the system, especially in sewers, and predicting its fate remains a considerable challenge. This paper summarizes some of the salient results of the research conducted over the last ten years at Université Laval.

In view of improving the receiving water quality, it is essential to consider the integrated urban wastewater systems (IUWS) as a whole. Indeed, interactions between the sewers, the treatment plant (WWTP) and the receiving water bodies can be significant. When dealing with such complex systems, mathematical models have been proven particularly useful. Models allow scenario elaboration to simulate management strategies and their impact, enabling the engineer to better understand the system, yielding better informed decision-making.

In this paper, particle settling velocity distribution (PSVD)-based models, using a relatively simple wastewater characterization method, the ViCAs method are presented. They allow better prediction of water quality in terms of TSS along the system. Anticipated benefits of water quality-based control in an integrated setting are briefly introduced.

2. PSVD CHARACTERIZATION AND MODELLING CONCEPT

2.1 Software and Modelling Approach

The ViCAs-TSS characterization protocol (“Vitesse de Chute en Assainissement”, French for “Settling velocity in wastewater management”, Chebbo and Gromaire, 2009) originally developed to characterize stormwater particulates was adopted in our work to characterize particulate matter throughout the urban wastewater system. A ViCAs lab experiment consists in filling a 60cm column with 4.5L homogeneous sample of storm- or wastewater, which is then subject to static settling. A series of cups is placed sequentially underneath the column to collect particles that settle from the column. At pre-determined instances (e.g. after 1, 3, 7, 15, 30, 60, 120 minutes), a cup is withdrawn and substituted by another one. The TSS collected in each cup is weighed and the cumulative mass of settled TSS is interpreted to yield the so-called particle settling velocity distribution (PSVD) of the water sample (Figure 1). This PSVD enables assigning settling velocities (Vs) to different mass fractions of particles.

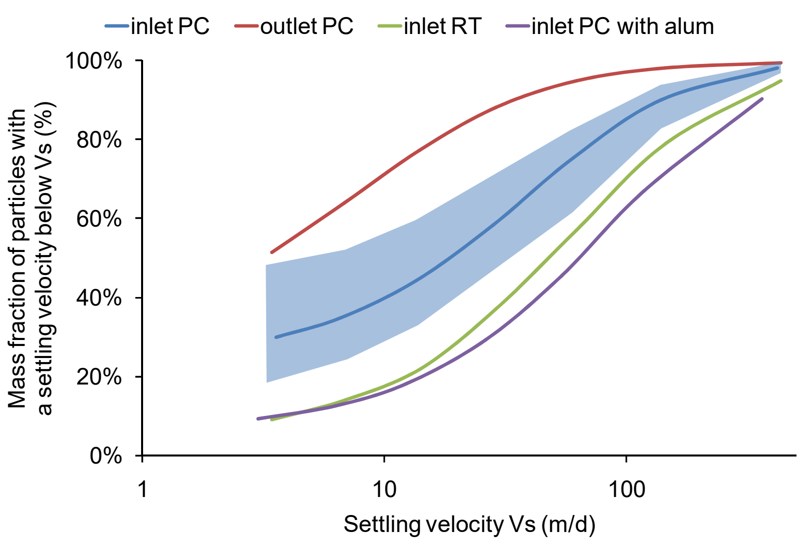

Figure 1. Examples of Particulate Settling Velocity Distributions (PSVD) along the IUWS and typical PSVD region observed at the inlet of the primary clarifier (PC). Alum addition 'lowers' the PSVD curve in a chemically enhanced PC (from blue to purple). Inlet RT (retention tank) curve characterizes combined wastewater during wet weather.

Over the last ten years, a large number of ViCAs experiments have been performed with samples collected at different locations within the urban storm and wastewater systems and this in different cities in Canada and Europe. Key information extracted from this extensive experimental work is that:

- the PSVD is not constant in space nor time. However, the PSVD of a sample taken under specific conditions (location, same operational conditions...) will be situated in typical regions (see, for instance, Figure 1 for the inlet primary clarifier region);
- within a specific region, the PSVD of a sample is quite well correlated with its TSS concentration (Bachis et al., 2015).

Settling is the most important process to consider when dealing with particulate pollution. Hence, the particle settling velocity is a key parameter to determine in view of modelling. Models that only consider a single, mean settling velocity to all particles do not allow embracing the heterogeneity of particulate pollution in storm- and wastewaters. The purpose of PSVD-based models is to improve the predictive capacity of models by fractionating TSS into a limited number of particle classes, each class defined by a mean settling velocity extracted from the relatively simple and inexpensive ViCAs experiments (Figure 2). The models of the different systems described below use dynamic mass balances of the different particle classes to predict the evolution of their concentrations.

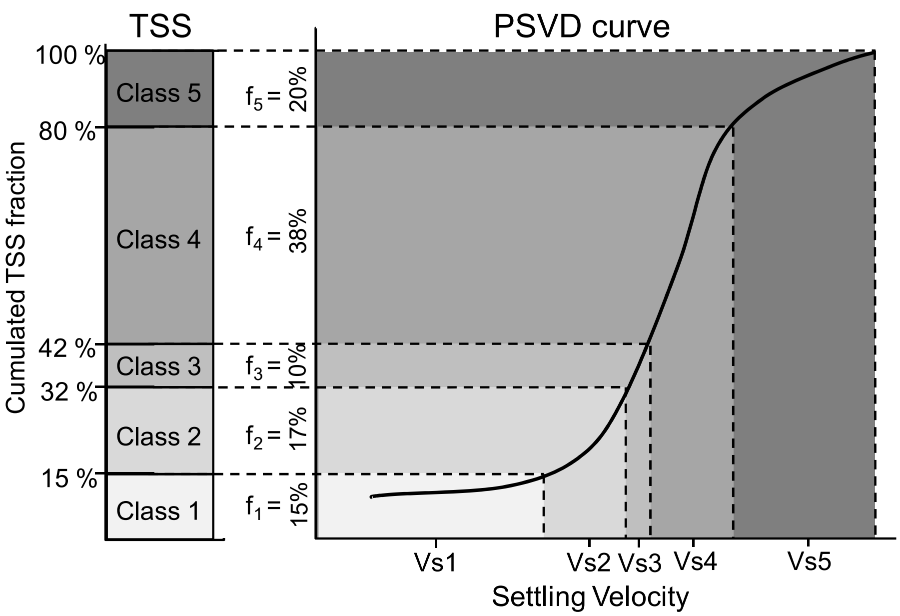

Figure 2. An example of TSS fractionation in five particle classes is presented (class delineation in dashed line). Each particle class, characterized by a mean settling velocity (Vs1 to Vs5) is associated with its TSS mass fraction (f_1 to f_5).

3. APPLICATIONS

3.1 Stormwater Basins

In separate sewer systems, rain water is often discharged to the receiving water without treatment, even though it is not exempt of pollution. At some places, stormwater basins have been built to attenuate the hydraulic impact of a sudden wet weather discharge to the receiving water, causing increased erosion and sometimes even flooding. Although these facilities have not been designed with treatment in mind, improvement in water quality due to settling in the basins was observed (Carpenter *et al.*, 2014). Hence, a better understanding of the phenomenon was deemed interesting to take advantage of. Vallet *et al.* (2014) developed a multi-layer stormwater tank model based on PSVD. The model has a varying volume and is able to reproduce settling and resuspension thanks to settling fluxes between the layers and a mixing model for resuspension. The model can reproduce both the particles' concentrations at the outlet of the tank and inside the tank. Indeed, the PSVD approach coupled with a discretization of the water column in layers enables to reproduce the TSS concentration gradient over the water column (Vallet *et al.*, 2014).

Gaborit *et al.* (2013) also demonstrated that a prediction of the TSS arriving at the stormwater tank inlet could be improved by taking over the PSVD approach for build-up and wash-off phenomena. They observed that consecutive rain peaks were not resulting in the same TSS concentration. By implementing various build-up and wash-off rates depending on particle classes (and thus particle settling velocity), they could reproduce TSS wash-off peaks of consecutive rain events.

3.2 Combined sewer retention tanks (RT)

When combined sewage is prevented from overflowing by storage in retention tanks (RT), it is not surprising that PSVD has proven a key property to take into account when trying to model the fate of TSS as the water resides in the RT. Very few studies have been carried out characterizing the settling process in RT. Métadier *et al.* (2013) and Maruéjouls *et al.* (2013) both highlighted the interest in observing particulate pollutant behaviour in RT in order to better understand and predict effective TSS removal in these tanks.

The calibration/validation work of the RT model of Maruéjouls *et al.* (2014) has proven the superiority of a model considering multiple settling velocity classes rather than a single average settling velocity. An important characteristic of the model is that it can accommodate for the fact that the PSVD of the TSS is not constant, but depends on a number of factors such as the time of the day − low TSS waters have a different PSVD than high TSS waters − dry or wet weather conditions, …. This highly enhanced the model adaptability to different case studies all the while keeping the calibration work limited since the PSVD model's parameter values are the direct result of ViCAs measurements. The model performance was compared with a former existing RT model from Lessard and Beck (1991) and found to be improved using the PSVD approach.

3.3 Primary clarifier and Chemically Enhanced Primary Treatment

The PSVD-based primary clarifier model of Bachis et al. (2015) is similar to the above RT model, with the exception that the volume of water in the tank is now constant. It was shown that the vertical gradient of the concentration of each of the particle classes in the settler can be simulated. To describe the vertical gradient, the settler is divided into a number of layers and a mass balance is calculated around each layer for each of the classes. Five particle classes with different (constant) settling velocities make up the core of the model (Bachis *et al.*, 2015). Again, ViCAs experiments allow simple calibration of the PSVD-based primary clarifier model.

Primary clarification is the first wastewater treatment process to suffer from the sudden changes in WWTP influent characteristics due to stormwater. To attenuate the negative impact of wet weather conditions, chemically enhanced primary treatment (CEPT) can be applied. Chemicals (usually alum as coagulant) is added to the primary clarifier influent, improving the TSS settling characteristics. By performing a ViCAs experiment on samples with and without alum addition, the impact of CEPT on the PSVD has been determined (Figure 1**Error!**

Reference source not found.). CEPT tends to "lower" the PSVD curve implying that the fraction of particles with higher settling velocity is increased at the expense of classes with lower settling velocity. CEPT can thus be modelled by making the TSS fractionation dependent on the chemical concentration. The layer structure of the model enables reproducing the hydraulic conditions in the clarifier, which is essential to describe the observed delay between chemical addition and its effect on the outlet TSS concentration. Properly dealing with this delay is essential for the development of a chemical dosing controller which aims at reducing chemical addition without jeopardizing settling performance (Tik and Vanrolleghem, 2017).

3.4 Integrated model and (water quality based) control possibilities

All models presented above have been developed using the modelling and simulation platform WEST® (mikebydhi.com), facilitating their combination in an integrated model. Based on data collected in the field, the system represented in Figure 3 has been modelled (Maruéjouls *et al.*, 2015). It includes three catchment areas, each equipped with an off-line RT. These three catchments are connected to a main interceptor bringing combined sewage to the WWTP. The plant is modelled by a grit chamber, a primary clarifier with possibility of CEPT and three bypasses. Data have been collected at multiple locations along this system and the model performance is remarkable given the complexity of the processes affecting TSS.

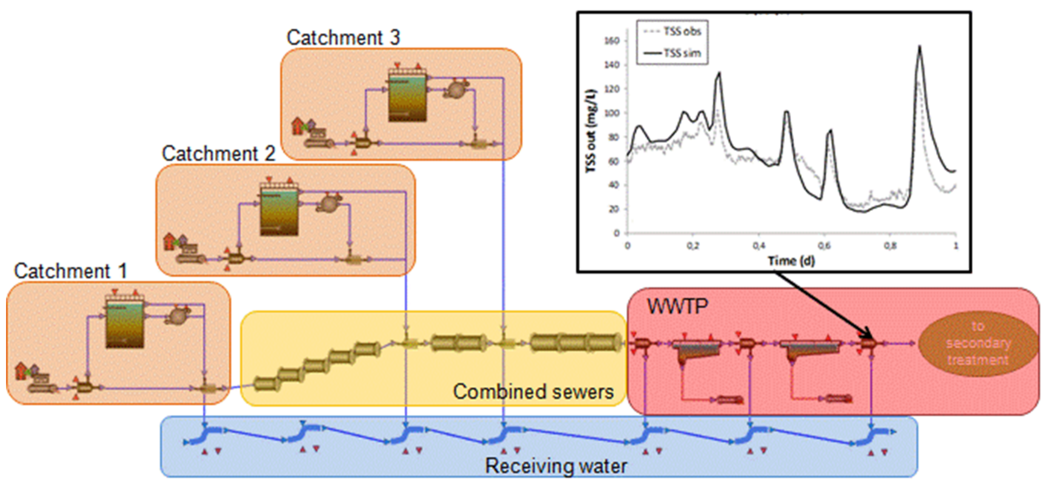

Figure 3. Integrated model configuration in WEST® (mikebydhi.com). Insert shows results of a validation of the primary clarifier PSVD-model (Bachis et al., 2015).

Using the integrated model, different control strategies have been evaluated (Tik *et al.*, 2016). Scenarios were designed around the following control actions that only use water height, flow rate and turbidity data:

- retention tanks emptying flow rate
- activation of CEPT and chemical dosing flow rate
- flow rate sent to secondary treatment

The impact of each scenario, in terms of water volume and TSS load discharged in the receiving water vs. time to empty the RTs, have then been calculated (Tik et al., 2014). The results showed a significant reduction in volume of untreated or partially-treated wastewater discharged into the receiving water, but more importantly from an environmental protection perspective, a percent-wise greater reduction of mass of suspended solids discharged.

However, this indisputable benefit for the environment comes at the expense of an increase in RT emptying times. Weather predictions should therefore be used to prevent such slower emptying in case the retention capacity is needed for an upcoming rain event.

4. CONCLUSIONS

This paper presented PSVD-based models of the major subsystems involved in stormwater and wastewater transport and treatment. The PSVD approach allows significantly better prediction of water quality, in terms of TSS concentration, compared to the standard approach of assigning a mean settling velocity to all particles. By combining these models in an integrated model, the potential of improving system management has been evaluated. Results of relatively simple control strategies show that there is room for considerable reduction of environmental impact of discharged particles. Further real-time control ideas are currently examined.

5. Acknowledgements

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Advances in modelling particle transport in urban storm and wastewater systems

Peter A. Vanrolleghem

UNIVERSITÉ LAVAL

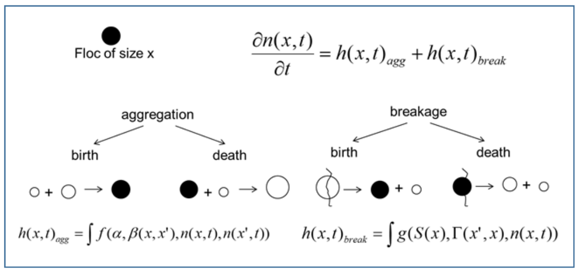
modelEAU

12,5 years ago …

- I left behind 12.5 years of research at BIOMATH - Ghent University …

12.5 years ago …

- But I took with me the experience and interest in particle sedimentation
- Primary and secondary settling in WWTP
  - Settlometer (batch settling for activated sludge)
  - Population Balance Models



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12.5 years ago …

- Scanning the horizon …

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Last year …

- Horizon scanning …

A 2017 Horizon Scan of Ubiquitous Sensing and Its Impact on Urban Drainage Management

Frank Blumensaat, João P. Leitão, Christoph Ort, Jörg Rieckermann, Andreas Scheidegger, Peter A. Vanrolleghem and Kris Villez

Important, Unfamiliar

Last year …

- Horizon scanning …

12.5 years ago …

- Scanning the horizon …

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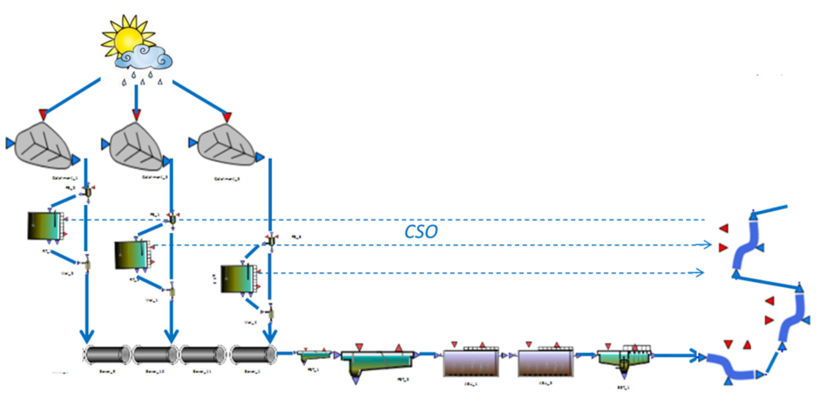
12.5 years ago …

- Embarked on a journey, monitoring and modelling particles from cloud and tap to river and lake …



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Advances in modelling particle transport in urban storm and wastewater systems

Peter A. Vanrolleghem and Paul Lessard
Bertrand Vallet, Émilie Berrouard, Jason Faber Carpenter, Etienne Gaborit, Dirk Muschalla,
Thibaud Maruéjouls, Bastien Wipliez, Sovanna Tik, Julia Ledergerber, Asma Hafhouf, Kamilia Haboub,
Giulia Bacchis, Imen Bel Hadj, Jessy Carpentier, Queralt Plana

Université Laval — modelEAU

My initiation to issues of TSS in integrated urban wastewater systems

"Fonctionnement du traitement des eaux usées en cas de fortes variations de débit"
Journée d'étude CB-IAWQ, Liège, 31.05.95

Variabilité des charges solides en suspension à l'exutoire des réseaux de collecte

Michel Verbanck

Université Libre de Bruxelles, Laboratoire de Traitement des Eaux et Pollution

 11 UDM2018

My initiation to issues of TSS in integrated urban wastewater systems

Wastewater treatment operations under high flow variations
Symposium Belgian Branche of IAWQ, May 31 1995

Variability of TSS loads at the outlet of the collection system

Michel Verbanck

Université Libre de Bruxelles, Laboratoire de Traitement des Eaux et Pollution

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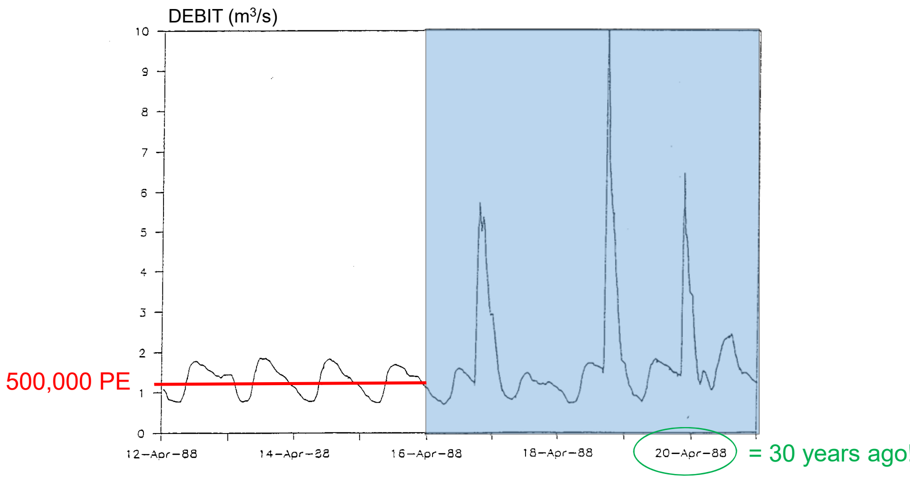
Brussels – Dry and Wet weather flows



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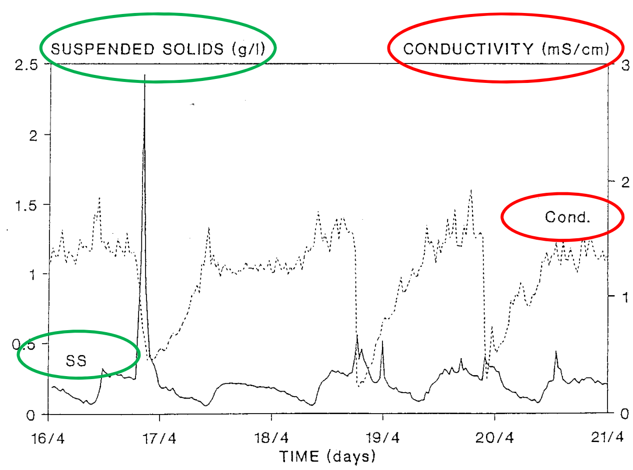
Brussels – Dissolved and particulate pollution



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TSS in the integrated urban wastewater system

- Vehicle transporting at least 50% of:
  - Organic matter
  - Nitrogen & Phosphorus
  - Pathogens
  - Heavy metals
  - Hydrophobic micropollutants (PAH, pesticides, …)

  - Inorganics (sand) abrasive to downstream equipment

Important

Damage caused by TSS

*Hydro International (2013)

Damage caused by TSS

*Hydro International (2013)

TSS in the integrated urban wastewater system

- Challenging for:
  - Sampling → homogeneity / representativeness difficult to guarantee
  - Modelling → many processes affect TSS in pipes, clarifiers, channels
    - *Horizontal transport: advection & rolling (bed load)*
    - *Vertical transport: settling & resuspension*
    - *Transformation: breakage, aggregation (coag./flocc.), degradation*
  - Characterization: Composition, size, density, settling velocity

Unfamiliar

TSS in the integrated urban wastewater system

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    - *Vertical transport: sedimentation & resuspension*
    - *Transformation: breakage, aggregation (coag./flocc.), degradation*
  - Characterization: Composition, size, density, SETTLING VELOCITY

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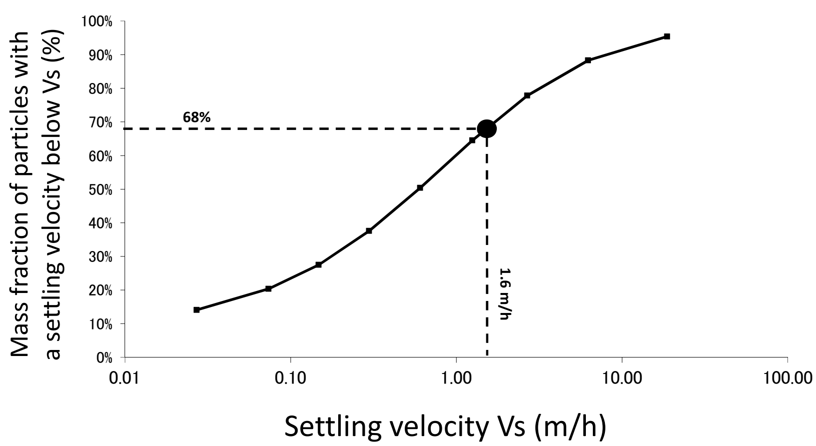
PSVD – Particle Settling Velocity Distribution



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PSVD – Particle Settling Velocity Distribution

- **ViCAs experimental set-up**
  (Vitesses de Chute en Assainissement)
  Settling velocities in urban drainage
- Simple and fast PSVD measurement

Gromaire and Chebbo, 2009
Journal of Environmental Engineering

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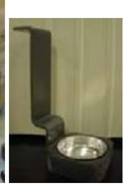
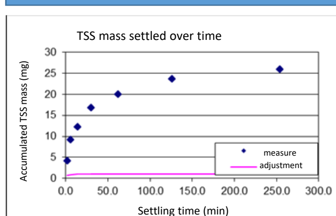
PSVD – Particle Settling Velocity Distribution

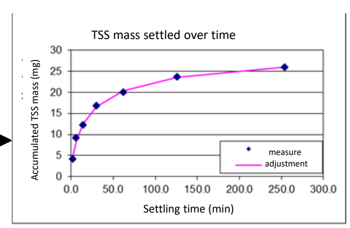
Inherent data quality check → Mass balance check ($t_0 - t_{fin}$)





Measurement of TSS collected in cups under the hanging column of wastewater sample

Numerical treatment



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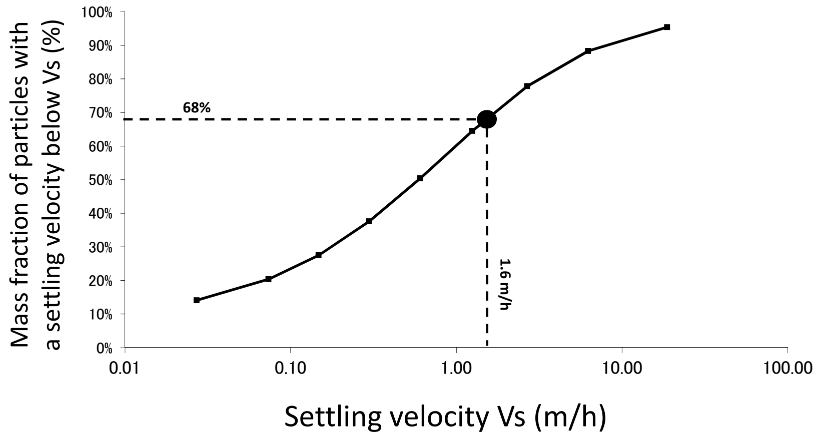
PSVD – Particle Settling Velocity Distribution



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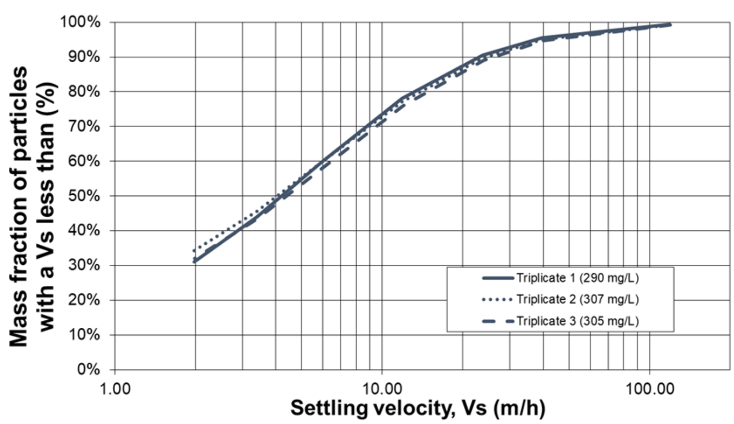
ViCAs equipment

- Reproducibility (triplicate test) :



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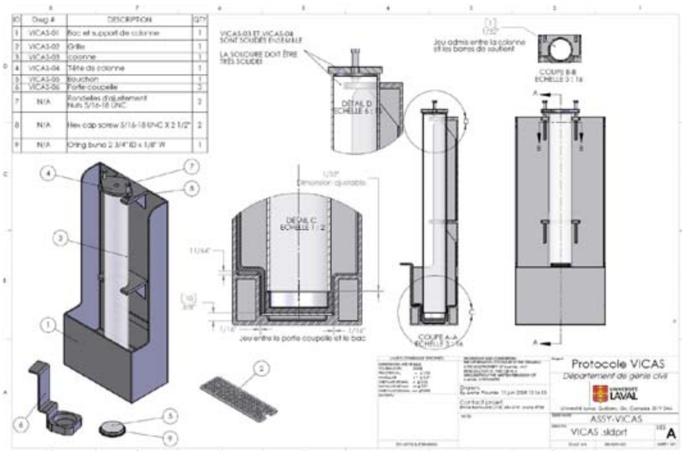
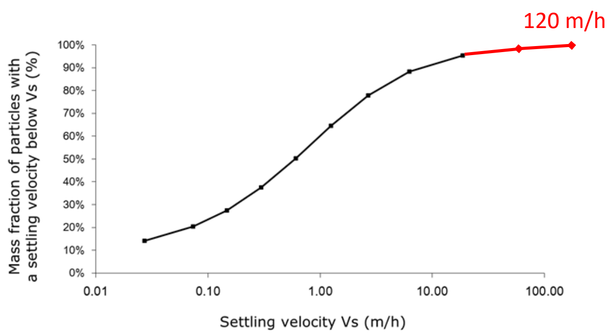
ViCAs equipment

- 1000$, any PVC shop can do it, detailed plans available !



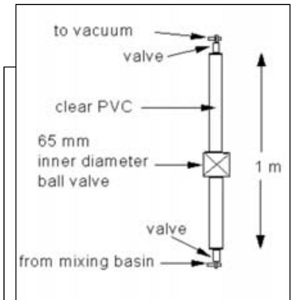
ViCAs equipment

- Extended version for higher settling velocity range needed for grit chamber work (> 40 m/h)

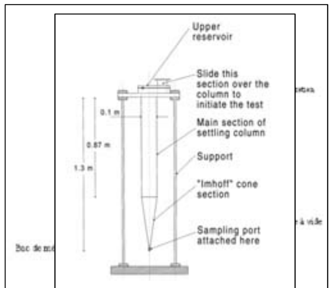


ViCAs alternatives

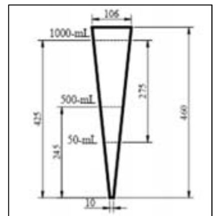
- Berrouard (2010) literature review



VICTOR column (EPA, 1999)



UFT-type column (Wong & Piedrahita, 2000)



Imhoff Cone (Lin, 2003)

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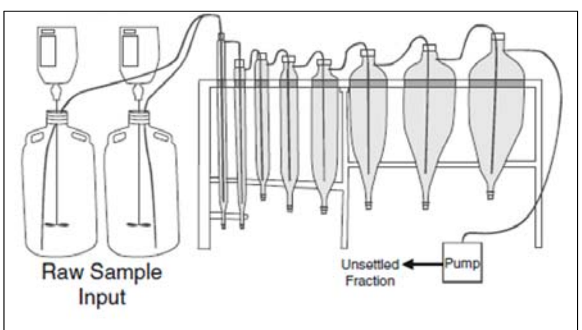
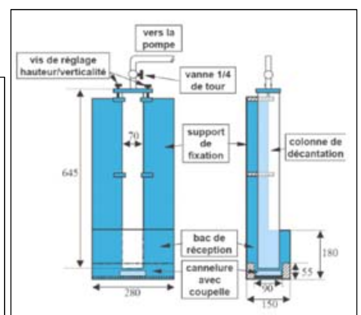
ViCAs alternatives

- Berrouard (2010) literature review



Elutriation set-up (Marsalek et al., 2006)



ViCAs column (Chebbo et al., 2003a)

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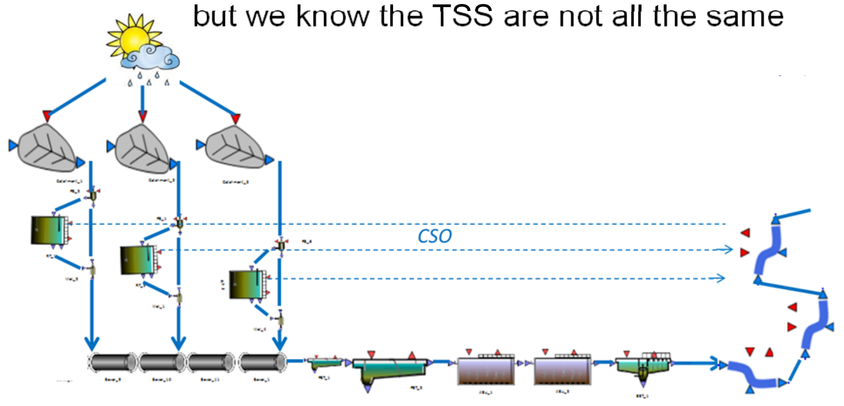
Now, what about the modelling?

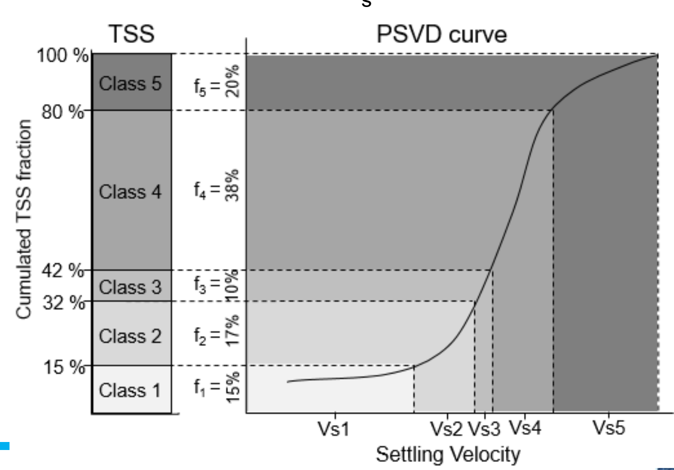
- The system under study …

and TSS(t,z) is the main variable of interest
but we know the TSS are not all the same

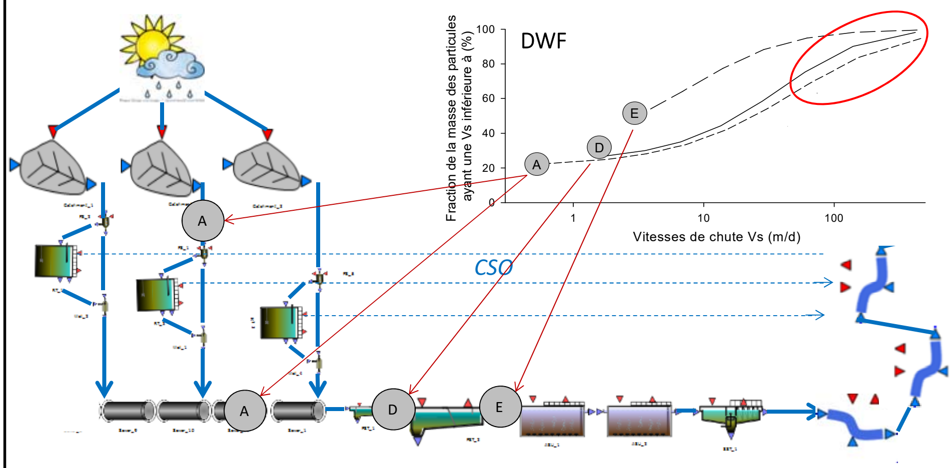


PSVD – Particle Settling Velocity Distribution

- To make a useful model → Split the continuous distribution into classes with characteristic V_s → Mass balances for TSS_i



PSVD dynamics in dry weather (DWF)



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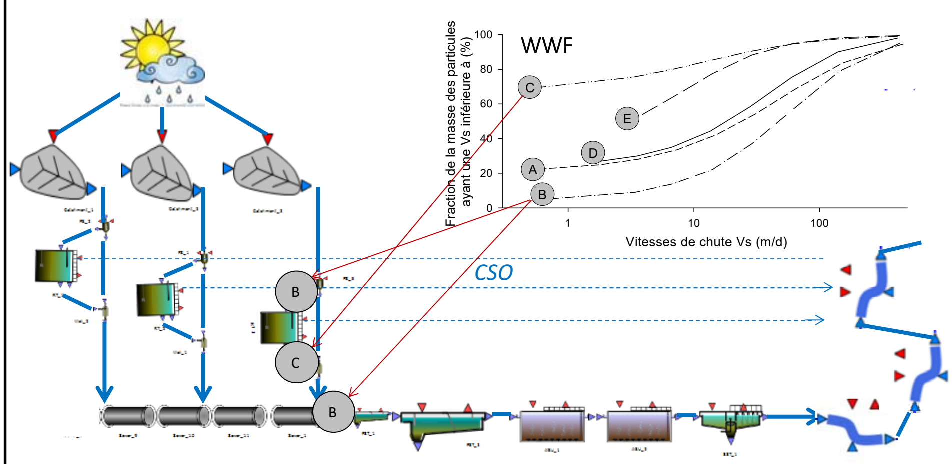
PSVD dynamics in wet weather (WWF)



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PSVD-model in storm water basins

Journal of Environmental Engineering and Science
Volume 11 Issue JS4

A storm water basin model using settling velocity distribution
Vallet, Lessard and Vanrolleghem

Journal of Environmental Engineering and Science, 2016, 11(4), 84–95
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Paper 15.00017
Received 02/10/2015; accepted 28/09/2016
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Keywords: hydrology & water resource/mathematical modelling/municipal & public service engineering

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A storm water basin model using settling velocity distribution

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Quantifying processes that affect the fate of particles in storm water basins is a complex but necessary step to predict the effect of various pollutants on receiving waters. A dynamic model for storm water basins taking advantage of the experimental fractionation of particles in different settling velocity classes has been developed to describe the water

PSVD-model in storm water basins

- Residential area (900 inh.)
- ~15 ha
- Imperviousness ~30 %

PSVD-model in storm water basins

- 3300 m^3
- Max. water level 1.4 m
- Max. outflow ~350 l/s

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PSVD-model in storm water basins

- 14 sampling series
  - 8 with open outlet (one rain event)
  - 6 with closed outlet (multiple rain events combined)

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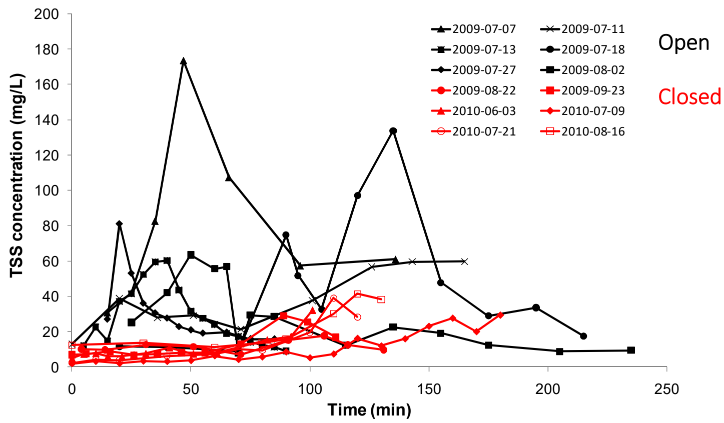
Outlet Concentrations – Open and Closed Outlets



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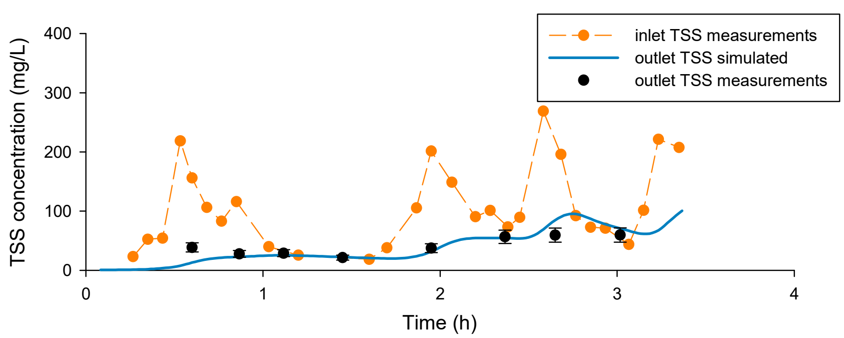
PSVD-model Calibration – Open Outlet



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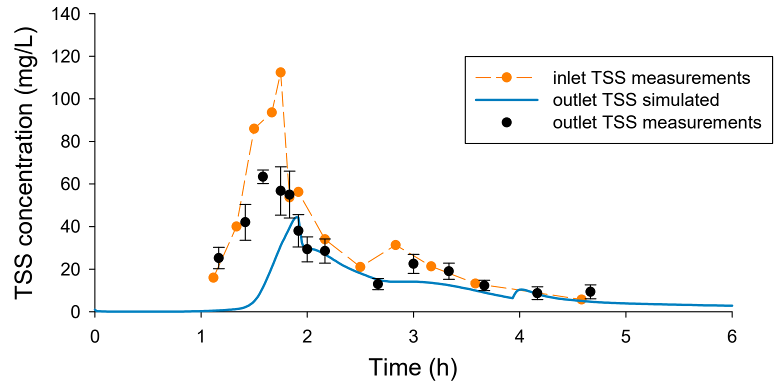
PSVD-model Validation – Open Outlet



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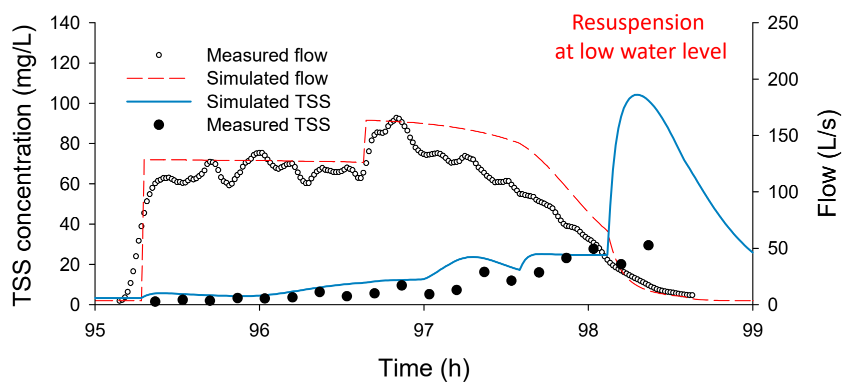
PSVD-model Calibration – Closed Outlet – Emptying



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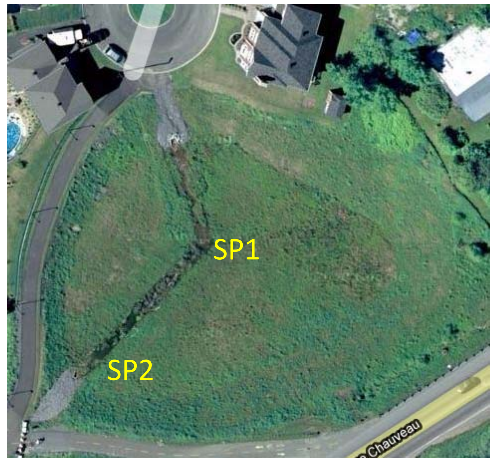
PSVD-model Calibration – Closed Outlet – In The Basin



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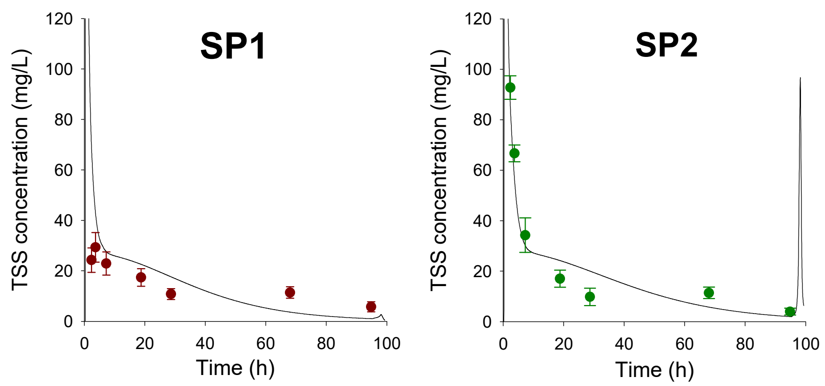
PSVD-model Calibration – Closed Outlet – In The Basin



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PSVD-model in Combined Sewer Retention Tanks

Urban Water Journal, 2013
http://dx.doi.org/10.1080/1573062X.2013.847462

Taylor & Francis

RESEARCH ARTICLE

Calibration and validation of a dynamic model for water quality in combined sewer retention tanks

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(*Received 26 November 2012; accepted 12 September 2013*)

As the integrated management of urban wastewater systems becomes more and more popular, the development of wastewater management subsystem models appears essential to improve the understanding of the pollutant dynamics and their interactions. In such a context, a review of the literature reveals a lack of efficient models describing the dynamics of the water quality stored in off-line retention tanks. A model has thus been proposed based on the fractionation of suspended solids into three classes according to the particle settling velocity distribution measured in the field using the ViCAs settling test. In this paper, a calibration methodology is developed and full-scale field data sets from three different events are used for 1) calibrating this new dynamic retention tank model (two data sets); and 2) validating that model on the last data set. The results show a good agreement between observed and simulated data both for the total suspended solids and the total chemical oxygen demand.

Keywords: combined sewer overflow; settling velocity; stormwater management; urban wastewater modelling; water quality; wet weather

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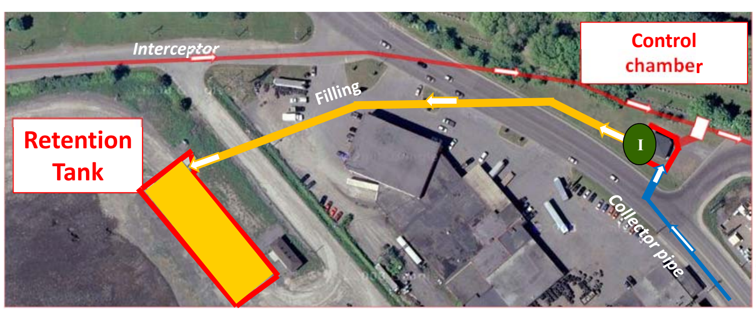
Wet weather (**Filling**) | Dry weather



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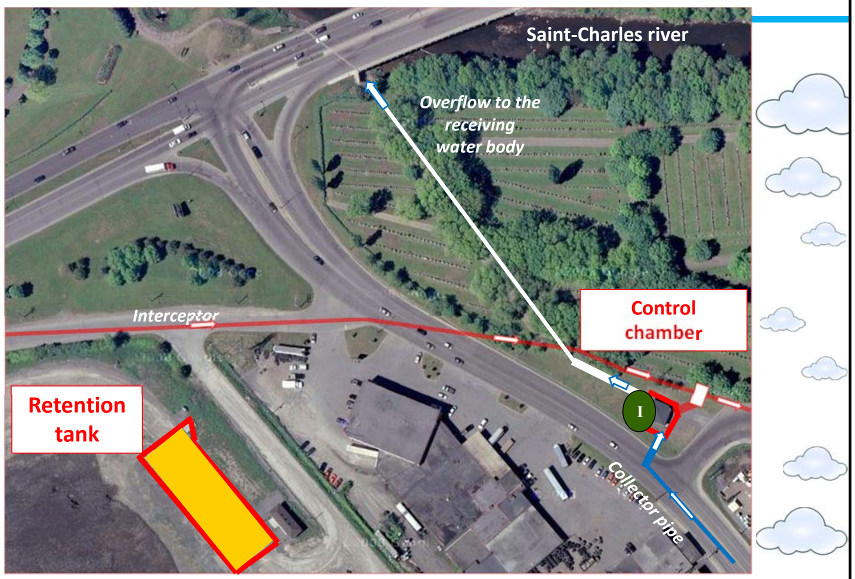
Wet weather (**Overflow**)



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Wet weather (**Emptying**)

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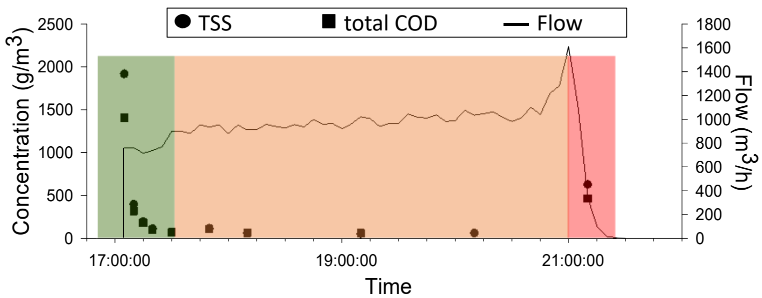
Water Quality Evolution during RT-emptying

- Typical pollutograph during emptying



3 phases

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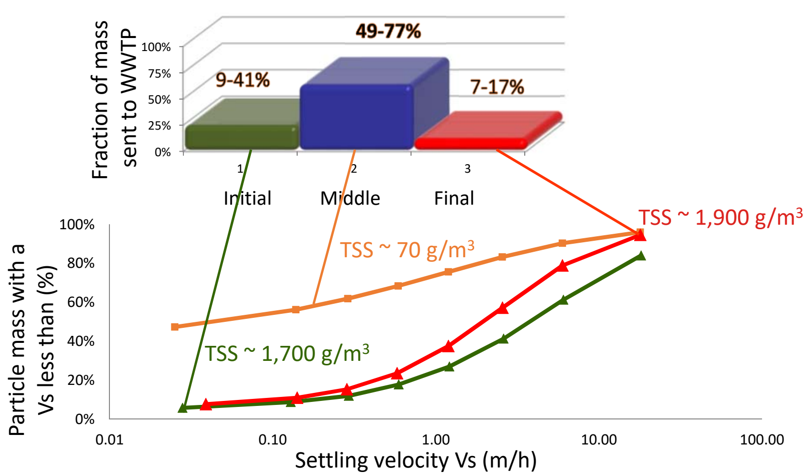
TSS Flux and PSVD during RT-emptying



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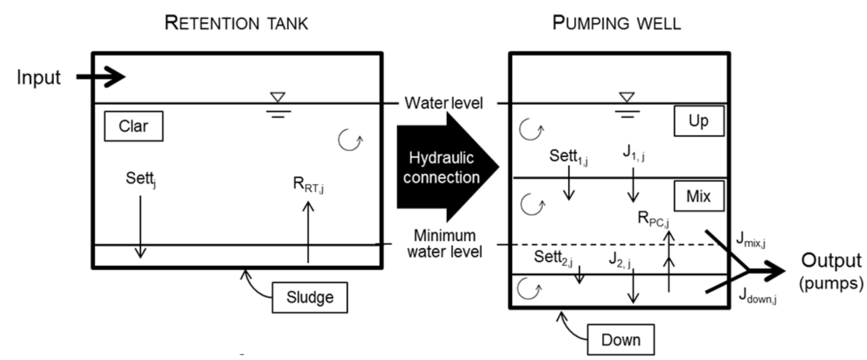
PSVD-model in Combined Sewer Retention Tanks

- Two main subsystems to be considered to predict TSS evolution:



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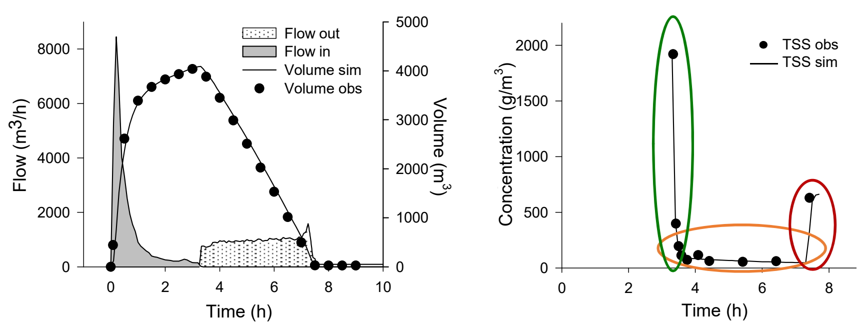
PSVD-model in Combined Sewer Retention Tanks

- Model performance



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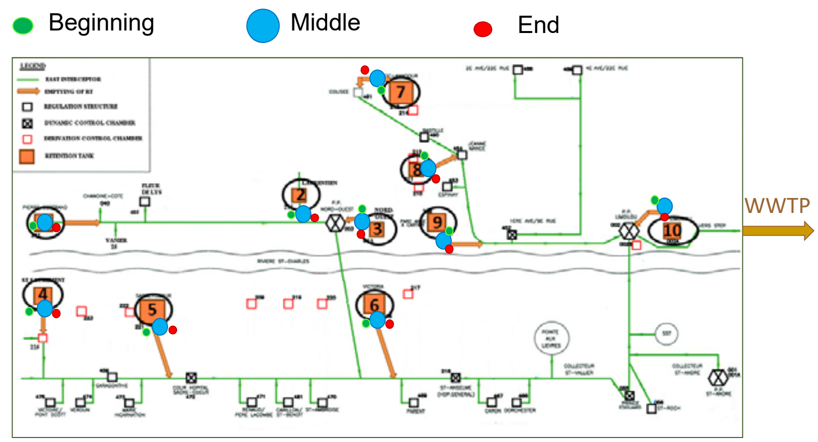
Using PSVD-model for Scheduling of RT Emptying



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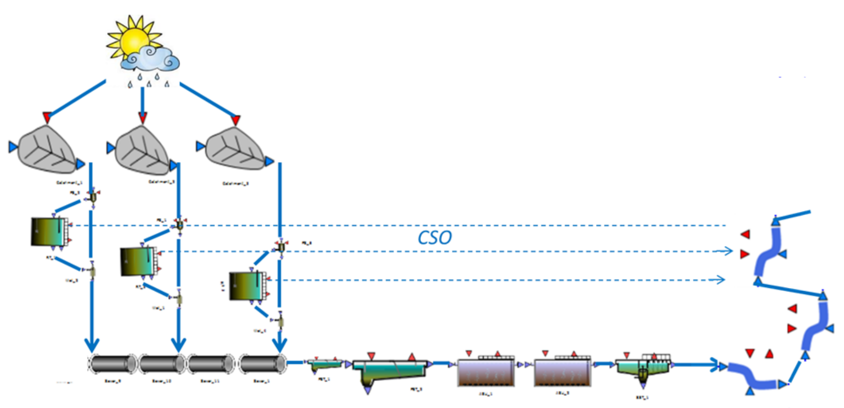
Now, what about integrated modelling?

- Bringing all the pieces together, including primary clarifier and grit chamber PSVD-models



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PSVD-model in integrated urban WW application

- Québec City (Canada) → East plant → 300,000 PE
- Bordeaux (France) → Clos-de-Hilde → 400,000 PE

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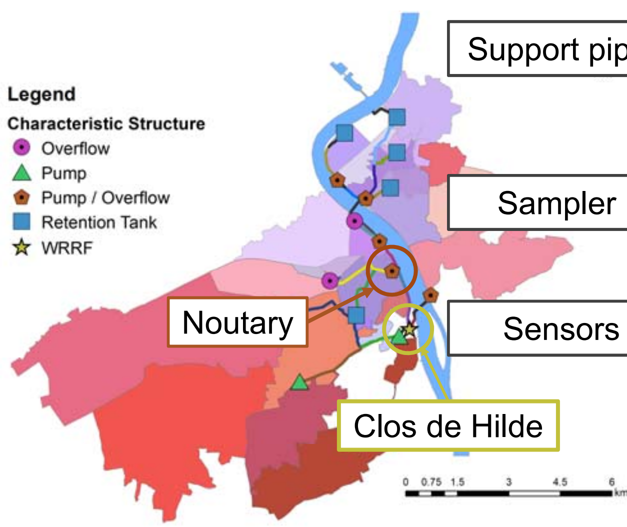
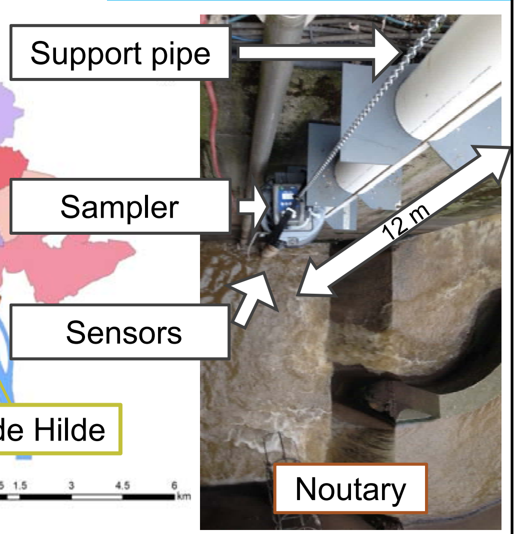
PSVD-model application in Bordeaux - Validation





Ledergerber, Maruéjouls & Vanrolleghem (2018)

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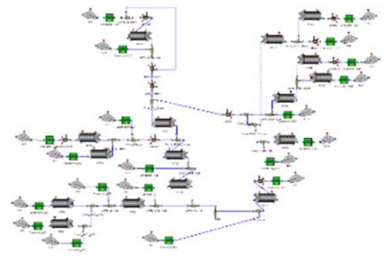
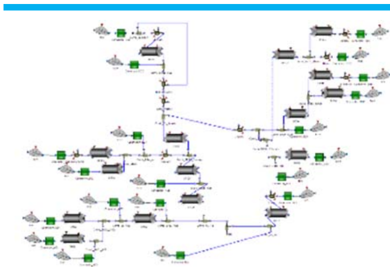
PSVD-model application in Bordeaux - Validation



- Catchment model:
  - KOSIM-WEST model
  - Accumulation/Wash-off
- Sewer model:
  - PSVD-based
  - Linear reservoirs in series
  - Settling and resuspension for ten particle classes

Ledergerber, Maruéjouls & Vanrolleghem (2018) 55

PSVD-model application in Bordeaux - Calibration

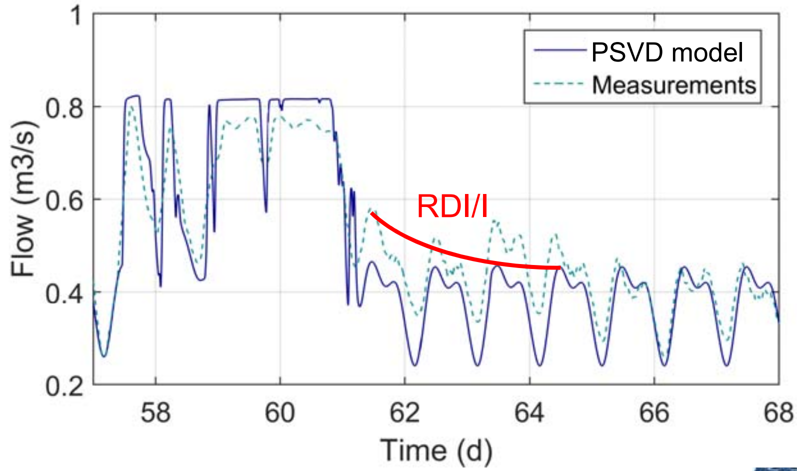


- Quantity
  - Initial calibration on existing Mike Urban by DHI model
  - Validation on flow data
    - Recalibration of DWF
    - Adjustments of characteristics at certain structures
- Quality (TSS at two locations)
  - 10 days of 2017 preliminary measurement campaign
  - ViCAs data
  - Continuous validated TSS data

Ledergerber, Maruéjouls & Vanrolleghem (2018) 56

PSVD-model application in Bordeaux - Validation

- Water quantity (rain → influent flow)



Ledergerber, Maruéjouls & Vanrolleghem (2018)

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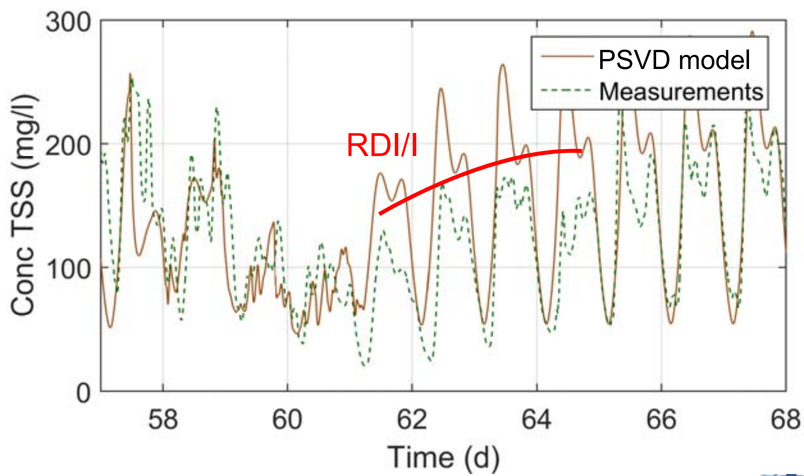
PSVD-model application in Bordeaux - Validation

- Water quality (rain → influent flow)



Ledergerber, Maruéjouls & Vanrolleghem (2018)

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PSVD in Sewer Catchments

Urban Water Journal, 2013
Vol. 10, No. 4, 230–246, http://dx.doi.org/10.1080/1573062X.2012.726229

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RESEARCH ARTICLE

Improving the performance of stormwater detention basins by real-time control using rainfall forecasts

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[a]*Département de génie civil et de génie des eaux, Université Laval, 1065 Avenue de la Médecine, Québec, Canada;* [b]*Institute of Urban Water Management and Landscape Water Engineering, Graz University of Technology, Stremayrgasse, Graz, Austria;* [c]*Aquafin NV, Dijkstraat 8, B-2630, Aartselaar, Belgium*

(*Received 22 April 2012; final version received 28 August 2012*)

Dry detention ponds are commonly implemented to mitigate the impacts of urban runoff on receiving water bodies. They currently rely on static control through a fixed limitation of their maximum outflow rate. Real-Time Control (RTC) allows optimizing their performance by manipulation of an outlet valve. This study developed several enhanced RTC scenarios of a dry detention pond located at the outlet of a small urban catchment near Québec City, Canada. The catchment's runoff quantity and TSS concentration were simulated by a SWMM5 model with an improved wash-off formulation. The control procedures rely on rainfall detection, on measures of the pond's water height, and in some of the RTC scenarios on rainfall forecasts. The implemented RTC strategies allow a substantial improvement of the pond's performance - the TSS removal efficiency increases from 46% (current state) to about 90% - while remaining safe and taking a mosquito-breeding risk constraint into account.

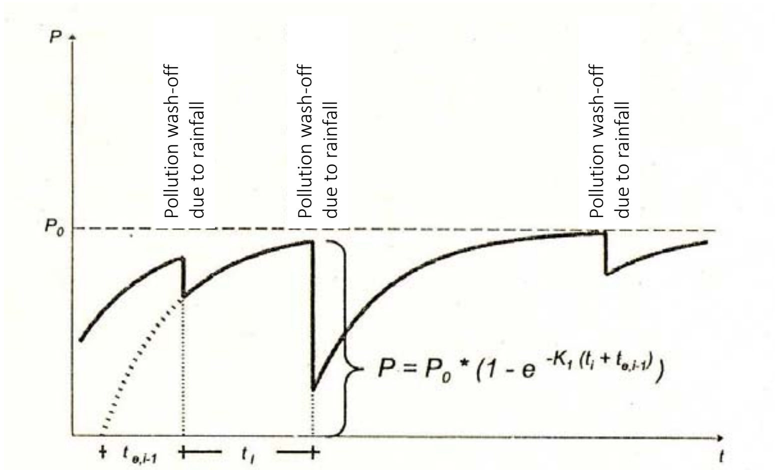
Keywords: dry detention pond; hydraulic stress control; rainfall forecasts; RTC; TSS removal; urban runoff mitigation.

PSVD – Specials (1)

• TSS accumulation/wash-off from sewer catchment

PSVD – Specials (1)

- TSS accumulation/wash-off from sewer catchment



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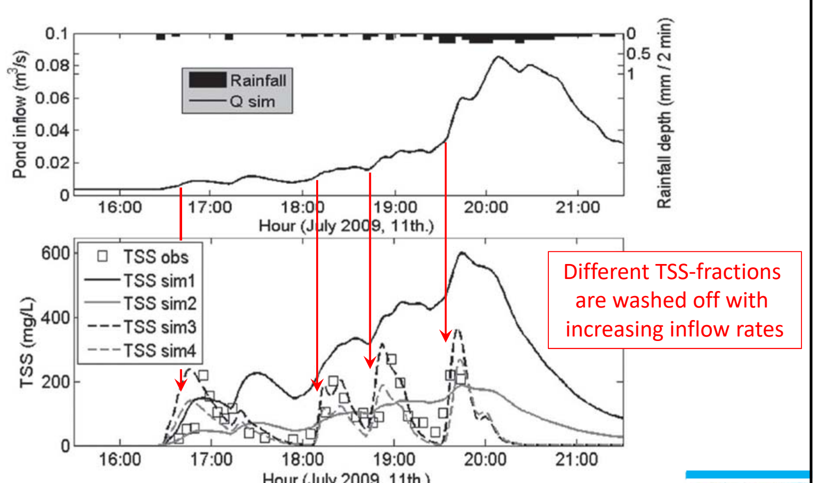
PSVD – Specials (1)

- TSS accumulation/wash-off from sewer catchment



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PSVD-model in Primary Settling Tanks

1185 © IWA Publishing 2017 Water Science & Technology | 75.5 | 2017

Chemically enhancing primary clarifiers: model-based development of a dosing controller and full-scale implementation

Sovanna Tik and Peter A. Vanrolleghem

ABSTRACT

Chemically enhanced primary treatment (CEPT) can be used to mitigate the adverse effect of wet weather flow on wastewater treatment processes. In particular, it can reduce the particulate pollution load to subsequent secondary unit processes, such as biofiltration, which may suffer from clogging by an overload of particulate matter. In this paper, a simple primary clarifier model able to take into account the effect of the addition of chemicals on particle settling is presented. Control strategies that optimize the treatment process by chemical addition were designed and tested by running simulations with this CEPT model. The most adequate control strategy in terms of treatment

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PSVD – Specials (2)

- Chemically enhanced primary treatment (CEPT)

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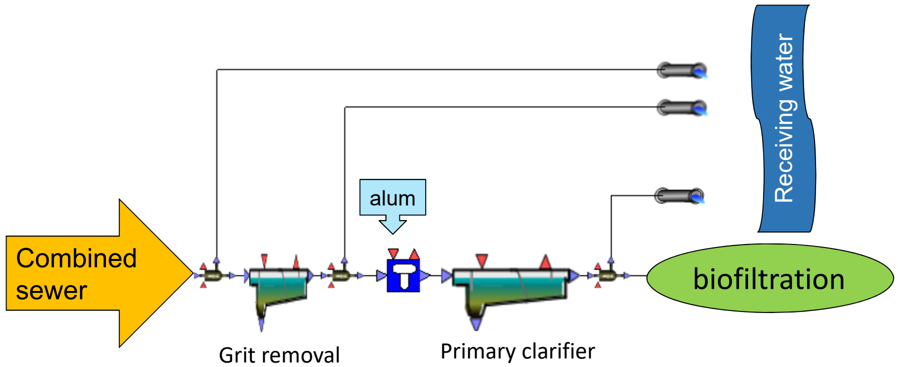
PSVD – Specials (2)

- Chemically enhanced primary treatment (CEPT)



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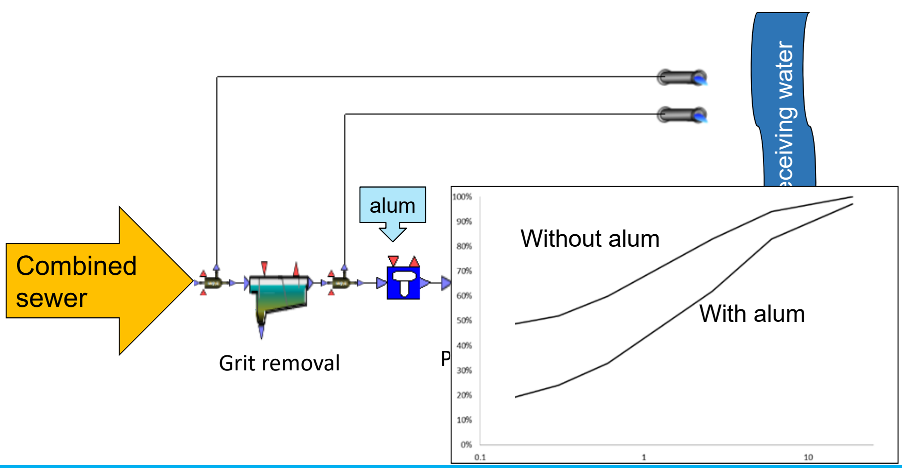
PSVD – Specials (2)

- Chemically enhanced primary treatment (CEPT)



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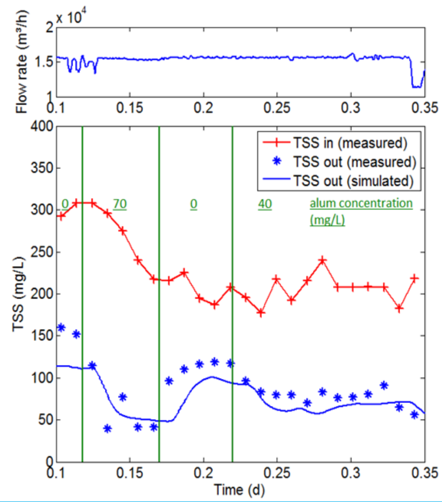
PSVD – Specials (2)

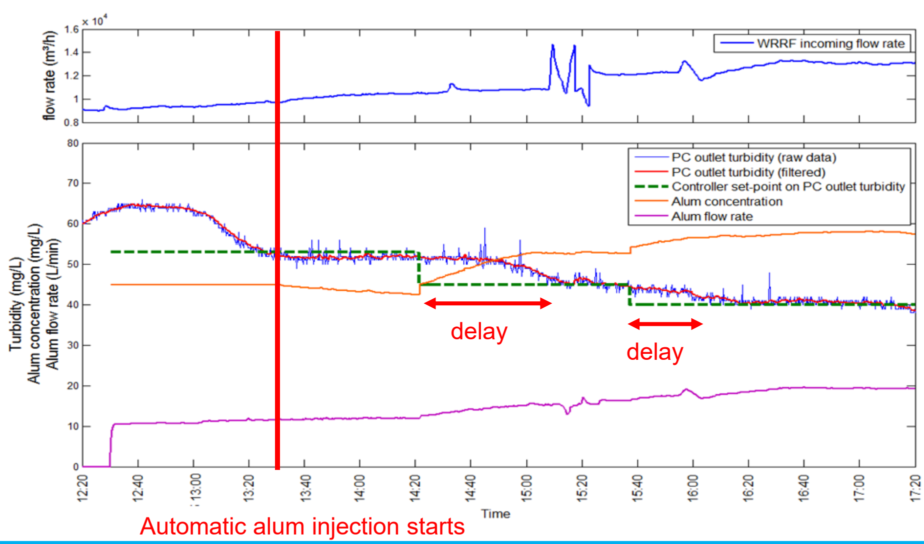
- Chemically enhanced primary treatment (CEPT)

  Model validation on experiment with different levels of chemical addition



PSVD – Specials (2)

- Process control performance:



CONCLUSIONS - Monitoring

- **ViCAs experimental set-up**
  (Vitesses de Chute en Assainissement)
  Settling velocities in urban drainage

- Simple and fast PSVD measurement for all types of particles in sewage
- Cheap to build yourself
- Easy to learn
- Built-in quality control

- Alternatives do exist (e.g. Elutriation)

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CONCLUSIONS - Modelling

- PSVD-based models
  - are powerful, yet simple models
  - capture settling phenomena well
  - allow describing different behaviours of different TSS-classes
  - can predict the PSVD at different locations in the system (catchment, storm tanks, pipes, RTs, grit chamb., primary clar.)
  - can be implemented in hydrodynamic models (e.g. in SWMM by Muschalla & Maruéjouls → SWMM6 2021?)

- TSS data and ViCAs characterization are needed to calibrate/validate the models

- PSVD-models can be used for Water Quality-based management, RTC, system optimisation

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Advances in modelling particle transport in urban storm and wastewater systems

Peter A. Vanrolleghem and Paul Lessard, and
Bertrand Vallet, Émilie Berrouard, Jason Faber Carpenter, Etienne Gaborit, Dirk Muschalla,
Thibaud Maruéjouls, Bastien Wipliez, Sovanna Tik, Julia Ledergerber, Asma Hafhouf, Kamilia Haboub,
Giulia Bacchis, Imen Bel Hadj, Jessy Carpentier, Queralt Plana

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