COACHS C2D2

(COmputations and their Applications in Channel Hydraulics for Sewers)

MENTOR

(MEasurement sites conception method for sewer NeTwORks)

4 September 2012

Assessment of the discharge in sewer pipes using two water level measurements

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Context

- Measurement of the discharge : traditionally performed using two measurements in the same cross-section:

$$Q(t) = V(t) \times S(t)$$

h(t)

Q = discharge

V = mean velocity

S = cross-sectional area

h = water level

Context

- Main constraints for the wastewater manager
  - Technical difficulty :

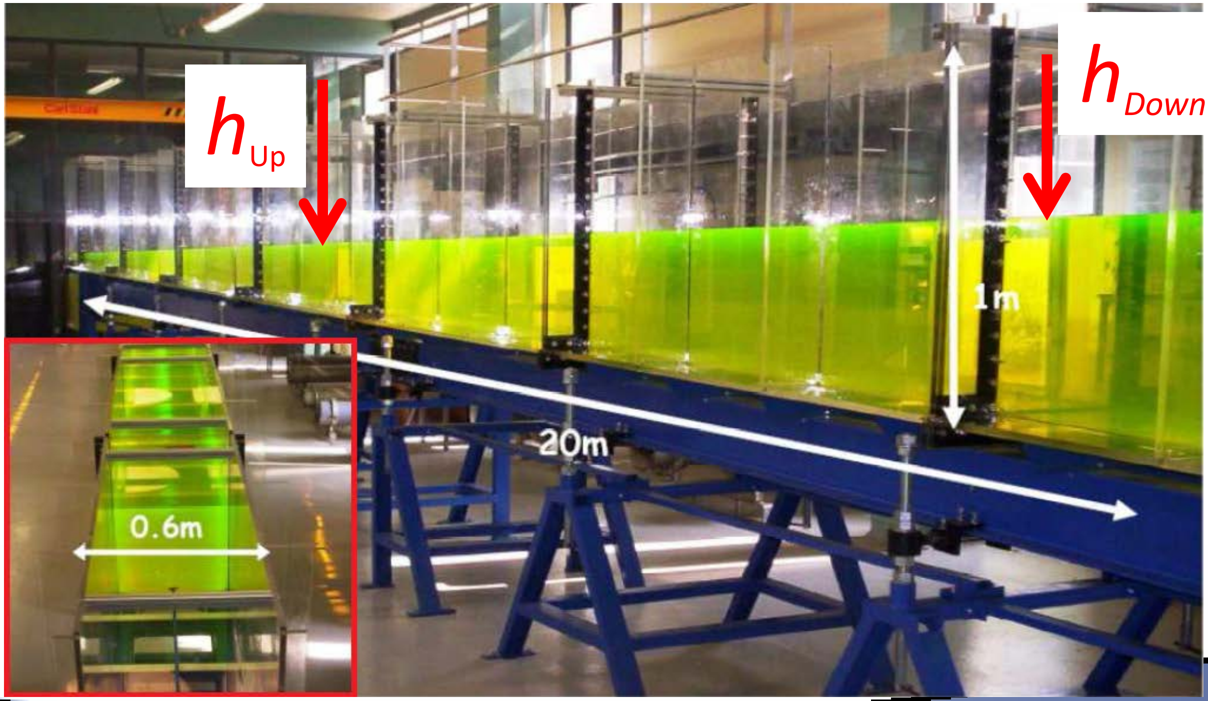
$$V_{local} \xrightarrow{?} V_{mean}$$

  - Operational constraint : maintenance related to the submersion of the sensors

➔ Proposal of an innovative method based on water level measurements

Objective

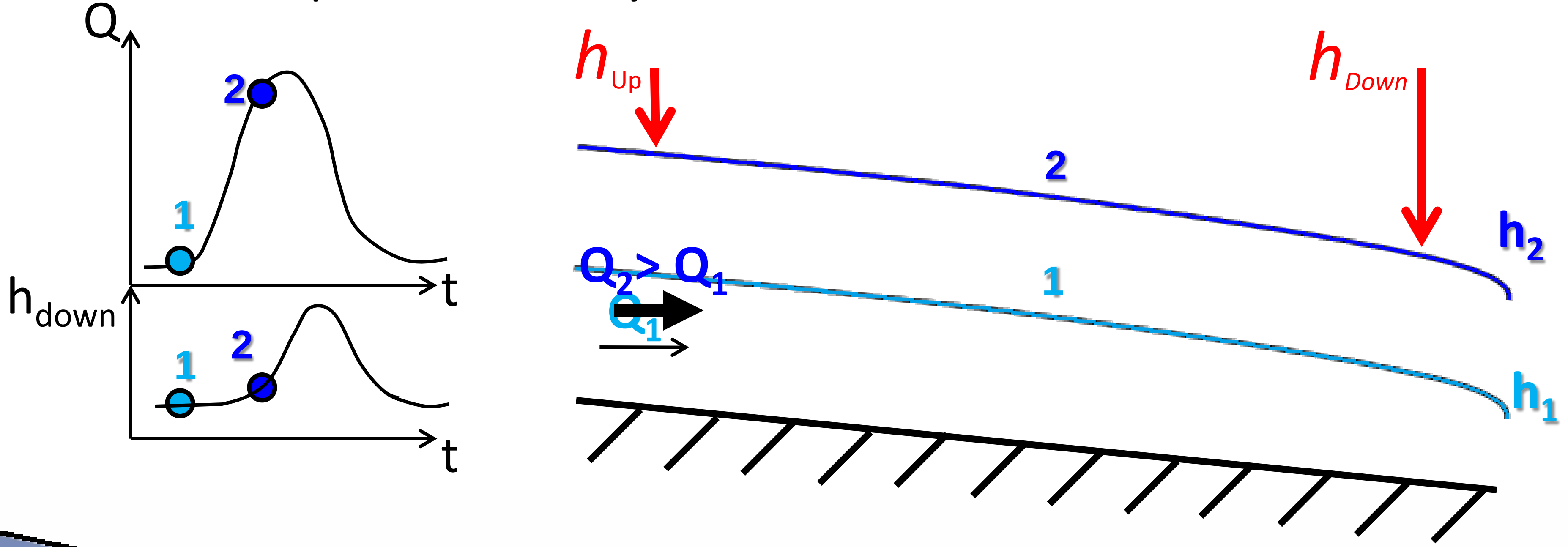
- Instead of measuring the velocity and the water level in one cross-section…
- Measuring the water level in two cross-sections



Fluid and Solid Mechanics Institute (STRASBOURG)

Scope of application

- Intended for sewers with
  - Subcritical flow
  - Complex boundary conditions



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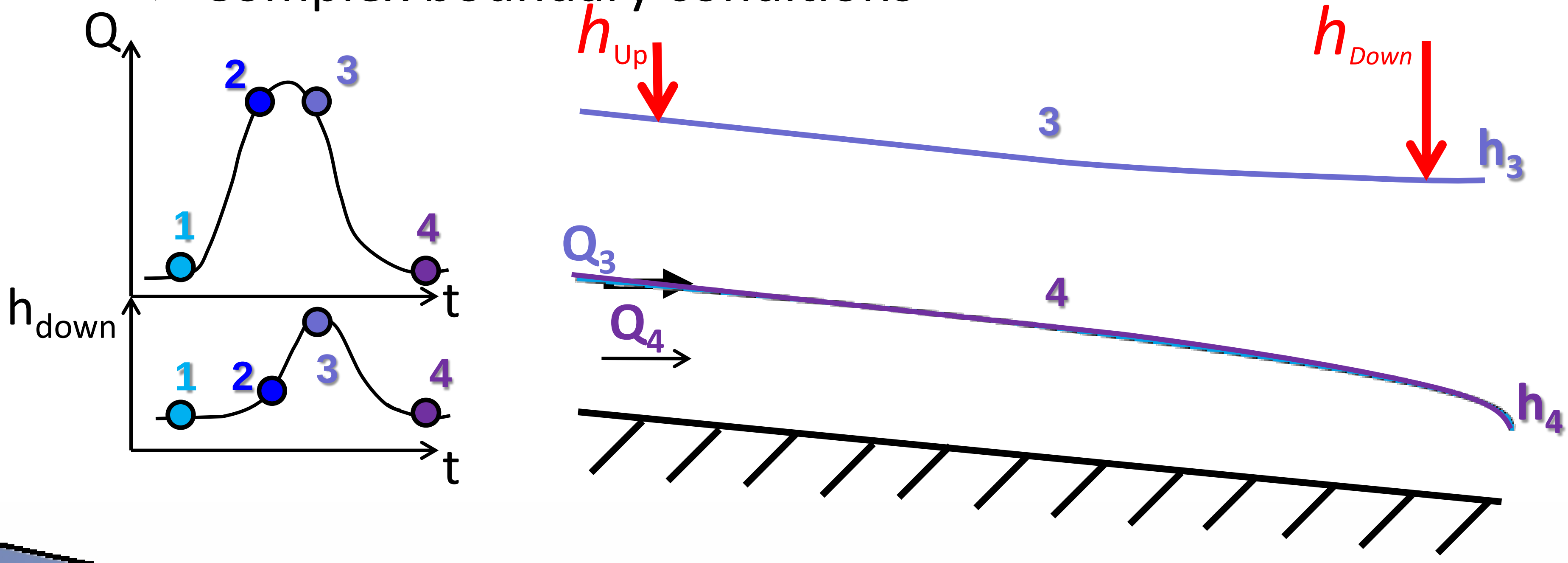

Innovative method

Spatial variation

Temporal variation

1D Model: shallow water equations (SW)

$$\frac{\partial S}{\partial t}+\frac{\partial Q}{\partial x}=0$$

Continuity

$$\frac{\partial Q}{\partial t}+\frac{\partial (Qu)}{\partial x}+g\cdot S\cdot\frac{dh}{dx}=g\cdot S(I-J)$$

Moment

Innovative method

Spatial variation

~~**Temporal variation**~~

1D Model: shallow water equations (SW)

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Continuity

$$\cancel{\frac{\partial Q}{\partial t}} + \frac{\partial (Qu)}{\partial x} + g \cdot S \cdot \frac{dh}{dx} = g \cdot S (I - J)$$

Moment

Backwater curve

$$\boxed{\frac{dh}{dx} = \frac{I - J}{\left(1 - Fr^2\right)}}$$

Methodology : backwater curves

1

- **Hydraulic analysis**: variation range of $h_{upstream}$, $h_{downstream}$ and Q **=>** creation of a **data bank**

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- Simulations with the **1D model** using **backwater curves**

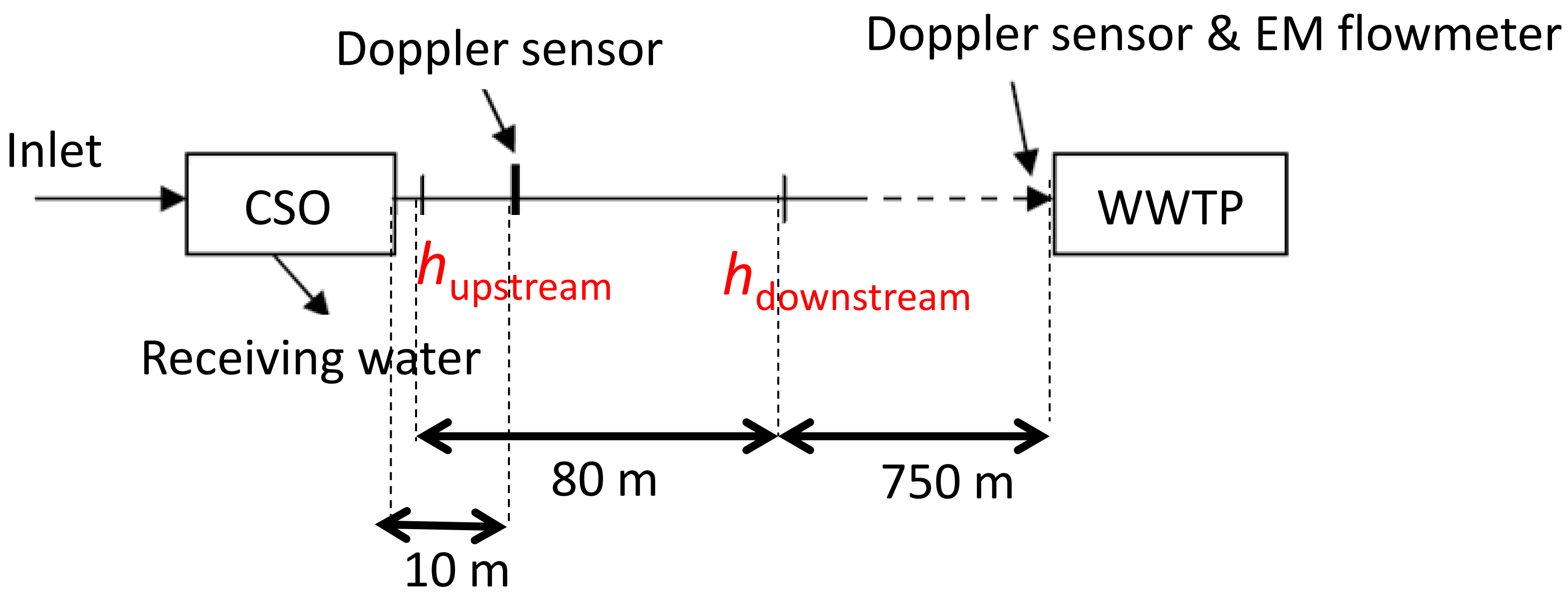
Methodology : backwater curves

1. **Hydraulic analysis**: variation range of $h_{upstream}$, $h_{downstream}$ and Q
   => creation of a **data bank**

2. Simulations with the **1D model** using **backwater curves**

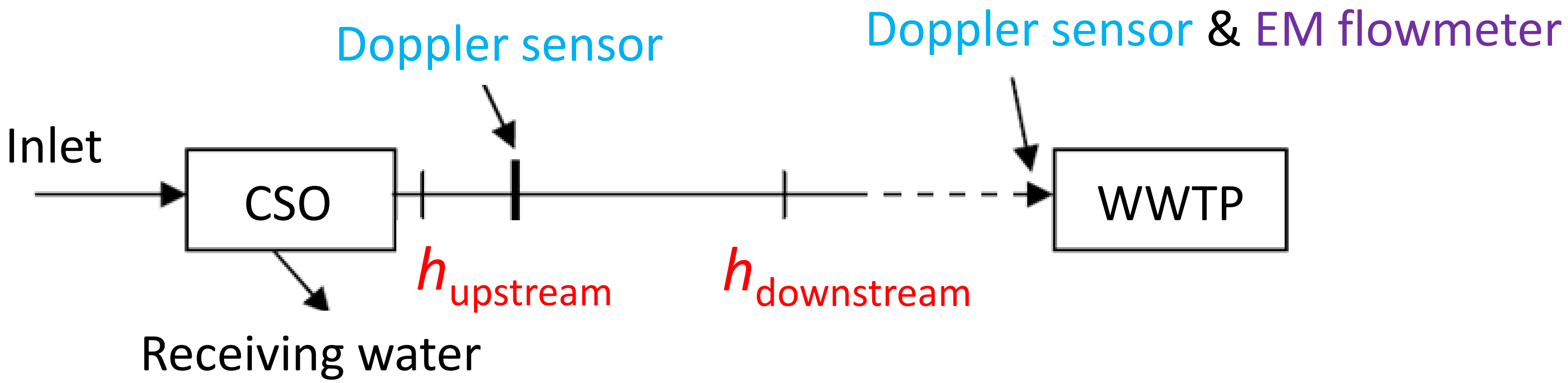
3. Interpolate the data bank using **neuronal network**
   => explicit height-discharge relationship

Validation against field data



- Characteristics of the Steingiessen collector (Strasbourg):
  - Circular shape: D = 2620 mm
  - Mild slope: 0.18%

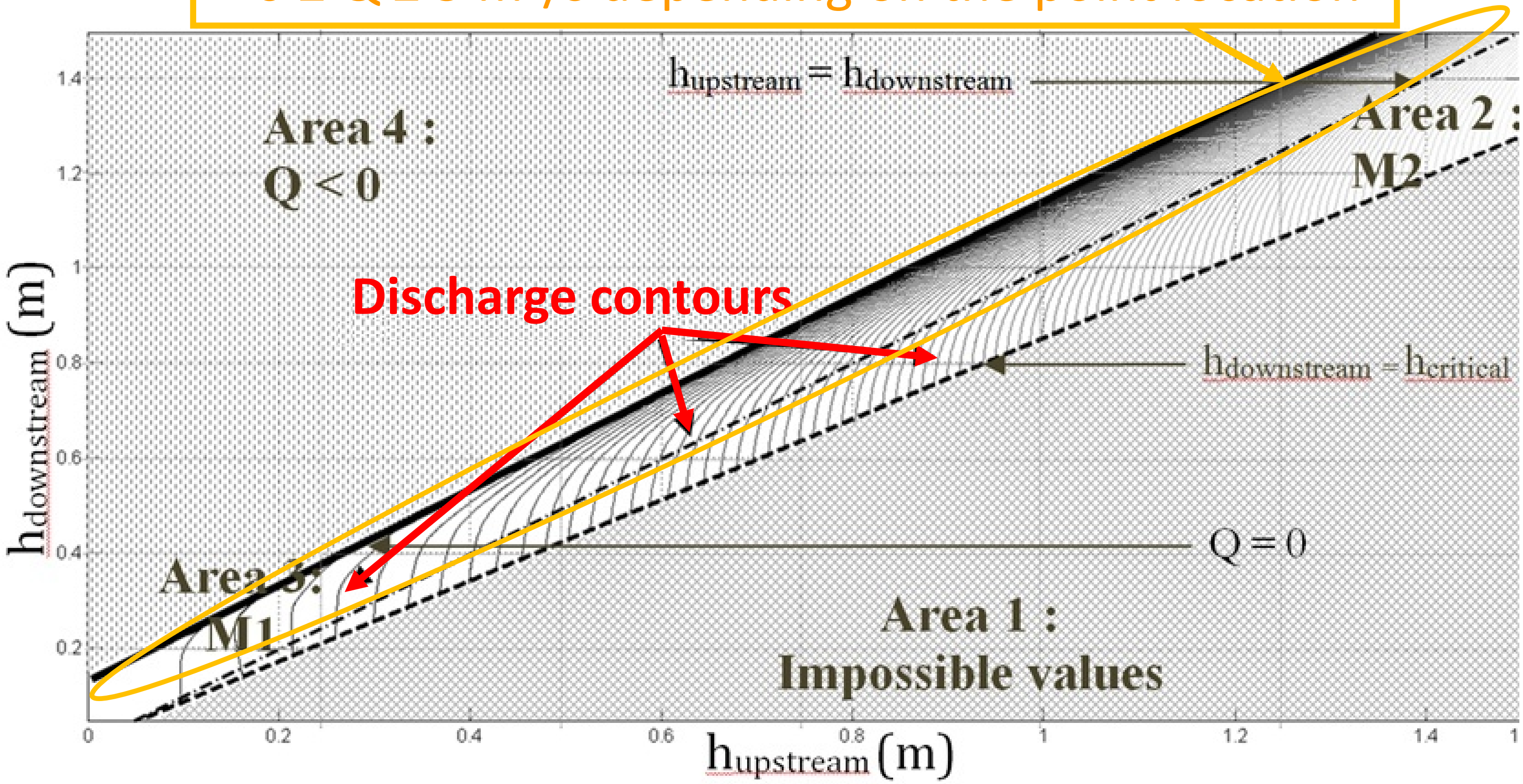
Validation against field data



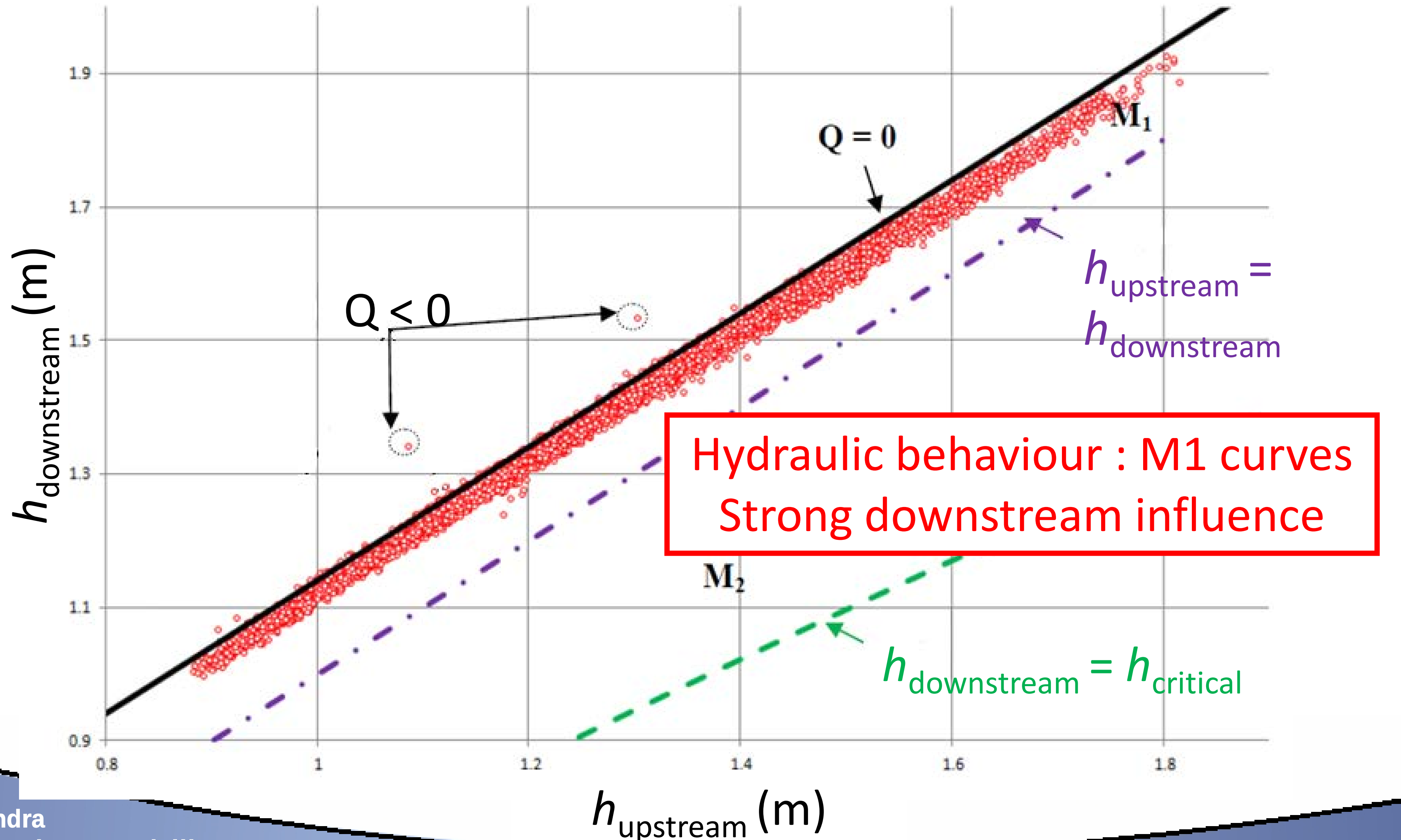
- 3 alternative discharge measurements:
  - 2 Doppler sensors (large uncertainties)
  - 1 electromagnetic flowmeter (reference)

Site-specific abacus

$0 \leq Q \leq 5$ m^3/s depending on the point location



Hydraulic characterization



Assessment of the discharge

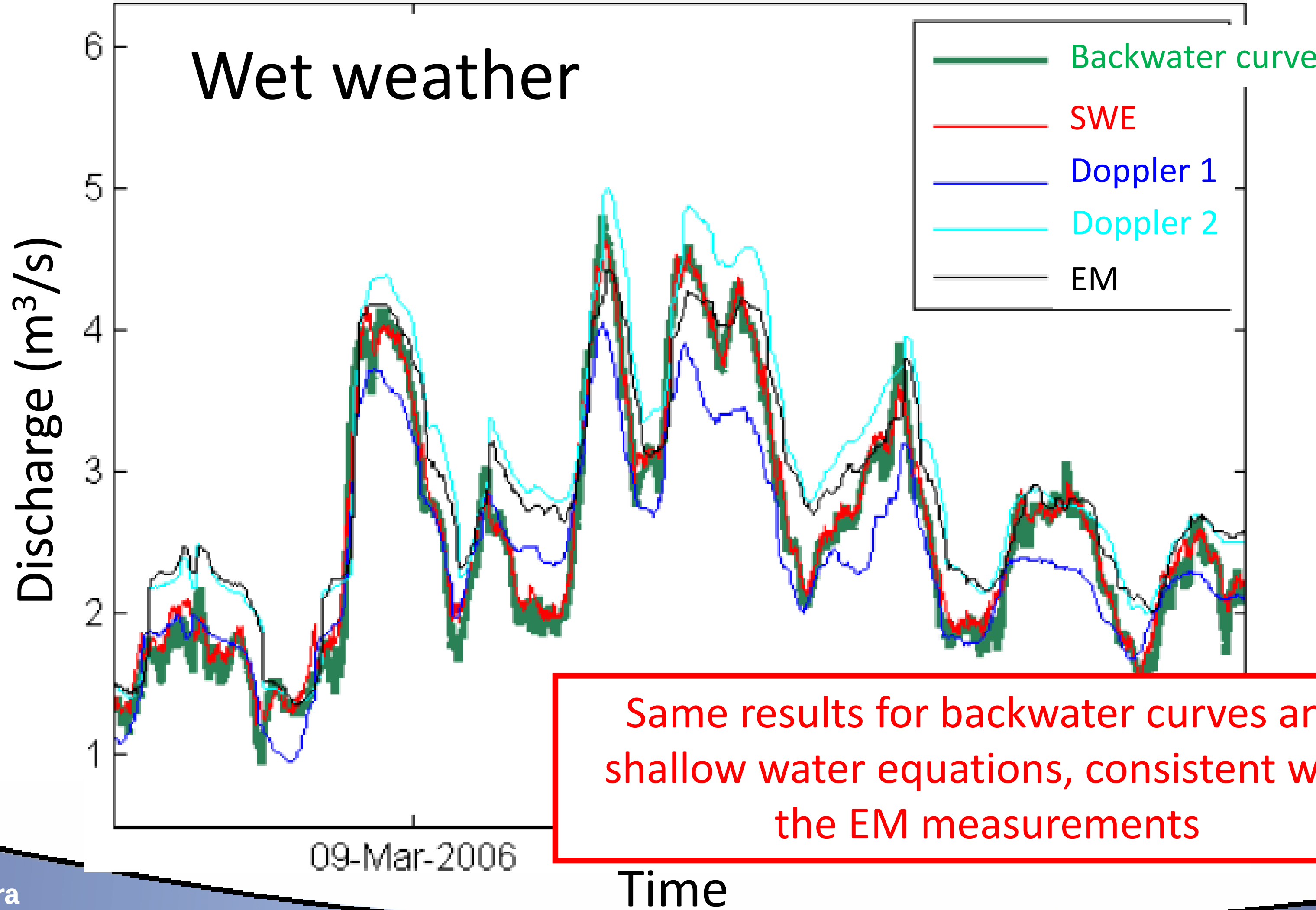
- Use of the abacus
- Or a mathematical relationship such as…

$h_{upstream}$ $h_{downstream}$

$$
\begin{aligned}
Q = 3.975*[&-16.6356*\text{tansig}(-3.1154*(H_{amont\_norm})+4.6944*(H_{aval\_norm})-1.6063)\\
&+0.71222*\text{tansig}(2.2047*(H_{amont\_norm})+0.046873*(H_{aval\_norm})-1.8911)\\
&-30.1953*\text{tansig}(0.030011*(H_{amont\_norm})-0.99198*(H_{aval\_norm})+8.4215)\\
&+2.394*\text{tansig}(0.9903*(H_{amont\_norm})-0.0018126*(H_{aval\_norm})-0.20582)\\
&-0.47615*\text{tansig}(-24.7241*(H_{amont\_norm})+27.6938*(H_{aval\_norm})-3.9172)\\
&-64.5167*\text{tansig}(-58.2189*(H_{amont\_norm})+62.586*(H_{aval\_norm})-8.4916)\\
&+24.688*\text{tansig}(-62.379*(H_{amont\_norm})+67.0257*(H_{aval\_norm})-8.7765)\\
&-30.2568*\text{tansig}(-4.4401*(H_{amont\_norm})+5.7166*(H_{aval\_norm})-0.97896)\\
&+48.7531*\text{tansig}(-391.8007*(H_{amont\_norm})+418.025*(H_{aval\_norm})-49.9482)\\
&-104.2377*\text{tansig}(52.5471*(H_{amont\_norm})-56.5127*(H_{aval\_norm})+8.4957)\\
&\ldots 7)\\
&\ldots 5)\\
&-196.7155*\text{tansig}(323.2098*(H_{amont\_norm})-344.8421*(H_{aval\_norm})+41.7628)\\
&+9.1005*\text{tansig}(-5.6903*(H_{amont\_norm})+7.1283*(H_{aval\_norm})-0.85864)\\
&+0.0095489*\text{tansig}(4.305*(H_{amont\_norm})-7.0151*(H_{aval\_norm})-2.4251)\\
&-31.5813*\text{tansig}(1.6585*(H_{amont\_norm})+0.38915*(H_{aval\_norm})+5.1055)\\
&-32.1302]\\
&+4.025
\end{aligned}
$$

Awful equation (neural network) but easily implemented in a sensor.

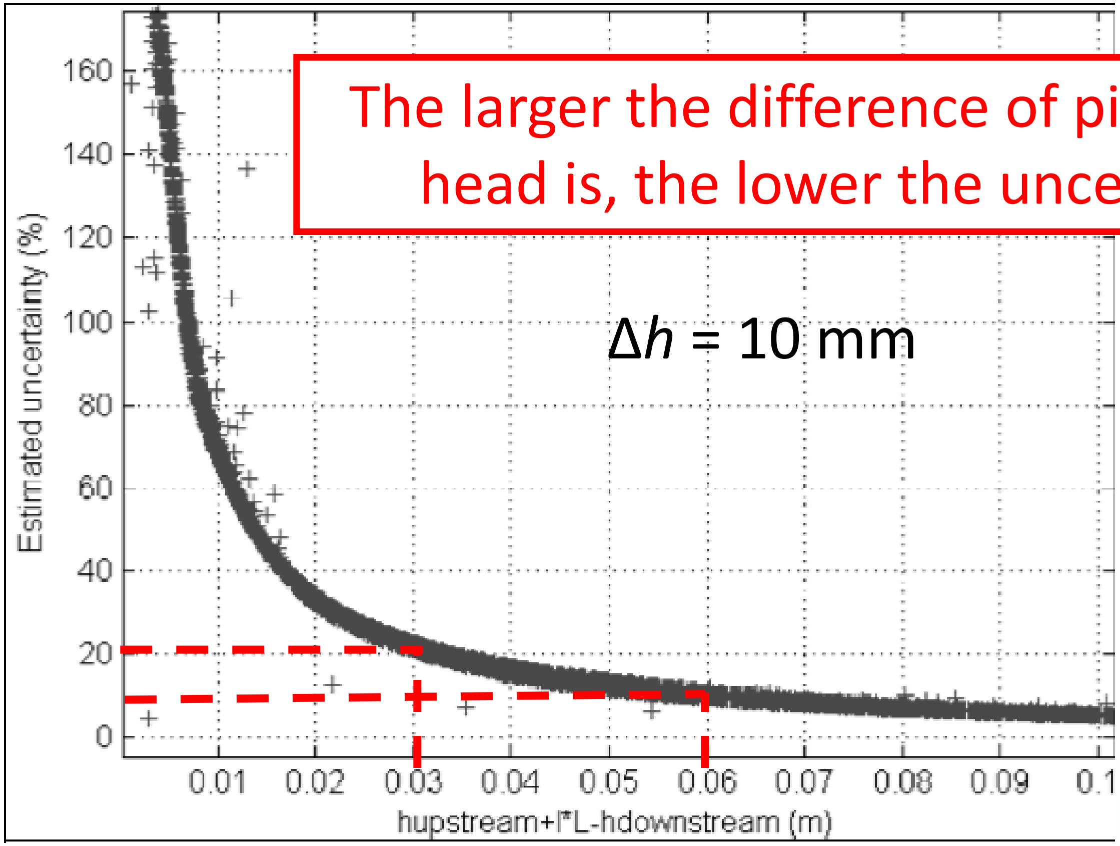
Results of the methodology



Same results for backwater curves and shallow water equations, consistent with the EM measurements

Related uncertainties

Propagation of uncertainty : $$\frac{\Delta Q}{Q} = \frac{\sqrt{\left(\frac{\partial Q}{\partial h_{upstream}}\right)^2 \cdot (\Delta h_{upstream})^2 + \left(\frac{\partial Q}{\partial h_{downstream}}\right)^2 \cdot (\Delta h_{downstream})^2}}{Q}$$



The larger the difference of piezometric head is, the lower the uncertainty.

Conclusion and prospects

	Gradually varying flow equations	Shallow water equations
Conditions of use	**Subcritical** flow Complex boundary conditions	
Domain of applicability	**Quasi-stationary**	**General**
Advantage	Easily **implementable**	No need for filtering the inlet data
Related uncertainties	- Operational over a few centimeters piezometric head difference	

<u>Upcoming work</u> : limit of application of the simplified approach (transient effects ? sewer dimension ? influence of the deposit ?)

Thank you for your attention !

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