Measurements for water

Marie-claire ten Veldhuis

Measurements in urban drainage

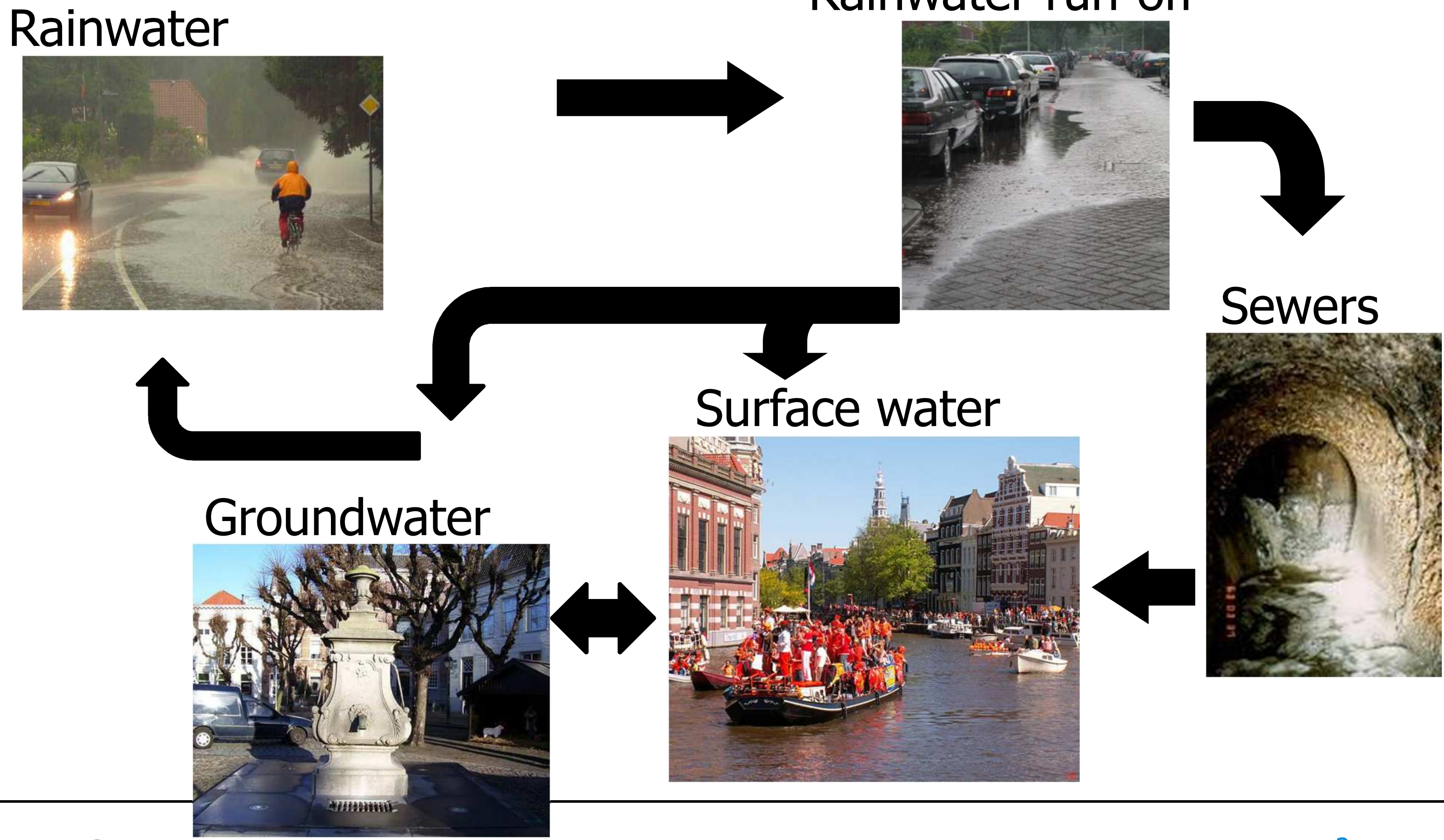
Measurements in urban drainage

CT3412MI

Marie-claire ten Veldhuis

≈ Urban Water ≈

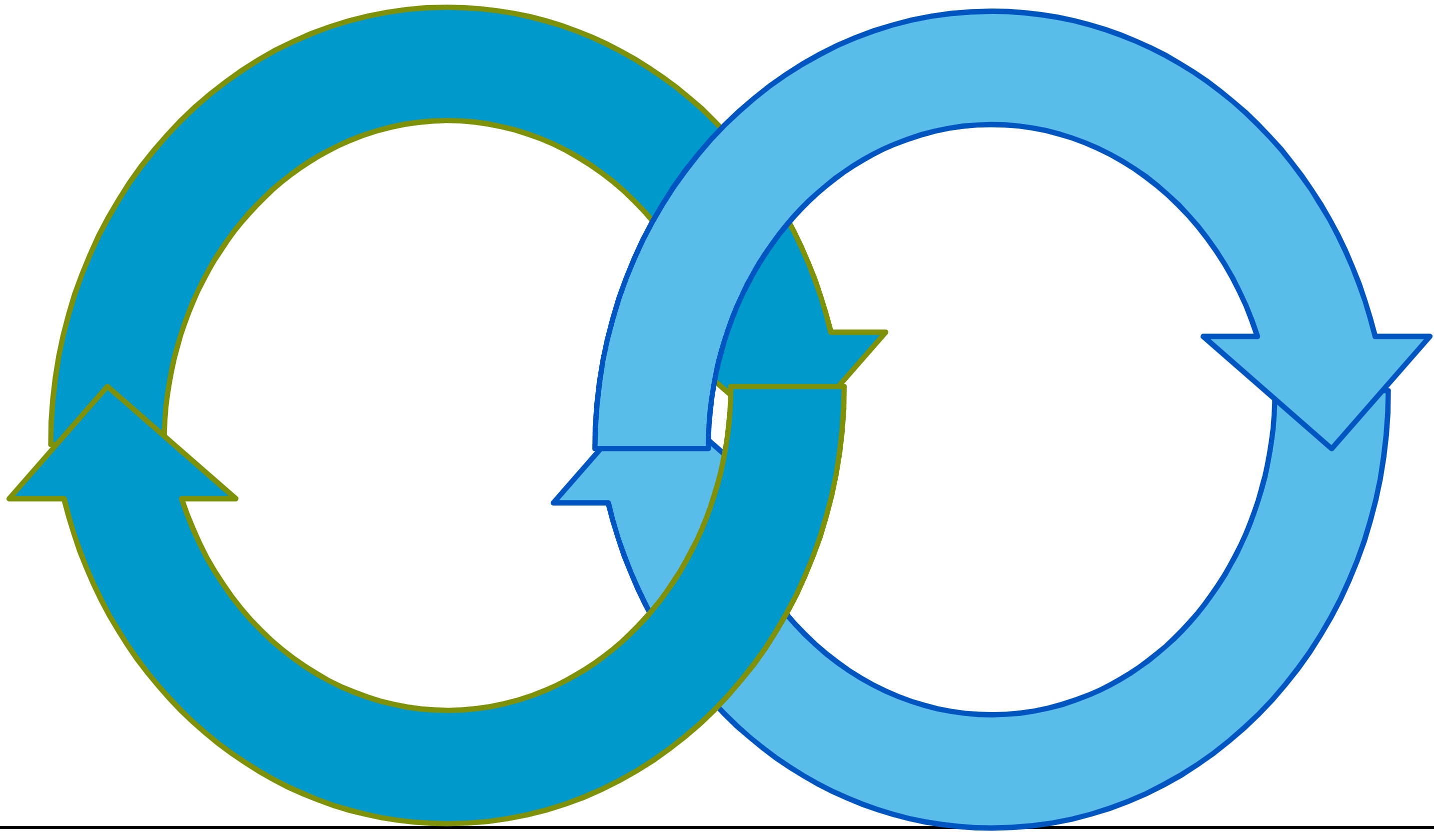
Urban Hydrological Cycle



≈ Urban Water ≈

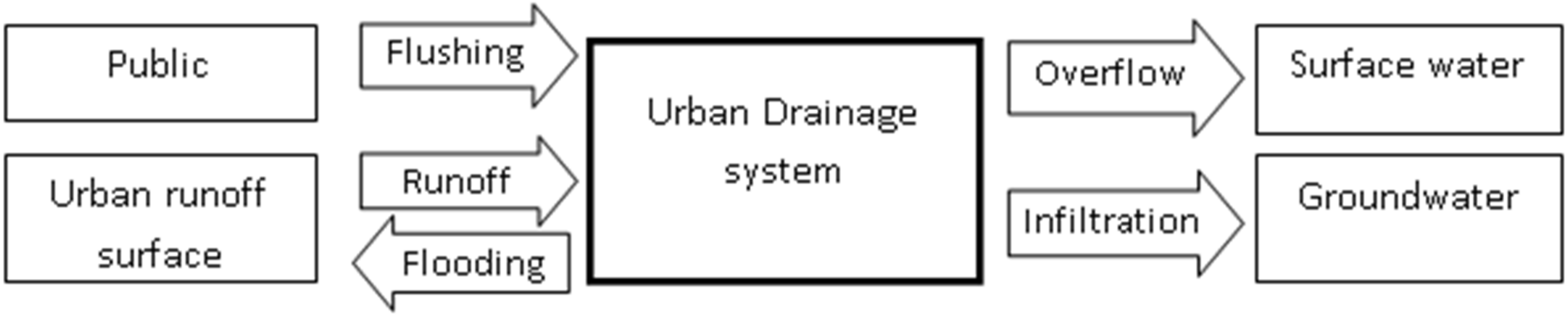
Urban Sanitary Water Cycle

Urban Hydrological Water Cycle



Urban water flows - urban drainage

Interactions of urban drainage system with surroundings:



Objectives of urban drainage systems

Objectives:

- Protect public health
- Prevent flooding

…while not transferring problems to the environment

Functions:

- Collection of wastewater: water, organic compounds, bacteria, nutrients, soap, medical residues, etc.
- Collection of stormwater: water, sand/clay, oil, heavy metals
- Control and collection of groundwater: water, nutrients, salts
- Transport of wastewater to wastewater treatment plant
- Storage and transport of stormwater to surface water/groundwater

Measurements in urban drainage

What parameters to measure and where ?

Measurement objectives

- Flooding: flood frequency, number of flooded locations

Measurement objectives

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- Combined sewer overflows: overflow frequency/yearly overflow volume

Measurement objectives

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- Check deficiencies: odour complaints, illicit connections

Measurement objectives

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- Calibrate and verify hydrodynamic models Increase understanding of flow processes





Measurement objectives

- Flooding: flood frequency, number of flooded locations
- Combined sewer overflows: overflow frequency/yearly overflow volume
- Check deficiencies: odour complaints, illicit connections
- Calibrate and verify hydrodynamic models
- Increase understanding of flow processes
- Real-time control and operation

Measurement parameters

- Water levels: quantify overflow frequencies, flooding frequencies, overflow volumes at weirs, calibrate hydrodynamic models
- Discharge: quantify overflow volumes, calibrate models
- Rainfall

- Water quality parameters, some examples:
  - Temperature: to identify illicit connections
  - Turbidity: erosion and sedimentation processes, relations with other pollutants
  - Oxygen content: odour complaints, effects of organic pollution loads
  - And many more...

Measurement plan

Combined sewer overflows:

- overflow frequency
- overflow volume
- rainfall

- Measurement parameters?

- Measurement locations?

Measurement plan

Flooding:
- flood frequency
- number of flooded locations
- rainfall

- Measurement parameters?

- Measurement locations?

Measurement plan

Check deficiencies:

- odour complaints
- illicit connections
- groundwater inflow

- Measurement parameters?

- Measurement locations?

Measurement plan

Calibrate and verify hydrodynamic models

- Increase understanding of flow processes
- Measurement parameters?
- Measurement locations?

Measurement locations

Outflow points

- Overflow weirs (water level)
- Pumping stations (discharge)

Inside sewer system

- Internal weirs (water level)
- Manholes at critical points in system:
    - Main flow routes
    - Co-currence of large flows
- Specific locations to detect source of problems (e.g. illicit connections, groundwater inflow)

Measurement parameters: Rainfall

Urban areas:

Fast runoff processes
→ Need for fine-scale rainfall data
→ High resolution in time and space

Processes at 5 – 10 minutes time-scale
→ Data at 1 - 5 minutes time-scale
Processes at 100 – 1000 m time scale
→ Data at 50 – 500 m spatial scale

Measurement parameters: Urban rainfall

Urban areas:

Fast runoff processes
→ Need for fine-scale rainfall data
High resolution in time and space:
→ 1 - 5 minutes time-scale
→ 50 – 500 m spatial scale

Currently available data:
KNMI radars: de Billt, Den Helder
→ 5 minutes, 1 km^2

Measurement parameters: Urban rainfall

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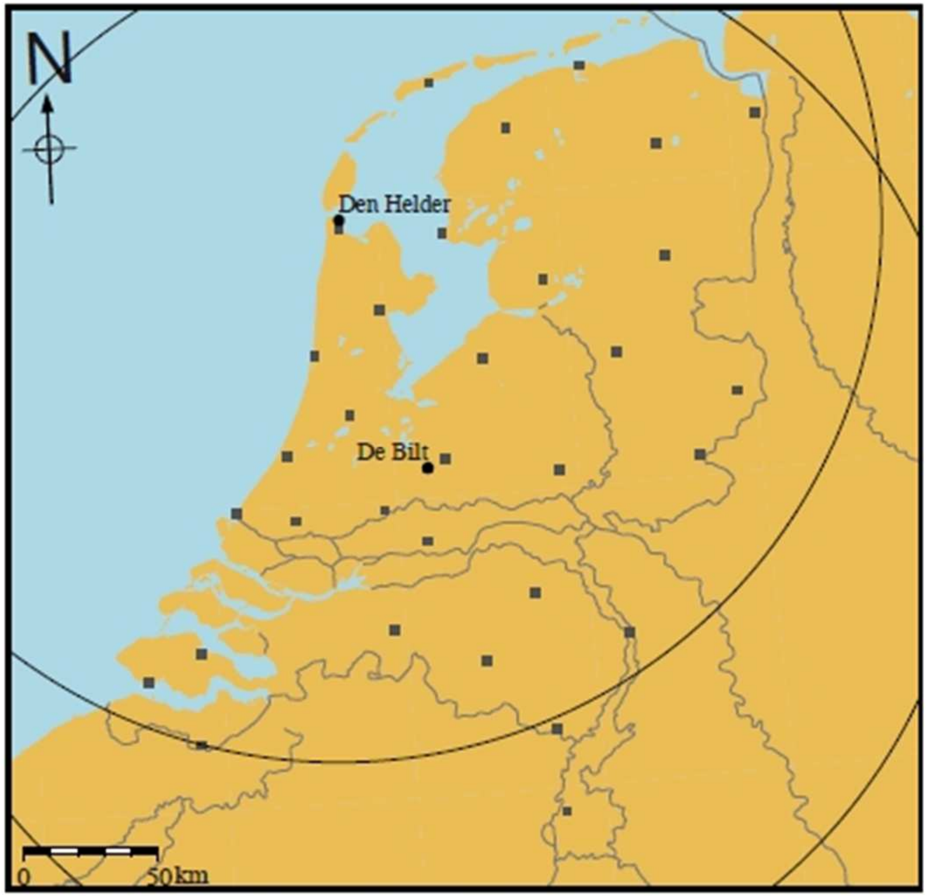
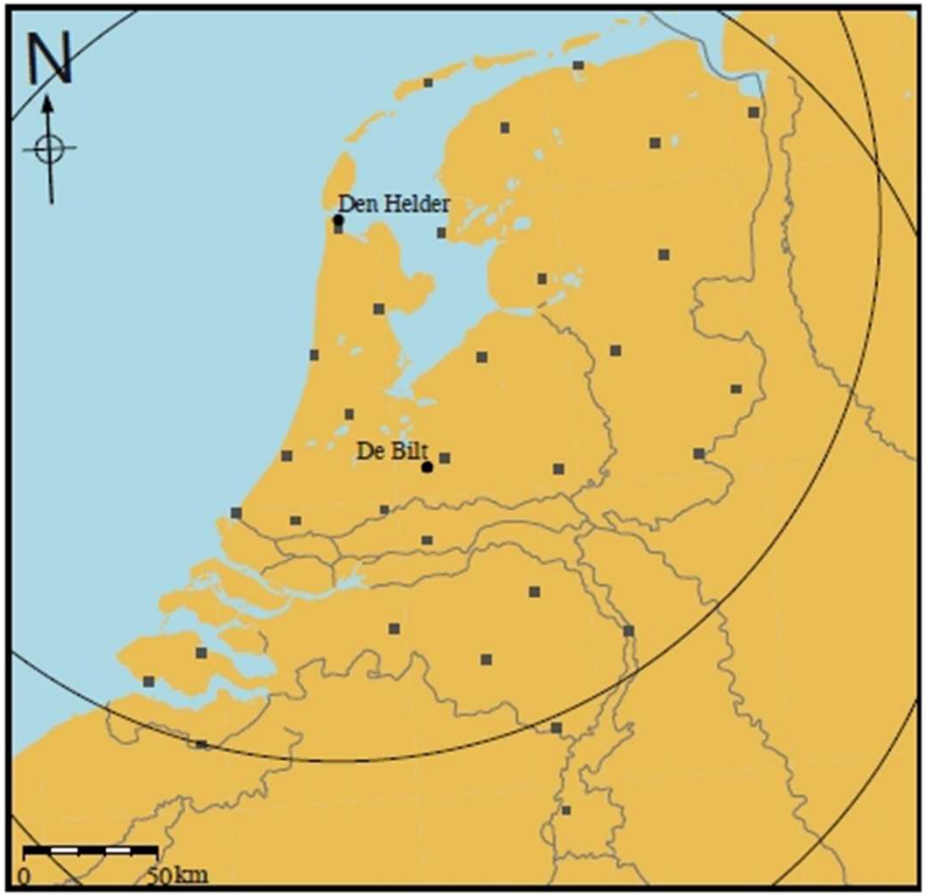
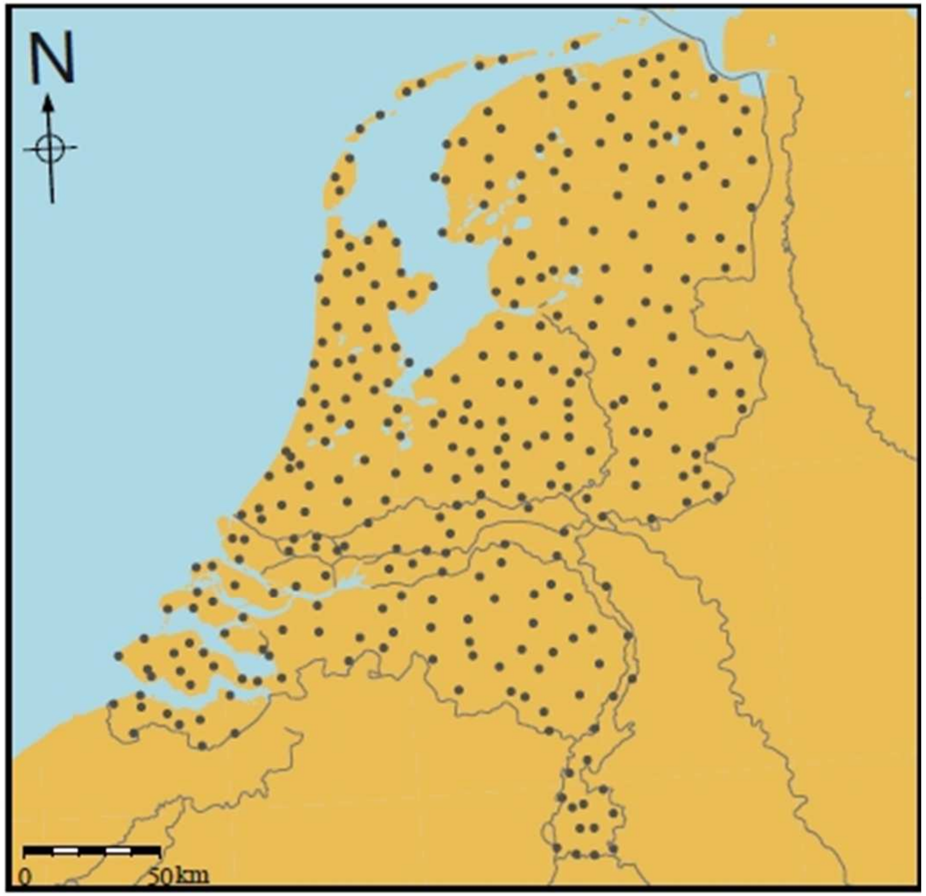
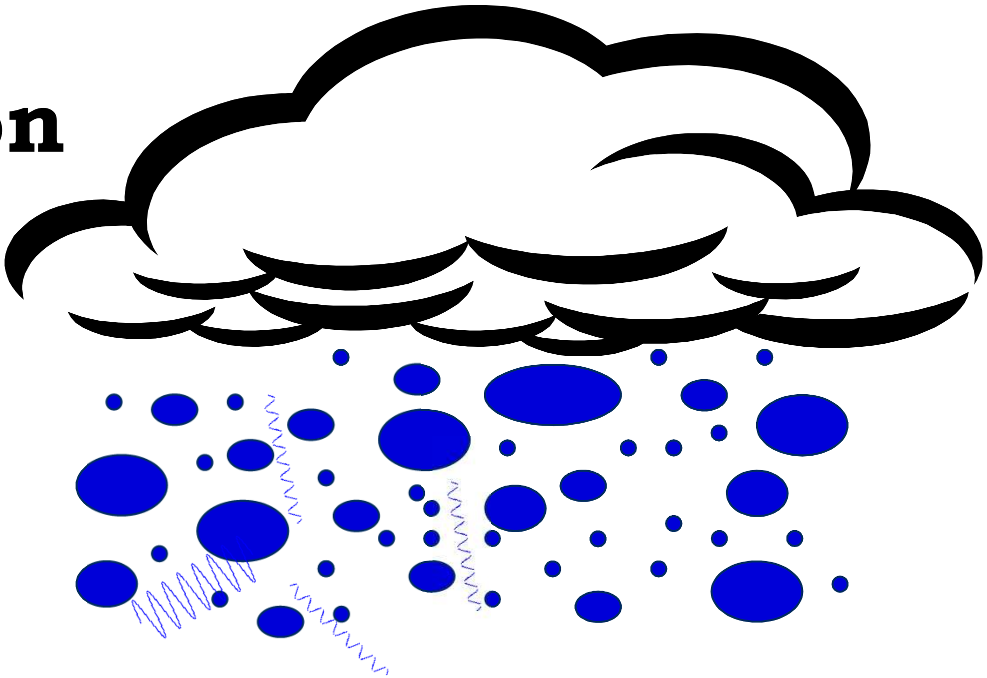


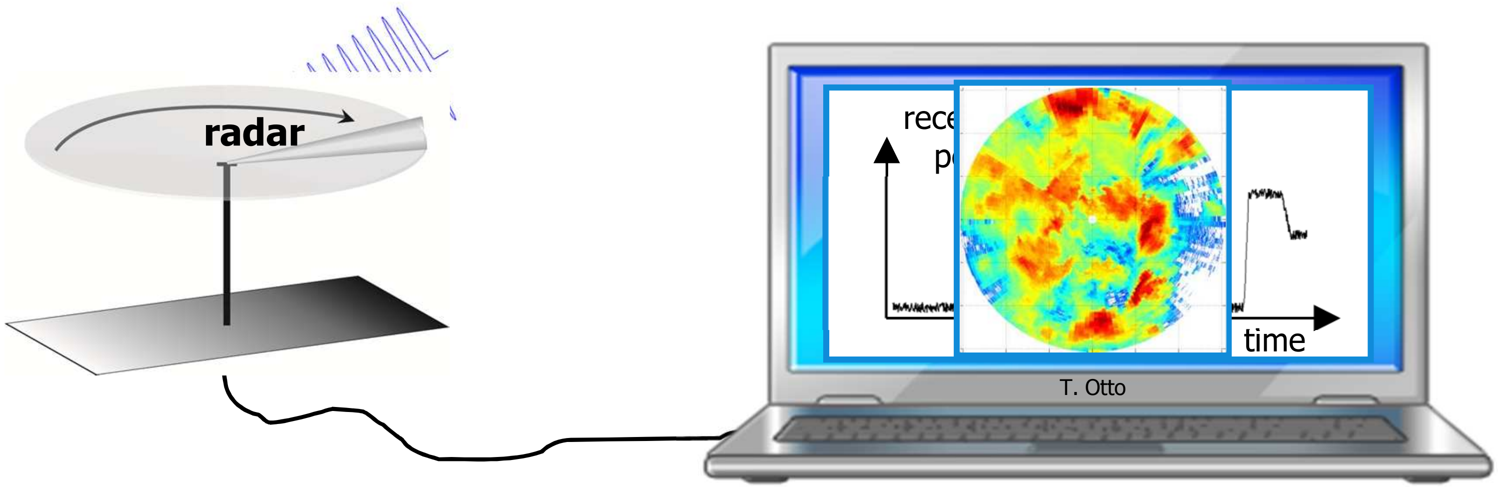
Rainfall radar (RAdio Detection And Ranging)





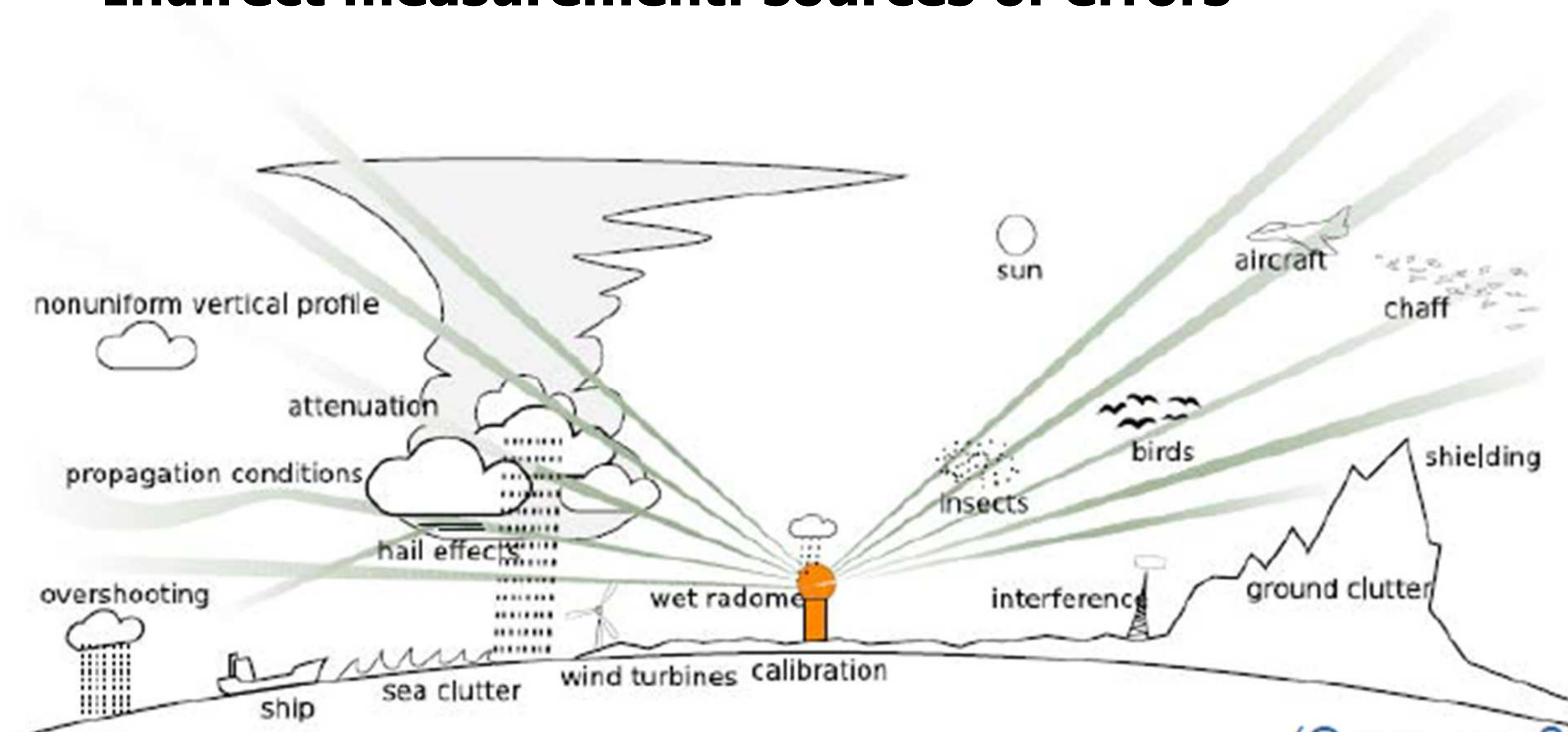
Radar reflection





Rainfall radar

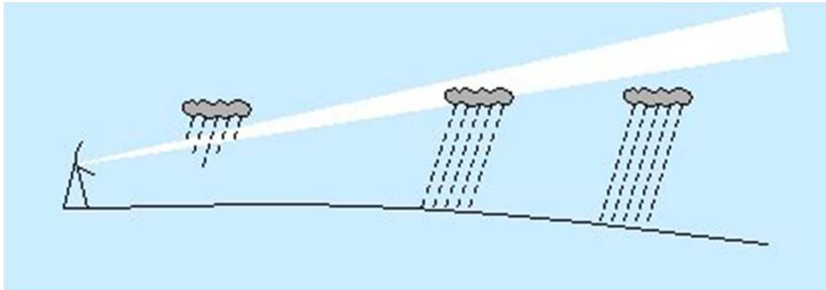
Indirect measurement: sources of errors



(Overeem, 2009)

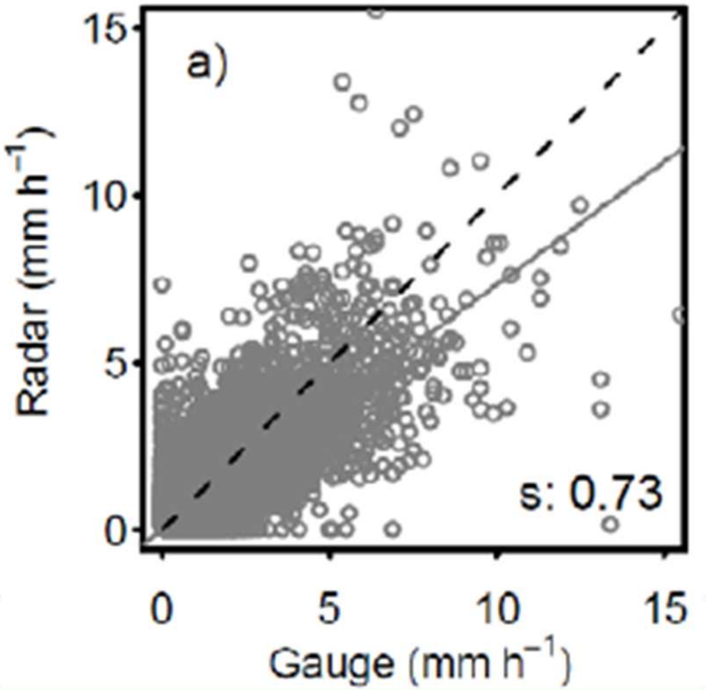
Rainfall radar for urban areas

Error sources:



- Overshooting
- Attenuation
- Ground clutter (!high buildings)
- Non-uniform vertical profile

Uijlenhoet, 2010

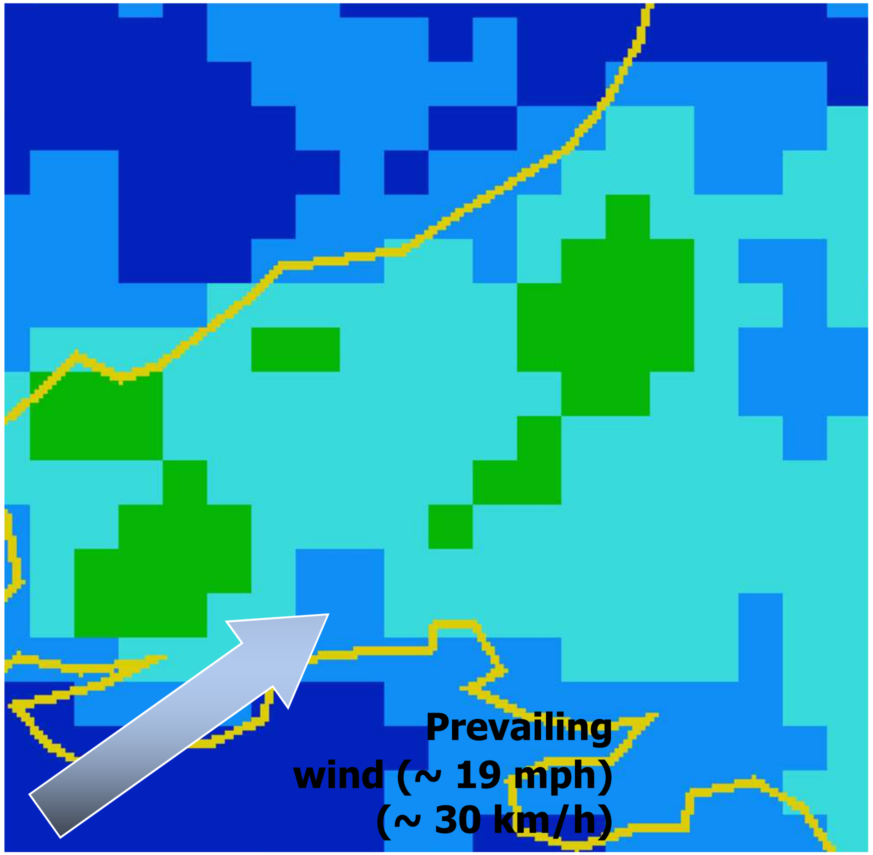


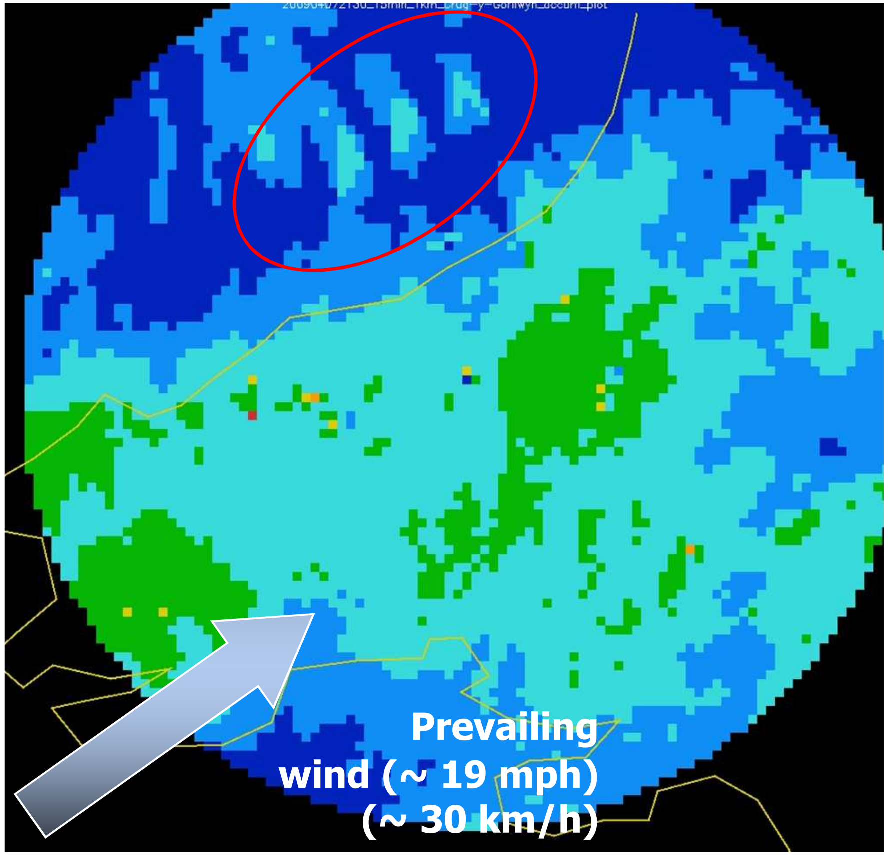
Radar versus rain gauge:
- Hourly rainfall
- 42 rain gauges

→ Higher resolution:
more sensitive to errors

Rainfall radar for urban areas
A problem of resolution

15 min accumulation for Crug-y-Gorllwyn, 07-04-2009 (Courtesy MetOffice)





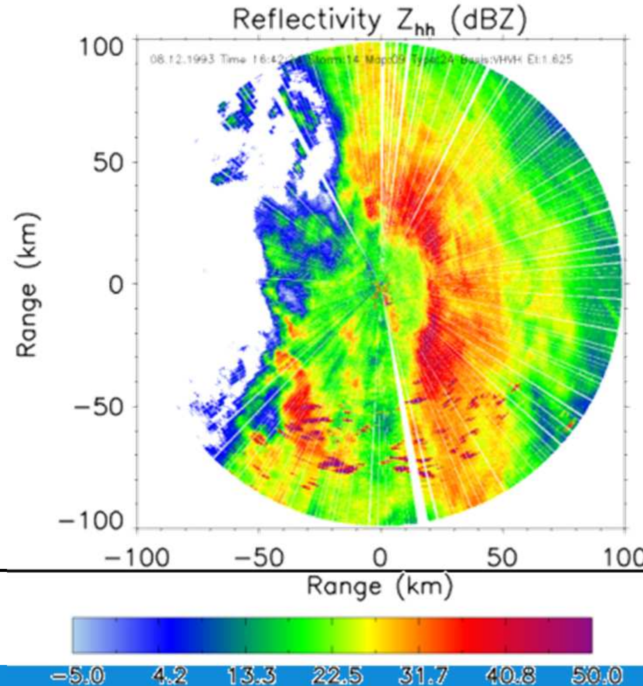
5 km
Not noticeable

1 km
Highly noticeable

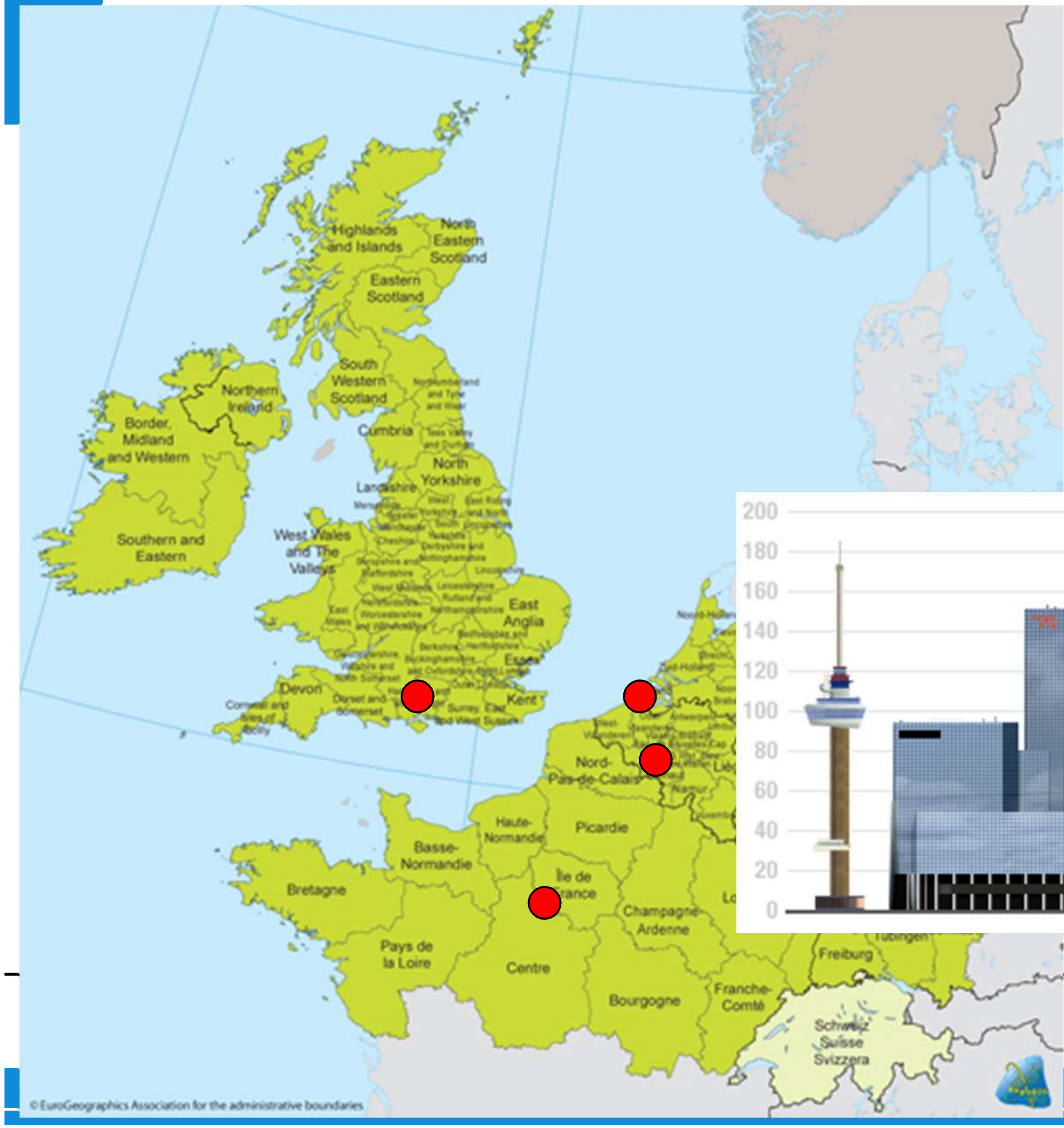
Radar for urban rainfall

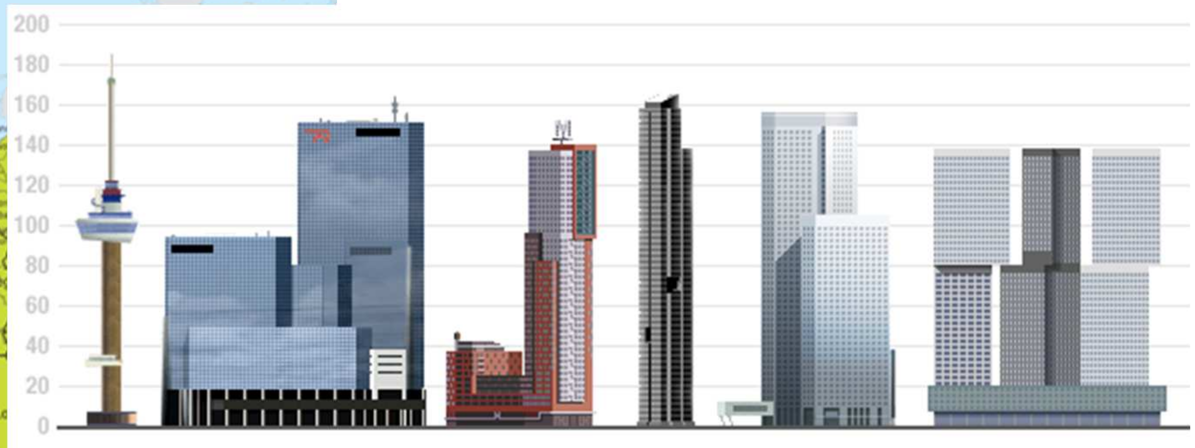
RAINGAIN

Objective: to improve fine-scale measurement and prediction of rainfall and to enhance urban pluvial flood prediction



Radar for urban rainfall

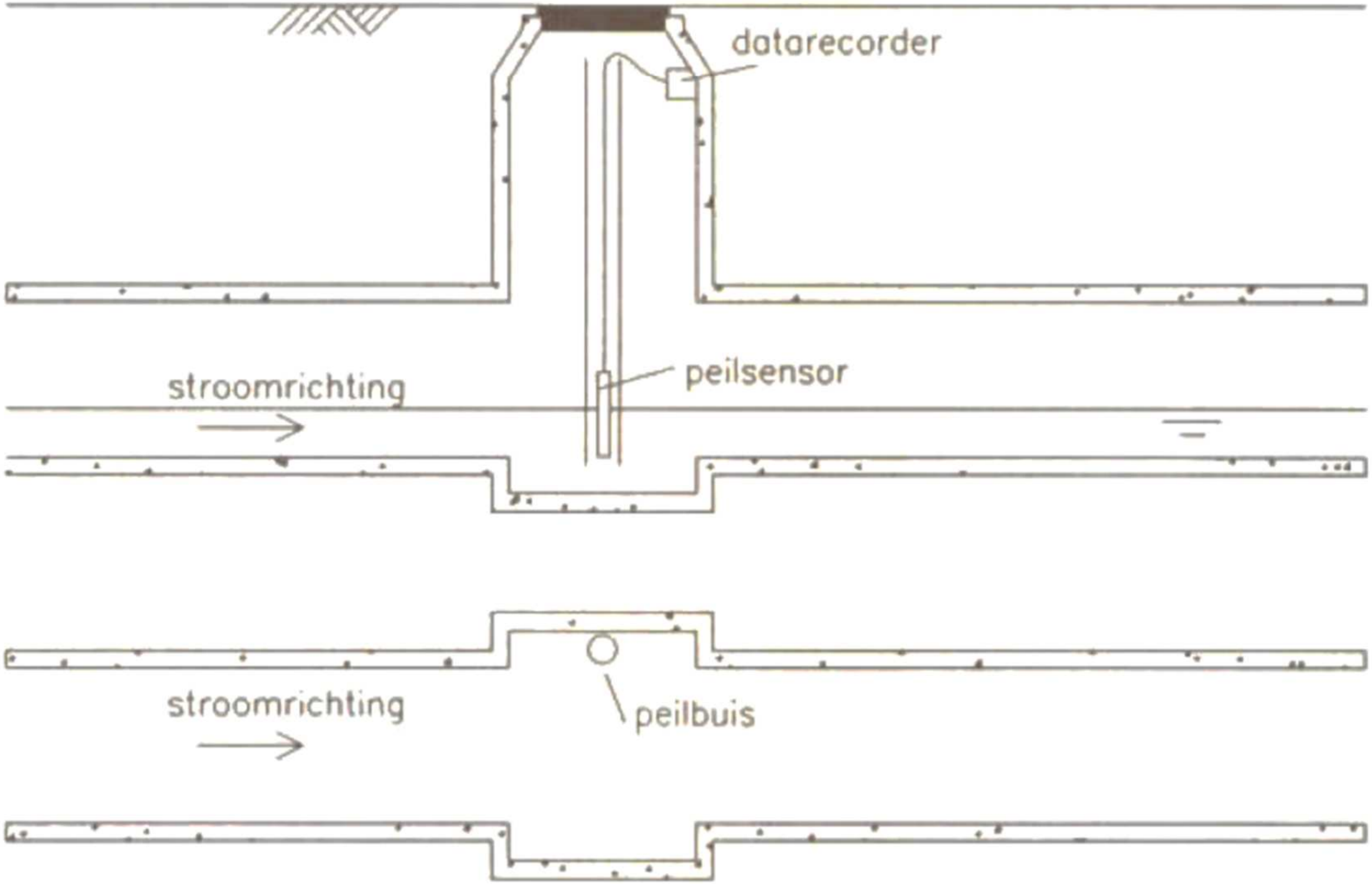




RAINGAIN
EU-funded, 13 partners:
Leuven, London, Paris, Rotterdam

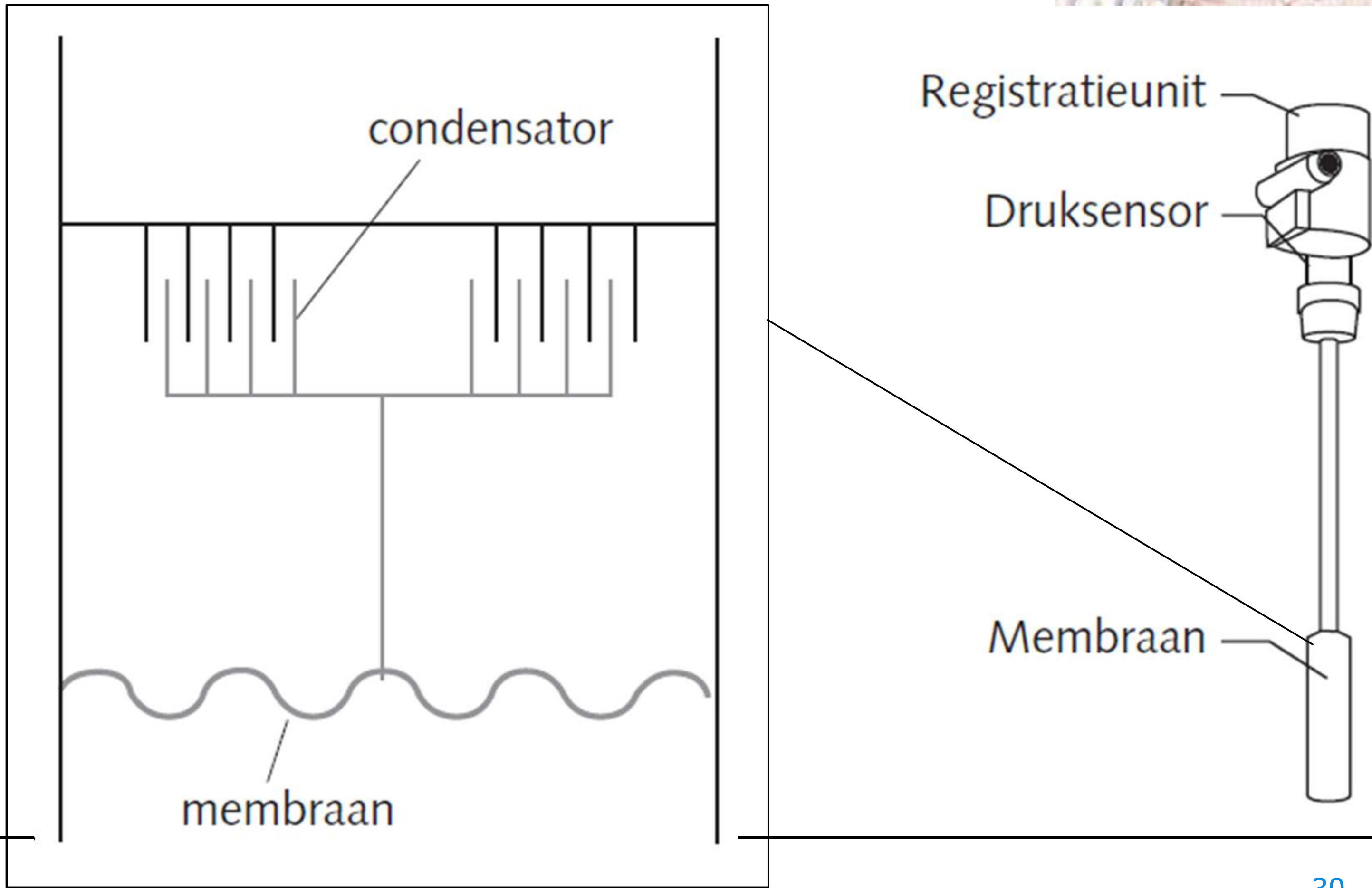
Water level measurements

Pressure sensors



Water level measurements

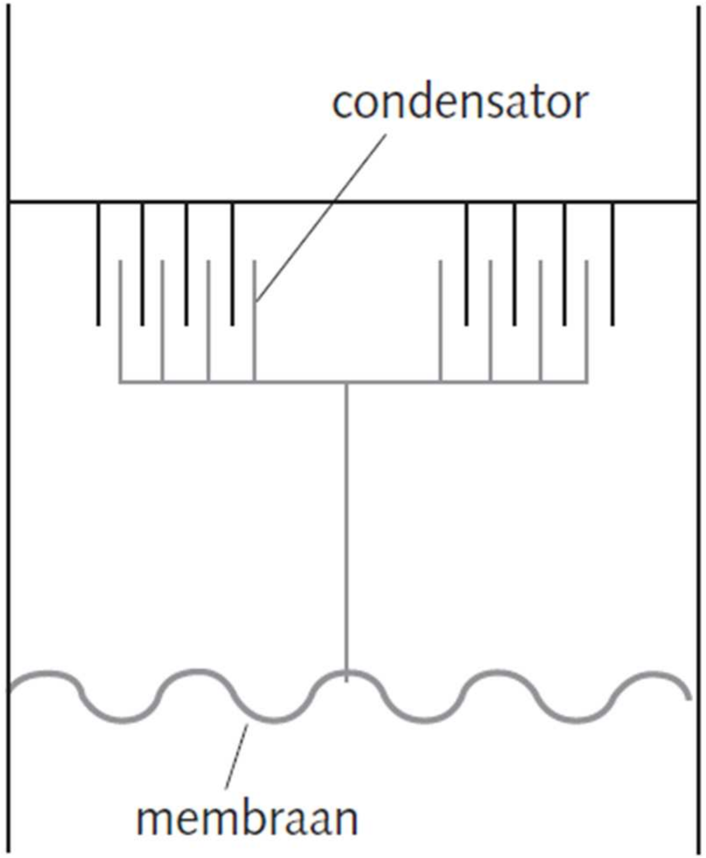
Pressure sensors



Water level measurements

Pressure sensors

- Membrane deforms under pressure
- Condensator translates deformation into electric signal:
- Deformation ↑ Electric signal ↑
- Electric signal translated into pressure
- (calibration!)
- Pressure translated into water level

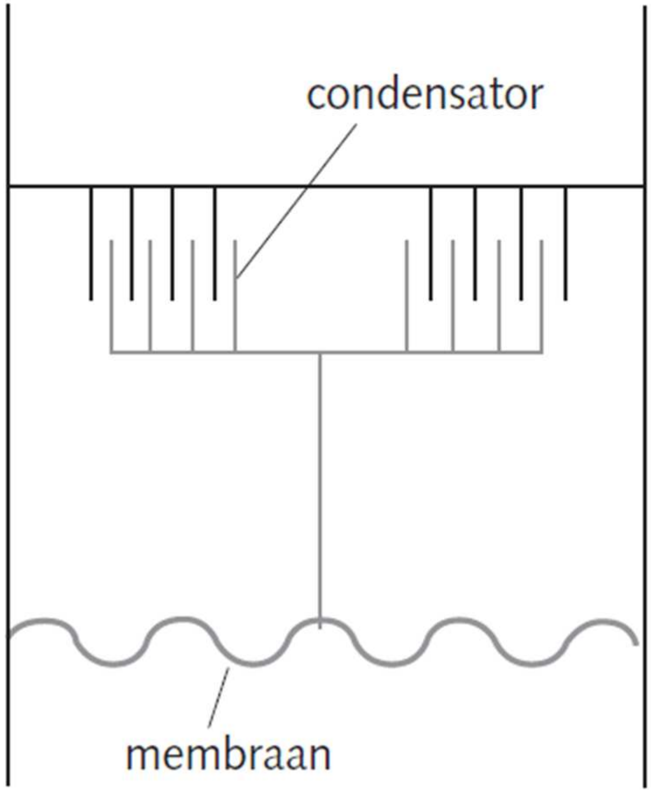


Water level measurements

Pressure sensors

- Pressure translated into water level:

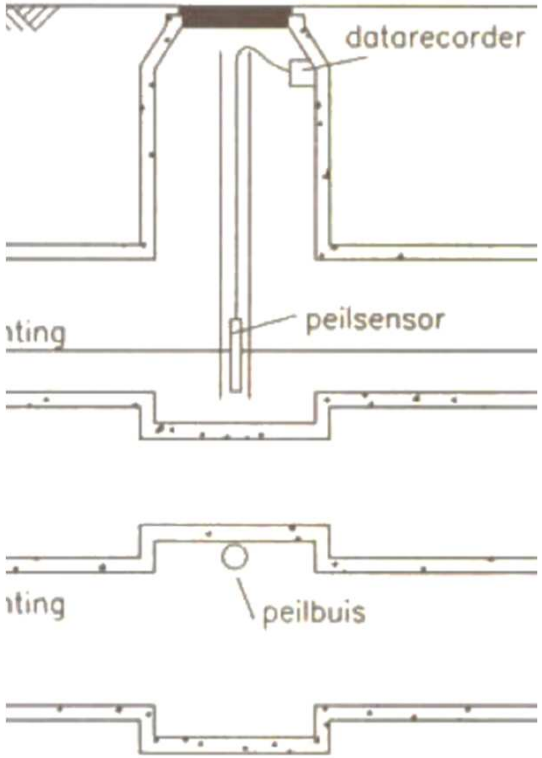
$$h = \frac{\Delta p}{g\left(\rho_w - \rho_a\right)} - \frac{\left(\Delta p\right)^2}{2gK\left(\rho_w - \rho_a\right)}$$



h : water depth (m)
g : gravitation acceleration (m/s^2)
K : Compression modulus (N/m^2)
ρ_w : density of water (kg/m^3)
ρ_a : density of air (kg/m^3)
Δp : difference between water pressure and atmospheric pressure (N/m^2)

Water level measurements

Pressure sensors

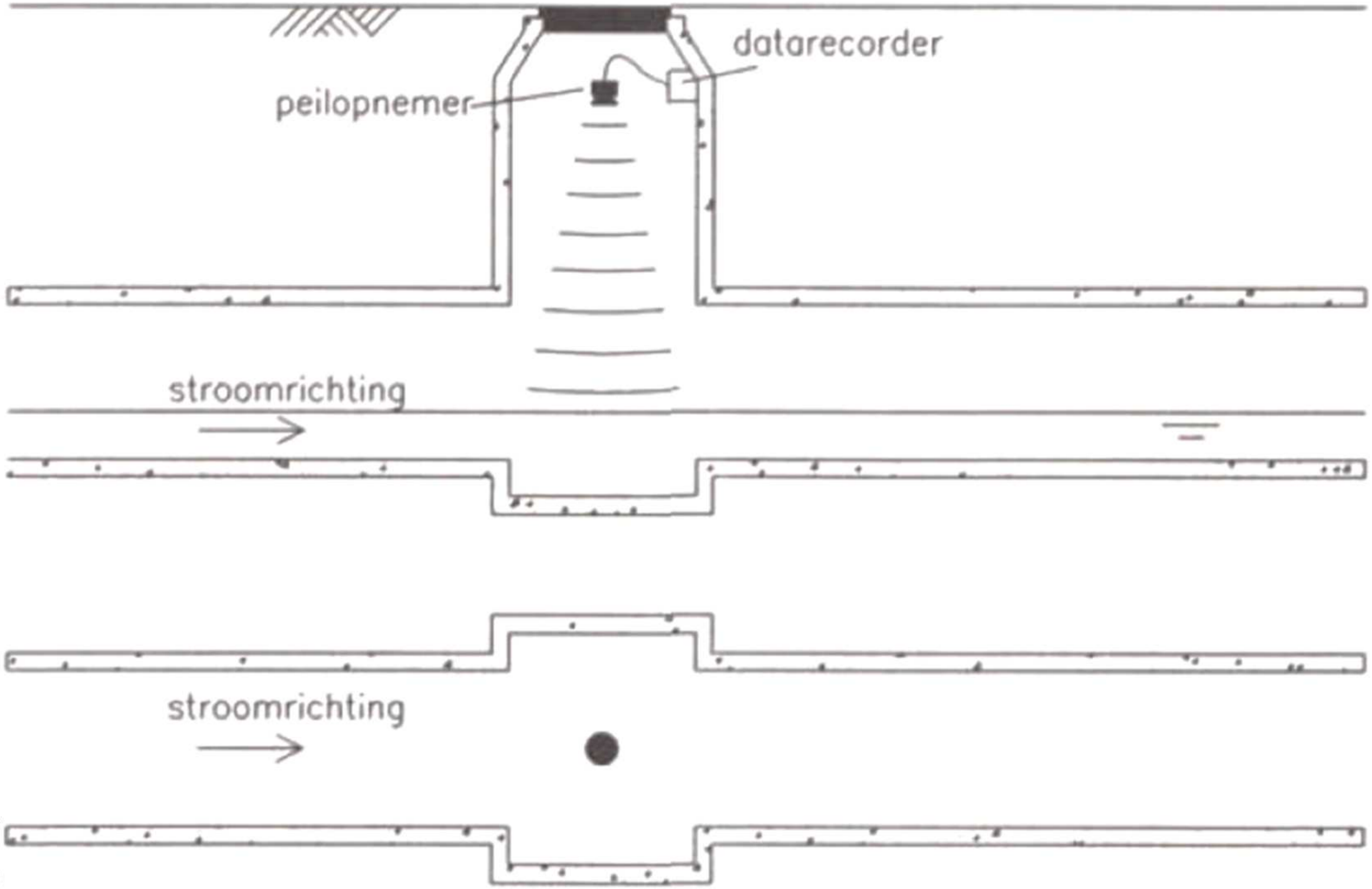


Practical considerations:

- Install in tube to protect sensor from damage, debris
- Prevent air entrainment in water near sensor
- Check and correct at regular intervals for zero point drift (pollution of vent tube)

Water level measurements

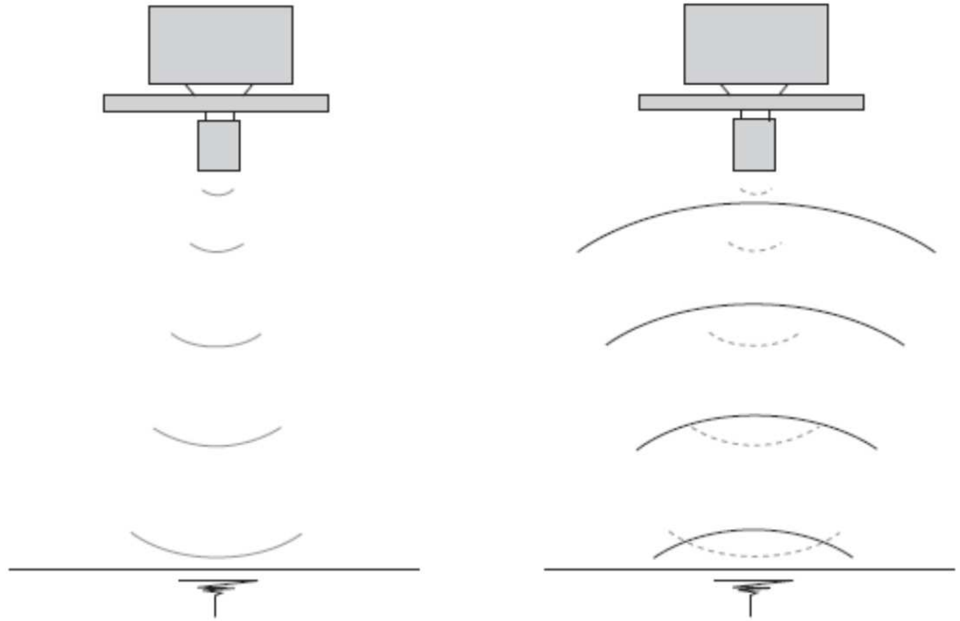
Acoustic sensors



Water level measurements

Acoustic sensors

- Sound wave travels to water surface – reflects – travels back
- Sensor measures travel time
- Travel time translated into distance → water level

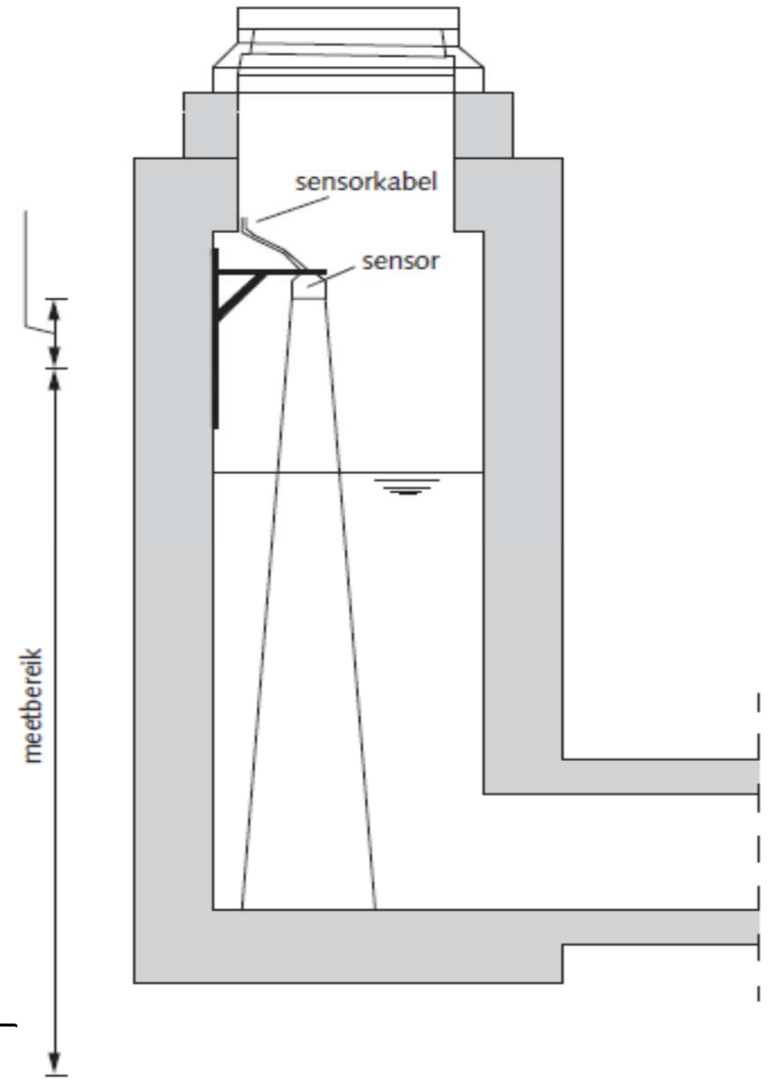


Water level measurements

Acoustic sensors

Practical considerations:

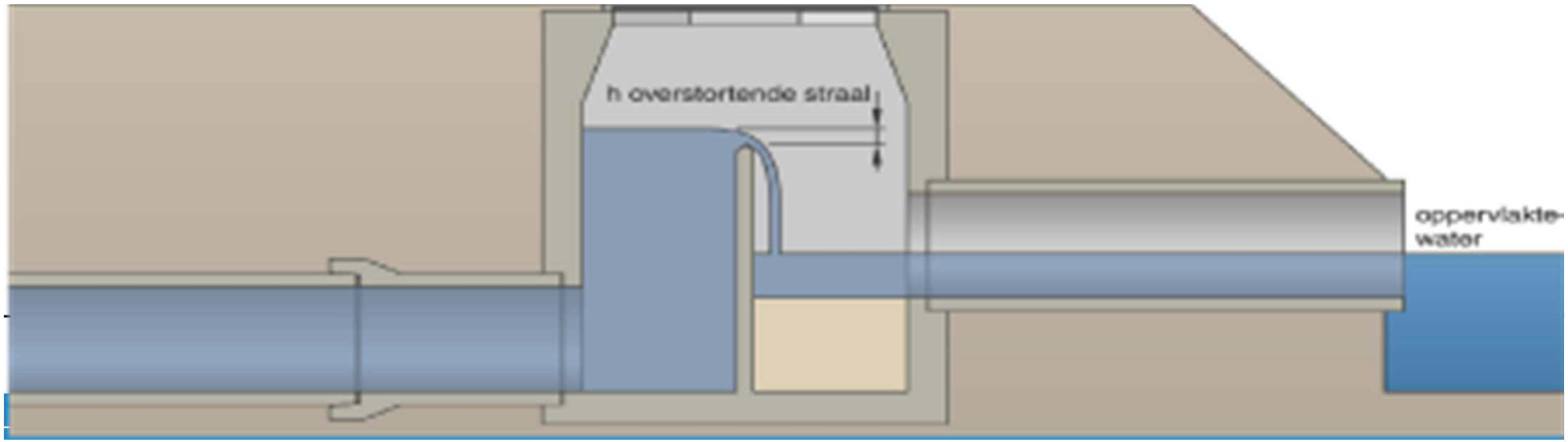
- Minimum distance to water level
- Prevent local reflections
- Check and correct at regular intervals for zero point drift (pollution of vent tube)



Discharge measurements

Flow measurement at weirs

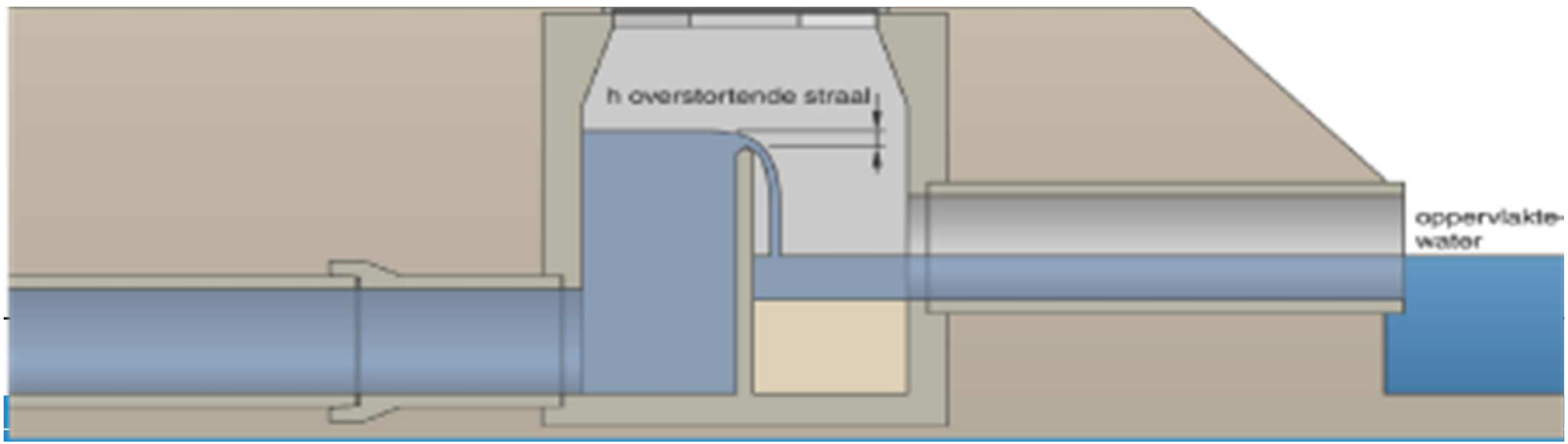
- Flow derived from water measurement above weir



Discharge measurements

Flow measurement at weirs

- Flow derived from water measurement above weir
- Location of water level sensor upstream of weir: distance at least >3x water depth



Discharge measurements

Flow measurement at weirs

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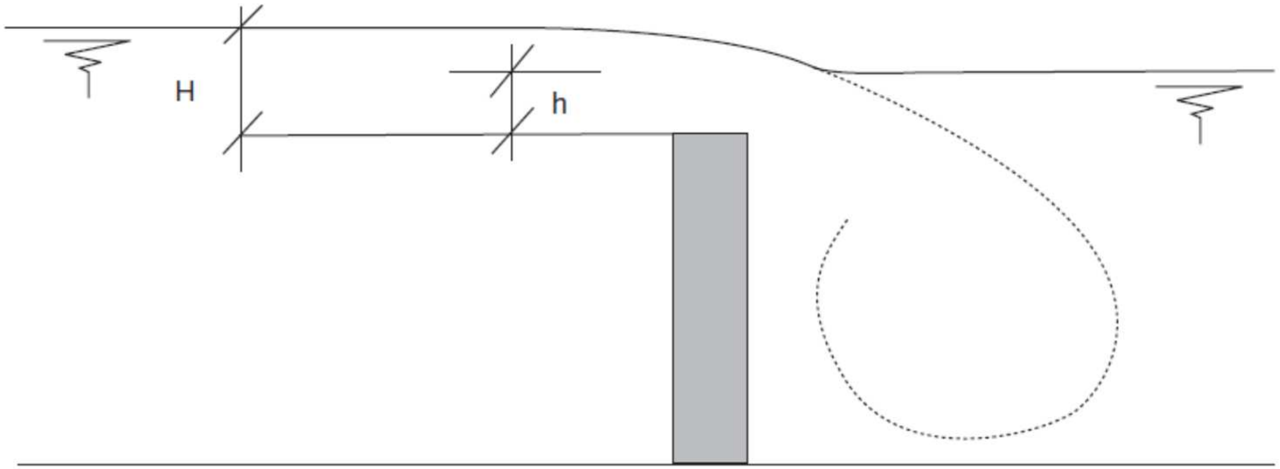


Discharge measurements

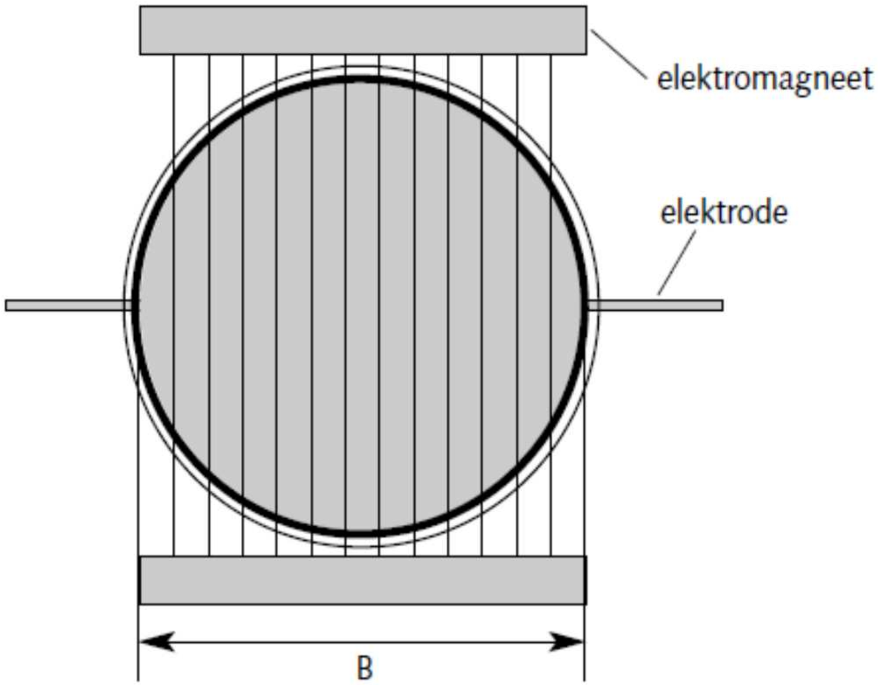
Flow measurement at weirs

- Flow derived from water measurement above weir
- Location of water level sensor upstream of weir: distance at least >3x water depth
- Check for submerged conditions
- Local calibration essential

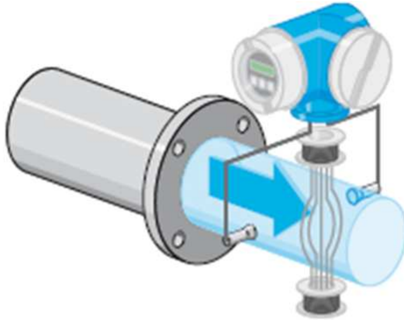
Discharge measurements

In full pipes: electromagnetic flow meter

- Water (conductive) flow through magnetic field creates electric voltage
- Voltage translated into flow velocity
- Discharge Q = v * A



Discharge measurements



In full pipes: electromagnetic flow meter

Applications:

- Outgoing main of pumps in pumping station
- Influent wastewater treatment plant
- Industrial discharge pipe
- Siphons in sewer system

http://youtu.be/f949gpKdCI4

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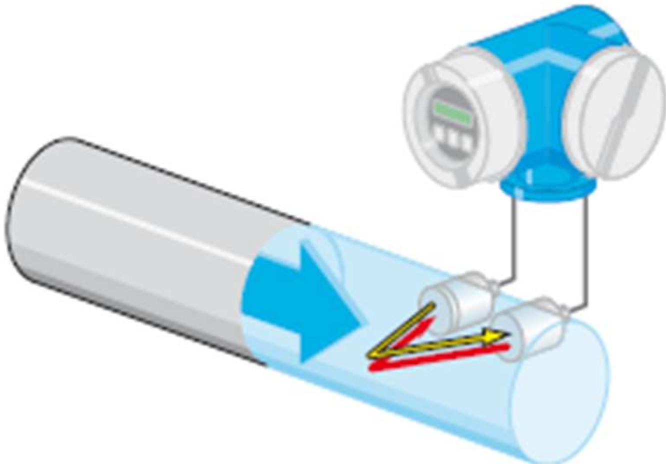
Discharge measurements

In full pipes: ultrasonic flow meter

- Acoustic send/receive sensors across pipe
- Can be clamped on outside of pipe



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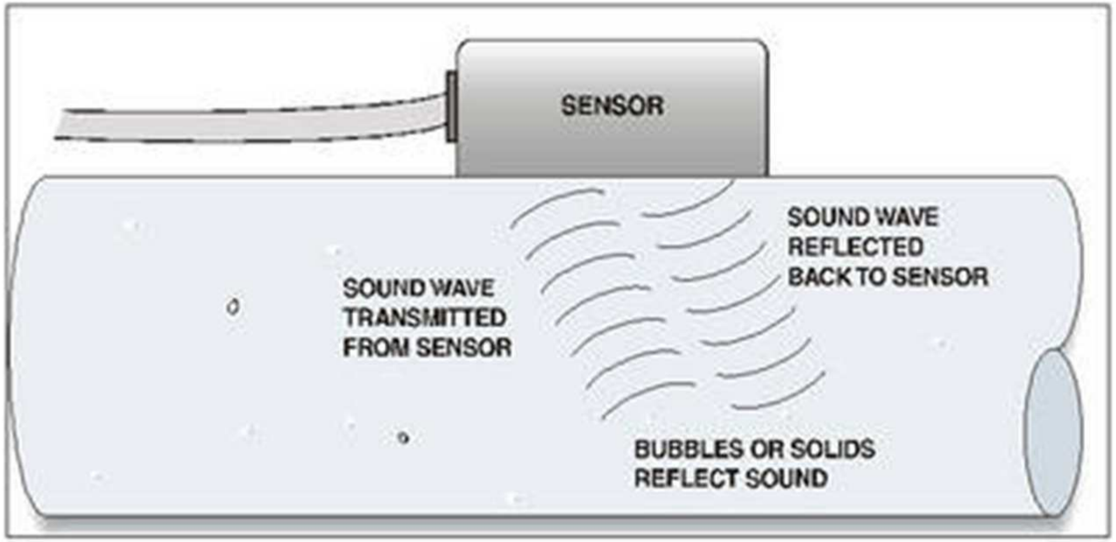
Discharge measurements

In full pipes: Doppler flow meter

- Doppler effect: wave length of sound changes as the sound source moves towards or away from the observer
- Can be clamped on outside of pipe



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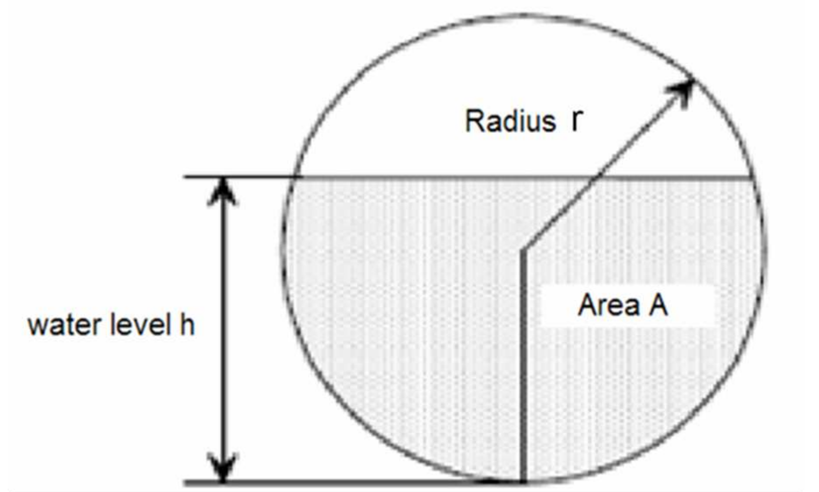
Discharge measurements

In part-full pipes, measurement principle:

Discharge (Q) → [m^3/h]

→ Water level measurement (h) → A(h)
→ Velocity measurement (v)



$$A(h)=\left(r^2 \arccos\left(1-\frac{h}{r}\right)-(r-h)\sqrt{rh-h^2}\right)$$

Discharge measurements

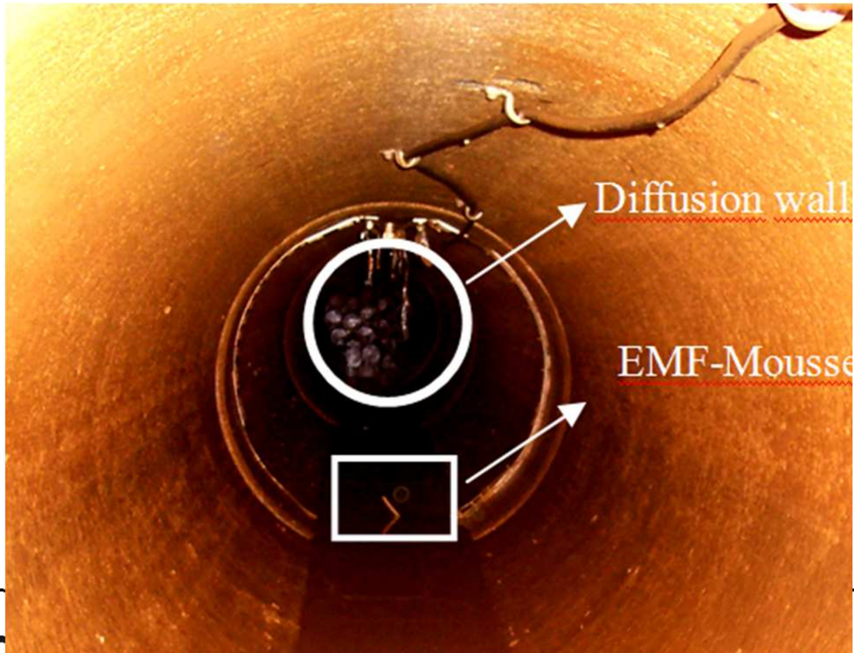
In part-full pipes: Electromagnetic flow meter

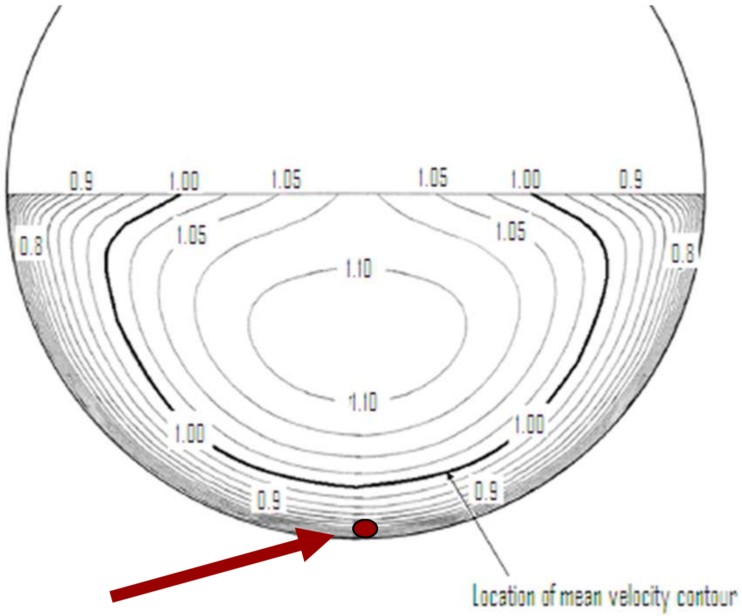
- Pressure sensor incorporated for water level
- Velocity measurement electromagnetic principle: at pipe bottom.

Discharge measurements

In part-full pipes: Electromagnetic flow meter

- Pressure sensor incorporated for water level
- Velocity measurement electromagnetic principle: at pipe bottom.

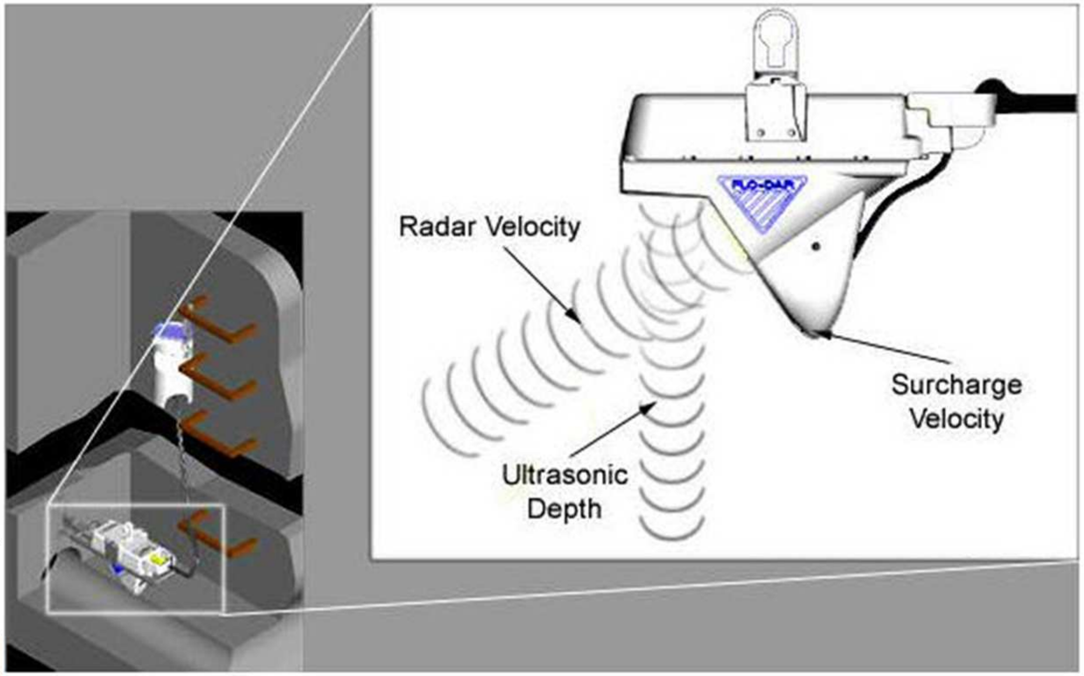




Discharge measurements

In part-full pipes: Doppler radar flow meter

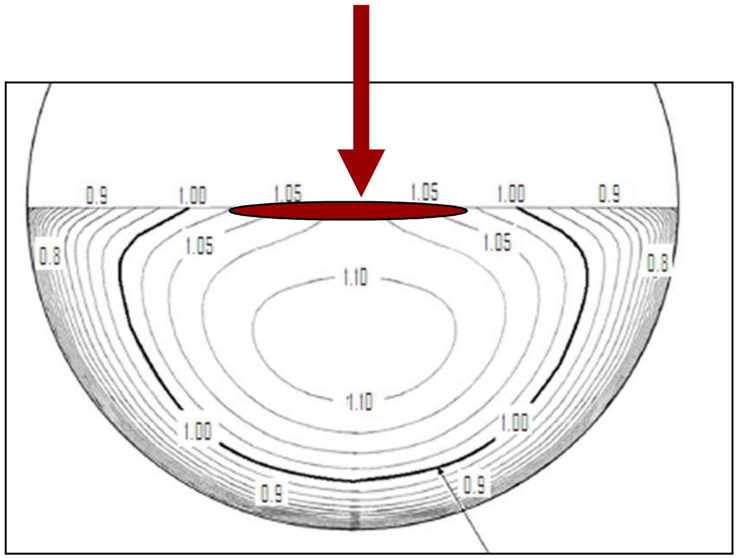
- Doppler effect: radar wave is reflected on liquid surface
- Separate pressure sensor for water level measurement



Discharge measurements

In part-full pipes: Doppler radar flow meter

- Doppler effect: radar wave is reflected on liquid surface
- Separate pressure sensor for water level measurement
- Translates surface flow velocity to cross-sectional average velocity

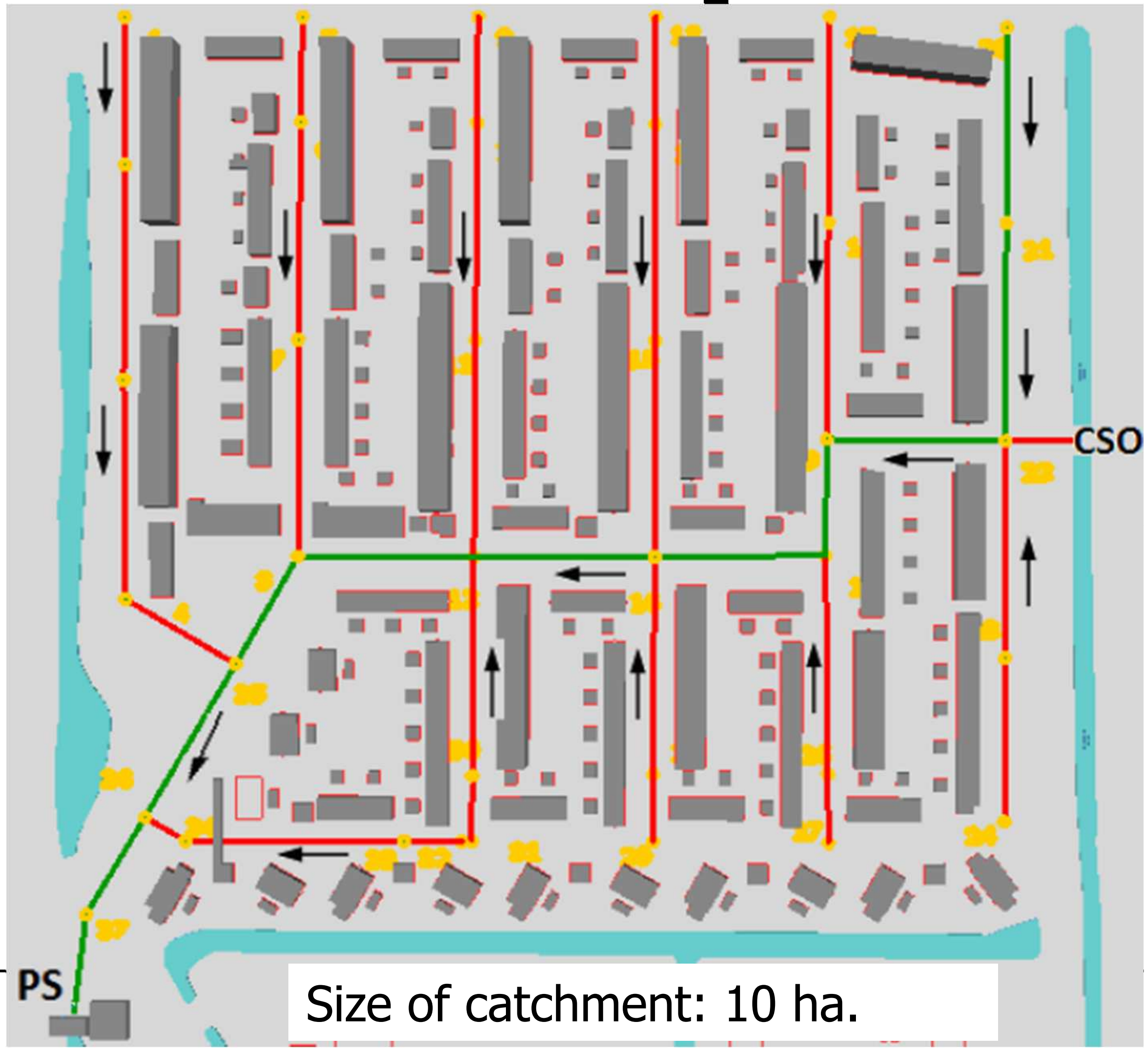


Type of measurement	Type of sensor	Accuracy	Remarks
Water level	Pressure sensor	++	Submerged sensor: pollution/damage
	Acoustic sensor	+	Air bubbles, turbulence, foam, fat can disturb measurement
Discharge at weir	Pressure sensor at weir	+/-	On-site calibration required; Obstacles/pollution on weir can disturb measurement
Discharge full pipe	Electromagnetic flow meter	++	Only conductive liquids
	Acoustic flow meter	+	Inaccurate at low flows; air bubbles etc. disturb measurement
	Doppler flow meter	+	Sediments, high concentration of susp. solids can disturb signal
Discharge part-full pipe	Electromagnetic flow meter	+/-	Measures flow velocity at pipe bottom: representative of cross-section?
	Doppler radar flow meter	+/-	Measures flow velocity at water surface: representative of cross-section?

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

- Measurement parameters?
- Measurement locations?
- Type of sensors?



Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

Measurement parameters:

-

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

Measurement parameters:

- Rainfall:
- Flow:
- Water levels:

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

Measurement parameters and locations:

- Rainfall:
- Flow:
- Water levels:

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

Measurement parameters and locations:

- Rainfall: 1 rain gauge + radar data KNMI
- Flow: outflow to CSO, outflow of pumping station
- Water levels:
  - In sewers: near CSO (inside) 2-3 locations along main sewer line (based on experience/first model calculations)
  - Surface water level near CSO (outside)
  - Groundwater level (if indications of high infiltration rate)

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

Measurement locations – special remarks:

- Rainfall: rain gauge in center. ! Select suitable location
- Flow: preferably in completely filled pipes
  - → Outgoing main of pumping station, at CSO only under CSO conditions
- Water levels: easy access for maintenance (i.e. not in manhole on busy road)

Assignment: Measurement plan

Measurement objective: Calibrate and verify hydrodynamic model

- Rain gauge
- Flow sensor
- Water level sensor