Tuning of a central controller for a sewer network using multiple simplified models

R.R.P. van Nooijen\textsuperscript{1} A.G. Kolechkina\textsuperscript{2} E. van Velzen\textsuperscript{3} P.E.R.M. van Leeuwen\textsuperscript{4}

\textsuperscript{1}Delft University of Technology, Delft, the Netherlands
\textsuperscript{2}Aronwis, Den Hoorn, the Netherlands
\textsuperscript{3}Waterschap Hollandse Delta, Ridderkerk, the Netherlands
\textsuperscript{4}Deltares, Delft, the Netherlands

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1 Context
   - Geography and System Properties
   - Goal

2 Preliminary experiments
   - Setup
   - Results
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Tuning of a controller for a sewer network
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Village sewer systems

- Pumping station 1
- Pumping station 2
- Pumping station 3
- P. s. 4
- Town hall
- Water board
- CSO location
- Open water
- WWTP
Village sewer system properties

- In one system mixture of
  - combined (sanitary and storm in same pipe)
  - separated (sanitary separate from storm)
  - improved separated (sanitary catches “first flush”)

- Transport
  - gravity (short distances)
  - pumps (limit on capacity)
  - pressurized pipe lines

- In case of heavy rain
  - Combined sewer overflows (CSO)
  - Settling tank in series with CSO
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Diagram of system used in experiments

- **Overflow Structure with settling tank (143 m³)**
- **Overflow structure**
- **Pumping station**
- **Free flow sewer pipe**

**Molendijk**
- CRKW-001: 2.4 ha (CSS), 302 m³ storage, 7.6 m³/h dwf

**Kern**
- CRKW-002: 17.6 ha (CSS), 1702 m³ total storage, 36 m³/h dwf
- 135 m³/h
- 13.7 m³/h

**Rijksstraatweg**
- CRKW-004: 2.2 ha (CSS), 274 m³ storage, 9.1 m³/h dwf
- 115 m³/h

**Bongerd**
- CRKW-008: 2.6 ha (Improved Separated), 101 m³ storage, 5.3 m³/h dwf
- 85 m³/h

**Industrieterrein**
- CRKW-003: 3.1 ha (CSS), 219 m³ storage, 1.6 m³/h dwf
- 230 m³/h

To WWTP
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How to avoid CSO events

- Bigger pumps
  - Costly
  - Eventually means bigger treatment plant
- More storage
  - Costly
  - Must be emptied between events
- Better use of existing storage (Central/Global Control)
  - Can compensate for imbalances due to village expansion
  - Cheaper than alternatives
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- Need to know dynamic effects of
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  - control

Design influenced by dynamic effects
- Either: large scale long term measurements
- Or: detailed and calibrated computer simulation

Detailed and calibrated computer simulation
- Either: for limited number design storms
- Or: large number of simulations (say 25 years worth of interesting events)
Central Automatic Control

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Exploring Controller Parameter Space

- One parameter per subcatchment, five subcatchments, hundreds of events = probably many runs needed
- Full hydrodynamical simulation
  - Expensive
    - time
    - data storage
- One simple model for all events
  - Cheap
  - Inaccurate
- One simple model per event (sub-event?)
  - Cheap
  - Moderately accurate?
  - Cost of model tuning?

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Software used

- Full hydrodynamical simulation
  - Sobek (Deltares)
  - linked to controller through OpenMI 1.4

- Controller
  - written in Java/Scala at Delft University

- Simple model
  - Matlab
  - linked to controller through Java call interface

- Tests
  - Matlab
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Simple model

- Subcatchment is 0D reservoir, calibration parameter
  - volume
- Pump: on or off, capacity as in Sobek
- CSO: linear, calibration parameter
  - proportionality constant
  - threshold is equal to subcatchment volume
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Controllers

- **Local**
  - On/off with hysteresis
    - on at $h_1$
    - off at $h_0 < h_1$

- **Central**
  - Prescribed storage use (local derived from total)
    - pumps used to track storage curve
    - storage curve (local vs global) given per subcatchment
Procedure

- **Calibration**
  - precipitation inflow from Sobek
  - local controller
    - simple model state as input
  - CSO compared to
    - Sobek under local control

- **Validation**
  - precipitation inflow from Sobek
  - central controller
    - simple model state as input
  - CSO compared to
    - Sobek under central control
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Results in words

- Time gain 93%, not representative because
  - Matlab code not optimal
  - Coupling between Sobek and central controller not optimal
  - ...  

- Accuracy
  - More runs needed for definite answers
  - Variable delay parameter between actual volume and volume in CSO formula may be needed
  - Missing gravity flow connection in model limits calibration to three subcatchments
Best case results in graphs

Local

Central

event 21, $V_{kern} = 1682$, $c_{spill} = 0.001$

event 118, $V_{kern} = 1750$, $c_{spill} = 0.001$
## Results in table

<table>
<thead>
<tr>
<th>Event</th>
<th>Sobek Local m³</th>
<th>Sobek Central m³</th>
<th>Simplified Local m³</th>
<th>Simplified Central m³</th>
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<td>1411</td>
<td>1450</td>
<td>1415</td>
</tr>
</tbody>
</table>

Total spills (189: one extreme peak)
Problem: delays

Fast versus slow filling

8mm/hour peak

5mm/hour peak

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Volume versus shape

![Graph showing discharge (m^3/s) over time (h) for RGD_CRKW-002 Kern. The graph compares model and sobek results.](image)
Summary

- Simple model per event better than just one simple model
- Simple model is faster
- But more work is needed on
  - Simple model calibration
  - Simple model characteristics
  - Delays when spill location is far from pump
Thank you for your attention