# Modellering af LAR anlæg samt modellering af stoffjernelse i LAR anlæg og bassiner

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# Background & Objective

- Developed under the umbrella of research project: “Cities in Water Balance”, 2011-2014
- Objective: Develop modelling support of green storm water infrastructure in MIKE URBAN:
  - Support modelling of various LID technologies in a generic but relative simple user interface
  - It shall be possible to connect implemented LID technology hydraulically to existing drainage network
  - Support of various treatment options

# MIKE URBAN - Modelling of LID technologies at two levels

- Screening method (**Catchment based**)
  - Method for assessment of the required capacity or efficiency of instalment of various LID controls in a catchment. The LID controls are integrated with MIKE 1D and the runoff model B

- Detailed method (**Network based**)
  - Detailed hydraulic assessment of Soakaway solutions with option to couple to existing drainage network.
  - Option for assessment of various treatments using ECO Lab.

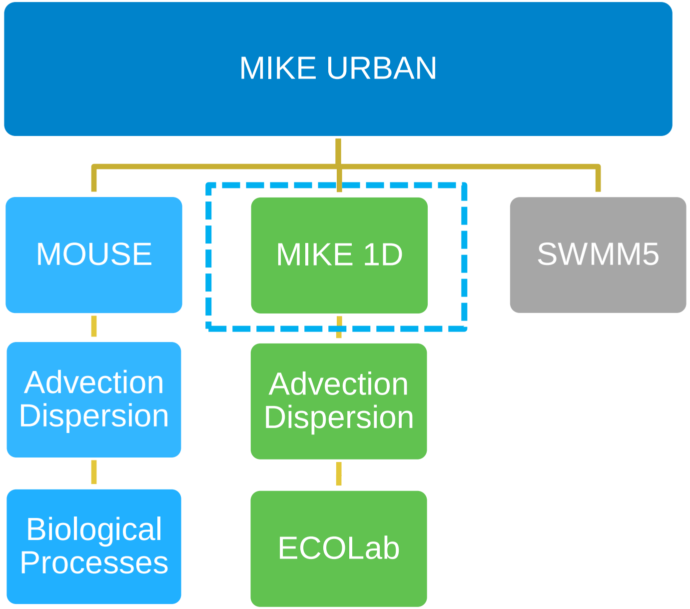
# Terminology

- Different terminology used in different countries
- MIKE URBAN – US terminology

| Grouping | UK | US | Australia | Denmark |
|---|---|---|---|---|
| | **SUDS**<br><br>**Sustainable Urban Design Systems** | **LID**<br><br>**Low Impact Development** | **WSUD**<br><br>**Water Sensitive Urban Design** | **LAR**<br><br>**"Lokal Afledning af Regnvand"** |
| Road layout | | **Bio–Retention Cell** | Bio-Retention<br><br>(- Systems, -Swales, -Basins), "Treatment Train" approach | **Vejbed, Faskine** |
| | Filter and Infiltration Trenches | **Infiltration Trench** | Infiltration Trenches and systems | **Vejgrøfter** |
| | | | Sand filter | |
| | Permeable surfaces | **Porous Pavement** | Porous Paving | **Gennemtrængelige belægninger** |
| Public open spaces | | | Sedimentation Basins | Sedimentations-bassiner |
| | | | Constructed wet lands | |
| | Swales | **Vegetative swale, Swales** | Vegetated swale | **Vejgrøfter** |
| | Filter strips | Filter strips | Buffer strips | Grønt område |
| | Ponds | Ponds | Ponds | Regnvandsbassiner |
| | Wetlands | Lakes, Wetlands | Lakes, Wetlands | Søer |
| Water Reuse | Rainwater tanks | **Rain Barrel, Cisterns** | Rainwater tanks | **Regnvandstønder** |
| | Aquifer storage and recovery (ASR) | Aquifer storage and recovery (ASR) | Aquifer storage and recovery (ASR) | |
| Local infiltration | | | Soakways / Soakwells | Faskine |
| | Green Roof | **Green Roof** | Green Roof , Roofwater | **Grønne tage** |
| | Rain Garden | **Rain Garden** | Rain Garden | **Regnbede** |

# MIKE URBAN 2016 – MIKE 1D

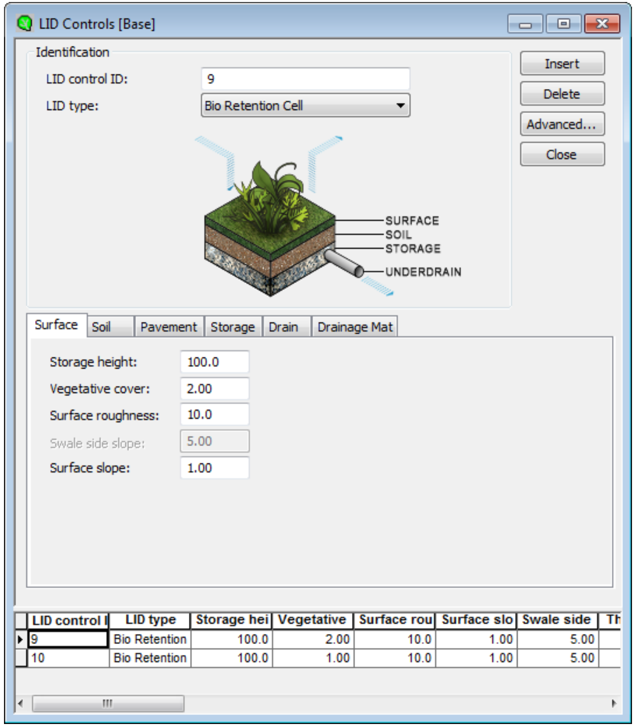
- MIKE 1D includes LID and Soakway (not available in MOUSE)
- MIKE 1D includes option for transport of pollutants by Advection-Dispersion
- MIKE 1D is coupled to ECO Lab for Water Quality modelling
- MIKE 1D can be coupled to MIKE 21 (MIKE FLOOD)



# Screening Level - LID Controls

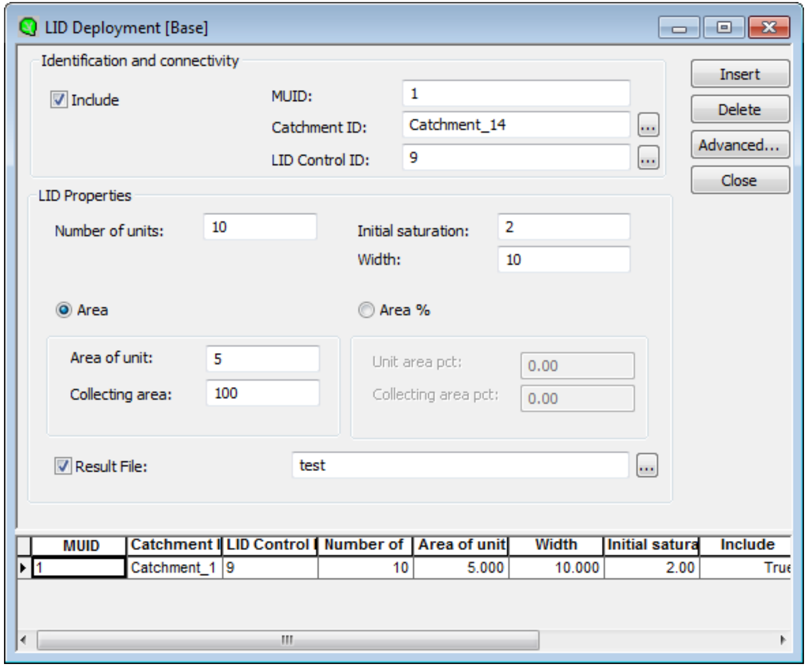
# MIKE URBAN – LID Controls

- Bio Retention Cell (Vejbed)
- Porous Pavement (Gennemtrængelig belægning)
- Infiltration Trench (Vejgrøft, rende)
- Rain Barrels (Regntønder)
- Vegetative Swale (Rende med beplantning)
- Rain Garden (Regnbede)
- Green Roof (Grønt tag)

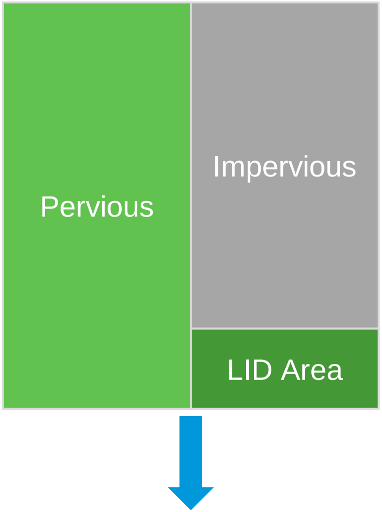


# MIKE URBAN – LID Deployment

- Deployment of LID Controls to each catchment
  - Number of a LID Control
  - Contributing area (ha or %)
  - Result file per deployment



# MIKE URBAN – Principle of catchment based LID modelling




- The original contributing area is reduced with the area included in the specified LID controls
- LID solutions can be considered as advanced methods for calculating the effective precipitation (storage and infiltration)
- Runoff from the LID controls towards outlet point is routed with the same routing method and parameters as used for the total catchment
- The result is a composite hydrograph made up by:
  - (a) runoff from catchment reduced by area connected to LID control
  - (b) runoff from the LID control

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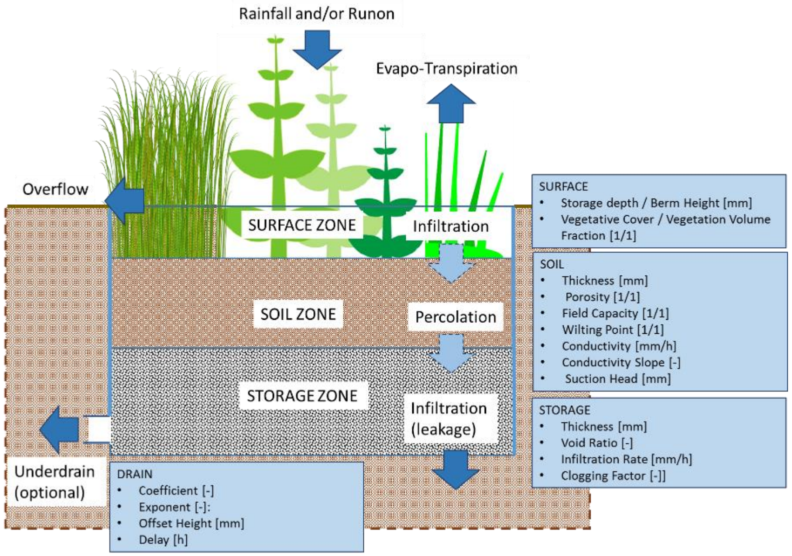
# Bio-retention Cell (Vejbed)

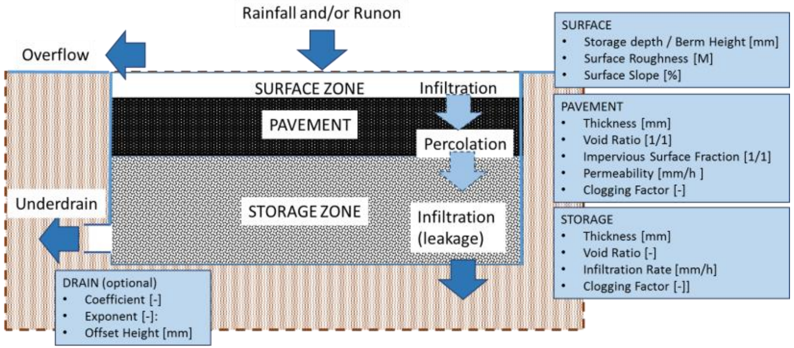
- *Bio-retention Cells* are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas.




Bio-retention Cell Concept

# Porous Pavement (Gennemtrængelig belægning)

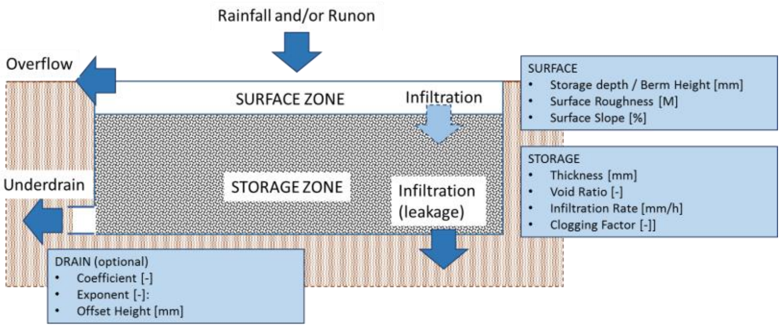
- *Porous Pavement* systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix


Porous Pavement Concept

# Infiltration Trench (Vej grøft)

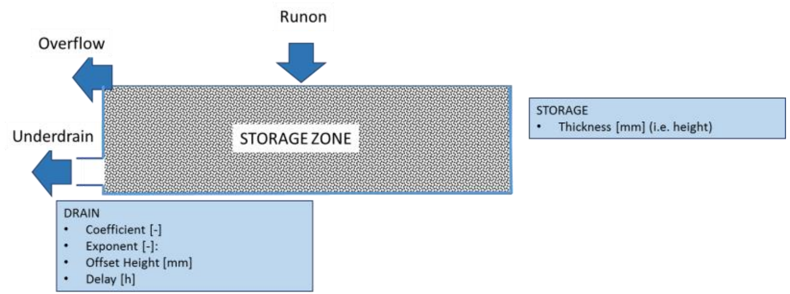
- *Infiltration Trenches* are narrow ditches filled with gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate the native soil below




Infiltration Trench Concept

# Rain Barrel (Regn tønder)

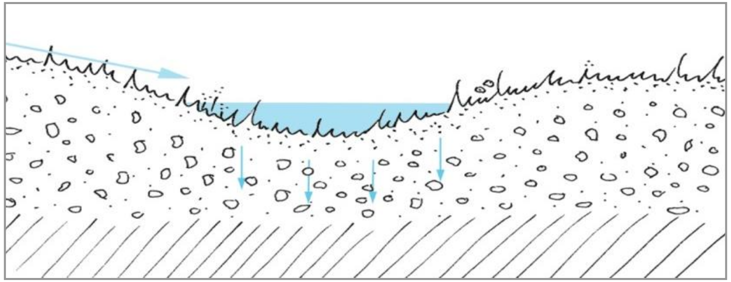
- *Rain Barrels* (or *Cisterns*) are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods




Rain Barrel Concept

# Vegetative Swales (Render med beplantning)

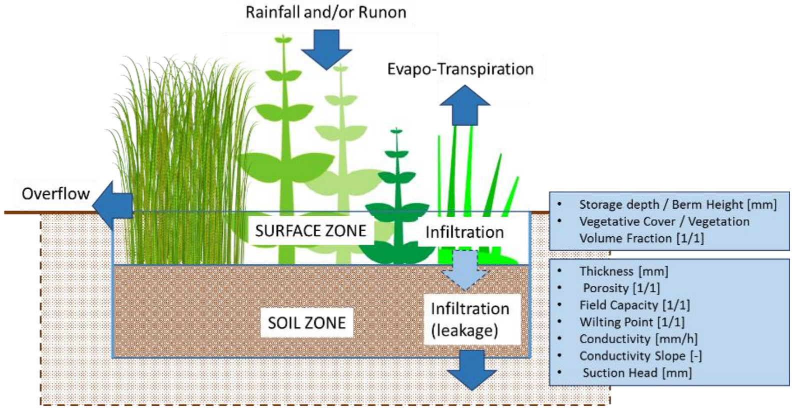
- *Vegetative Swales* are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.



Vegetative Swale

# Rain Gardens (Regnbede)

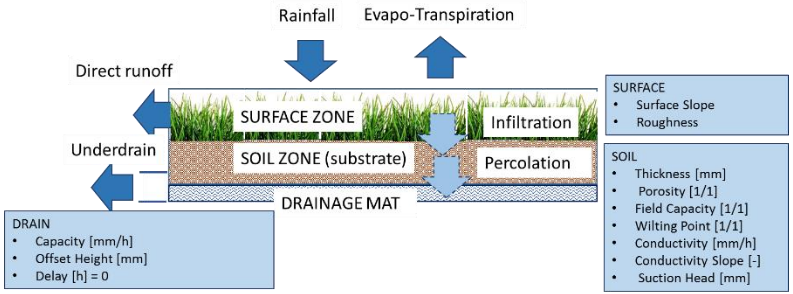
- *Rain Gardens* are a type of bio-retention cell consisting of just the engineered soil layer with no gravel bed below it.




Raingarden Concept

# Green Roof (Grønne tage)

- *Green Roofs* are another variation of a bio-retention cell that have a soil layer laying atop a special drainage mat material that conveys excess percolated rainfall off of the roof.




Green Roof Concept

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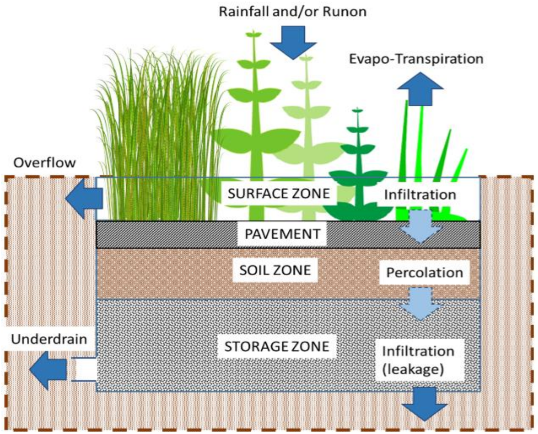
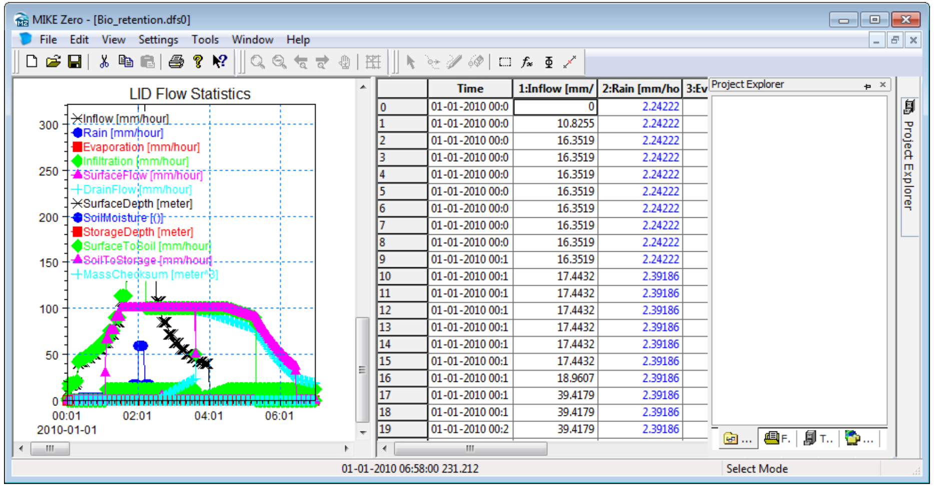
# LID Flow Statistics

- Runon / Inflow
- Rainfall
- Evaporation
- Infiltration
- Surface Flow (Overflow)
- Drain Flow (Underdrain)
- Surface Depth
- Soil Moisture
- Surface to Soil Flow
- Soil to Storage Flow
- Mass Balance

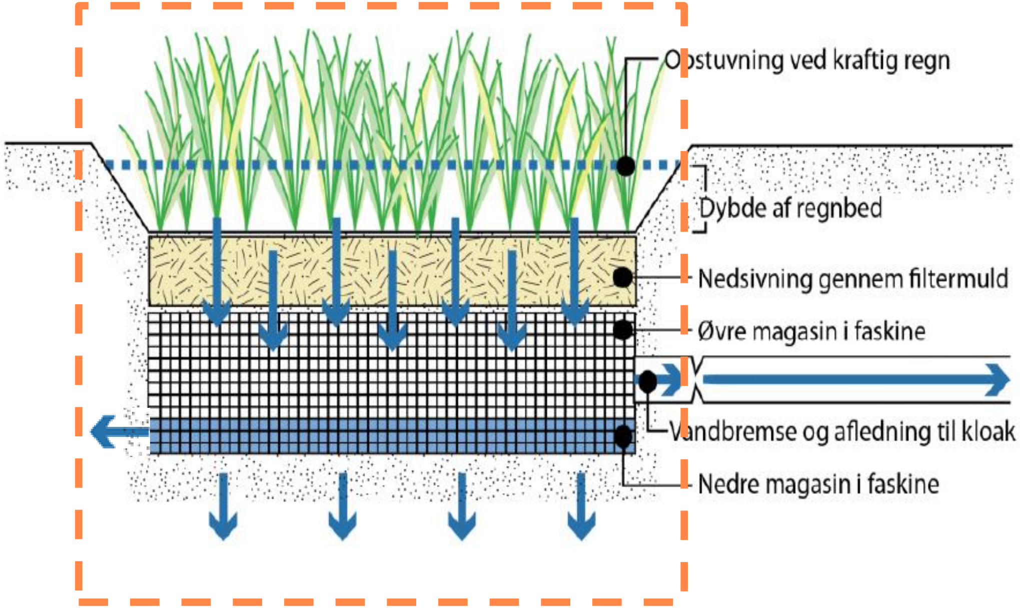


# Detailed Level – “Soakaway”

# MIKE URBAN – “Soakaway” Concept

- **Network based** – “Soakway” modelling



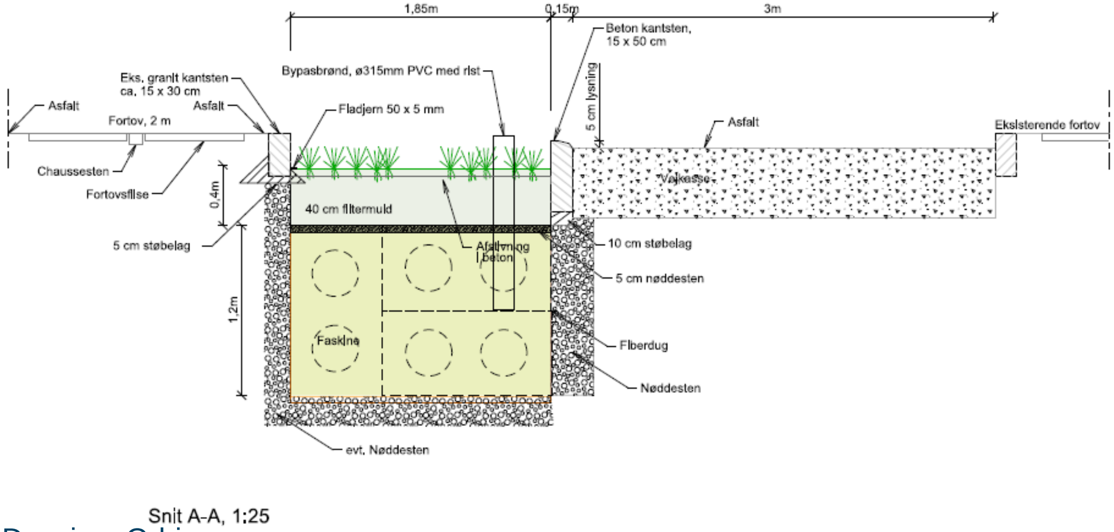

**“Soakaway”**

# Key numbers – Lindevang, Brøndby

- 7 bio-retention cells
- 2*8 metres in dimension
- Partially decoupled with overflow to drainage system
- Sizing – 3 year rain event with climate factor 1.56
- Decoupled road area: approx. 2000 m2
- Volume: 112 m3
- Traffic: max. 30 km/h

# Bio-retention cells – Lindevang, Brøndby

- 7 bio-retention cells constructed
- Not coupled directly to existing drainage system




Drawing: Orbicon

# Key numbers – Møllebakken, Brønshøj

- 4 bio-retention cells
- Blocking storm water inlets
- 2 cells - 1.8*10 metres
- 2 cells - 1.8*8 metres
- Coupled to drainage system
- Sizing – 10 year storm event
- Decoupled road area: 1329 m2
- Volume: 19.3 / 24.1 m3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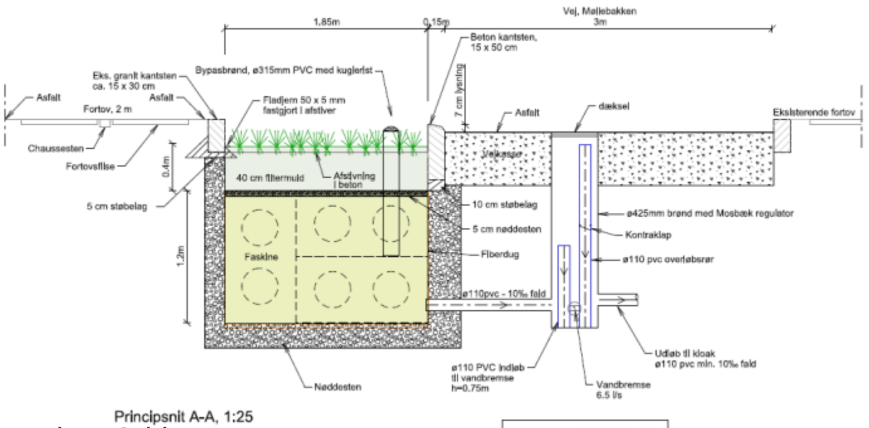
# Bio-retention cells – Møllebakken, Brønshøj

- 4 bio-retention cells constructed
- Some street storm water inlets closed off
- Connected to existing drainage system by outlet pipe, outflow control, offset level, bypass pipe and weir




Drawing: Orbicon

# MIKE URBAN – ”Soakaway”

- New node type (ID, point feature)
  - User defined basin geometry
  - An average porosity of filling material
    - (under consideration to support multiple layers)
- Boundary Condition
  - Initial water level
- Infiltration
  - No infiltration
  - Constant infiltration
  - Infiltration through side and bottom as a function of water level
- Saturated hydraulic conductivity (side and bottom)

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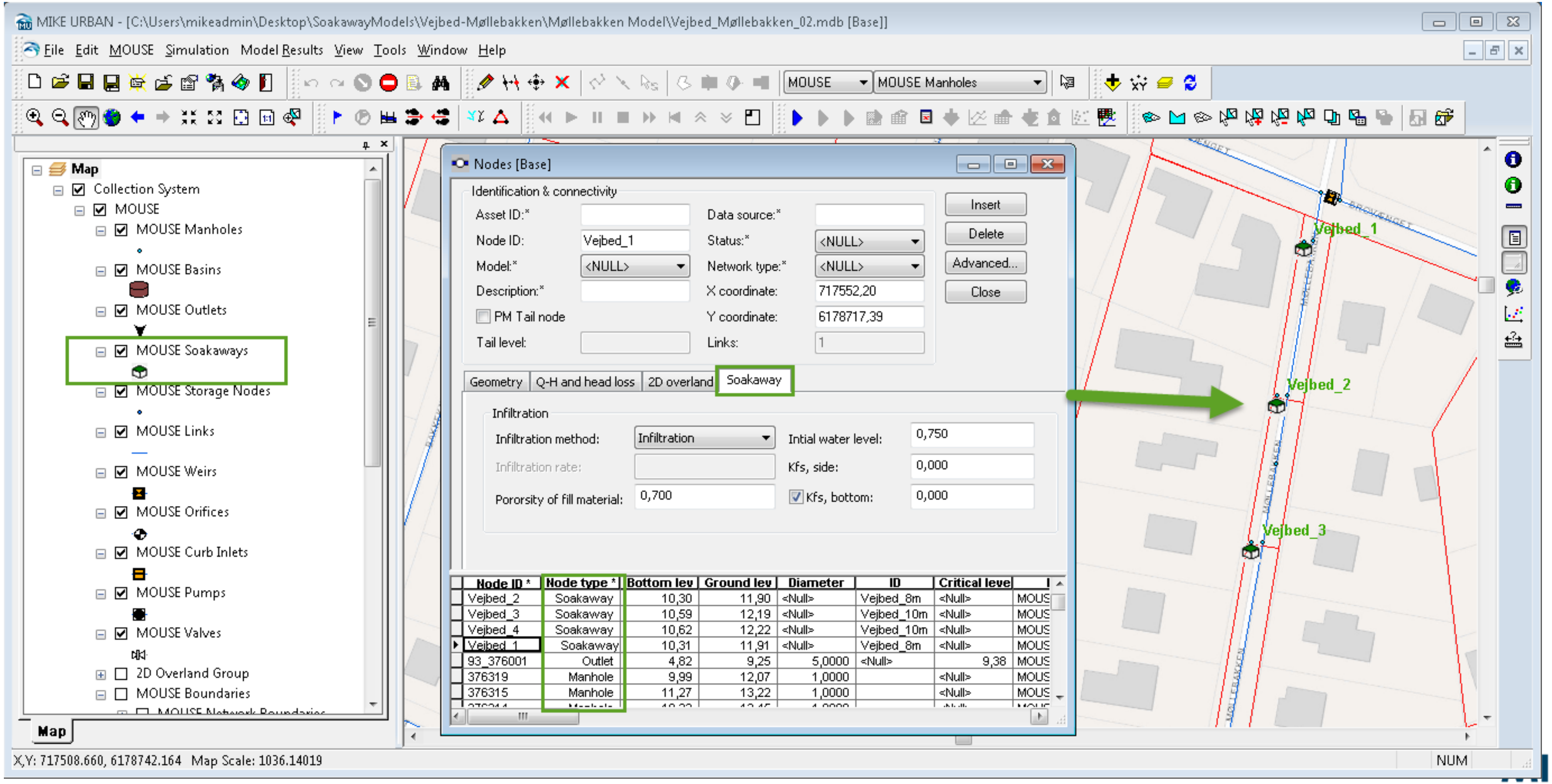
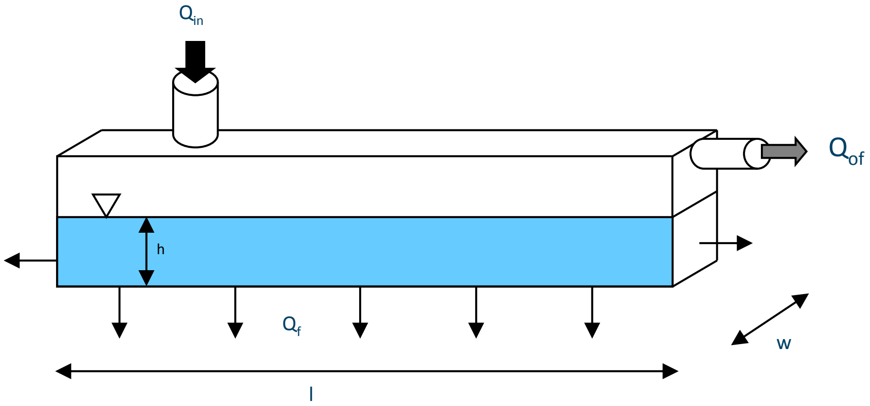
# MIKE URBAN Software Implementation - ”Soakway”



# MIKE URBAN – “Soakaway” infiltration formula




$$\frac{dh}{dt} = \frac{1}{l*w*\theta}\left(Q_{in}(t) - Q_f(t) - Q_{of}(t)\right)$$

$$Q_f = K(l * w + 2h(l + w))$$

$$Q_f = K_{bottom} * A_{s,\,h=0} + K_{side} * (2 * A_c + 2 * \frac{Vol}{A_c})$$

| Definition and SI unit | Symbol |
|---|---|
| Soakway porosity [-] | $\theta$ |
| Field-saturated hydraulic conductivity [m/s], bottom | $K_{fs,\ bottom}$ |
| Field-saturated hydraulic conductivity [m/s], side | $K_{fs,\ side}$ |
| Water level (calculated by MIKE 1D) | h |
| Surface Area | $A_s$ |
| Cross sectional Area | $A_c$ |

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# Porosity - Filling material

- Stone, ρ = 20

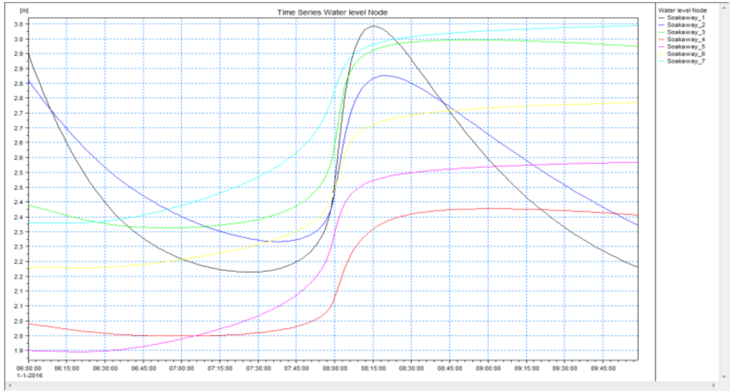
- Leca, ρ = 50

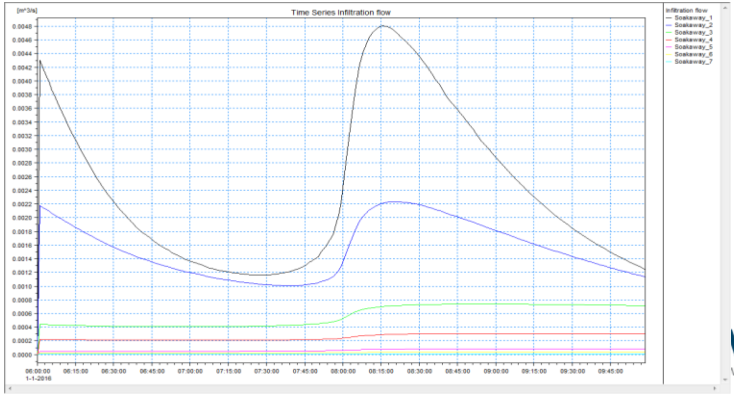
- Plastic soakaway crate, ρ = 90

# Water level and Infiltration flow for various soil conductivities

- Typical values for various soil classifications

| Soil classification | Hydraulic Conductivity [m/s] |
|---|---|
| Gravel | $1e^{-3}$ to 0.1 |
| Sand | $1e^{-5}$ to $1e^{-2}$ |
| Silt | $1e^{-9}$ to $1e^{-5}$ |
| Clay | Below $1e^{-9}$ to $1e^{-2}$ |
| "Moræneler" | $1e^{-10}$ to $1e^{-6}$ |



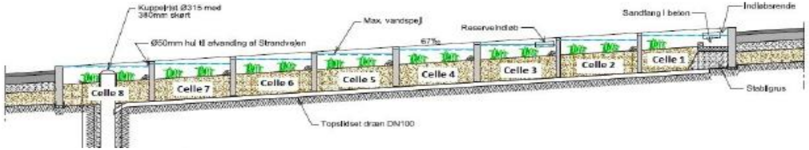



# MIKE URBAN – ”Soakway” - Hydraulics

- Can be connected to network as any other point feature in MIKE URBAN with links, weirs, orifices, gates, and pumps.

- Flow control on outlet can be applied

- Can be coupled in series by weirs to represent constructed swales

# Water Quality – Treatment using ECO Lab

# MIKE URBAN 2016 – MIKE 1D

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- ECO Lab is coupled to MIKE 1D for Water Quality modelling
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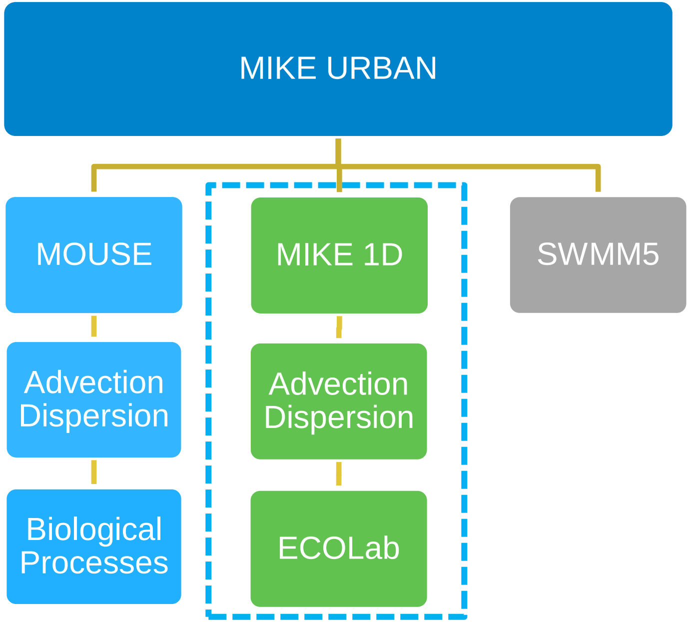


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# What is “ECO Lab“?

ECO Lab

- A numerical laboratory for ecological modelling in aquatic environments
  - Open Equation solver for coupled ordinary differential equations
  - Designed for point descriptions of processes of chemistry, ecology etc.
  - All equations, parameters contained in generic, portable ECO Lab templates

- Seamless coupled into most Mike-by-DHI hydraulic engines
  - Transport calculations, result representation etc.

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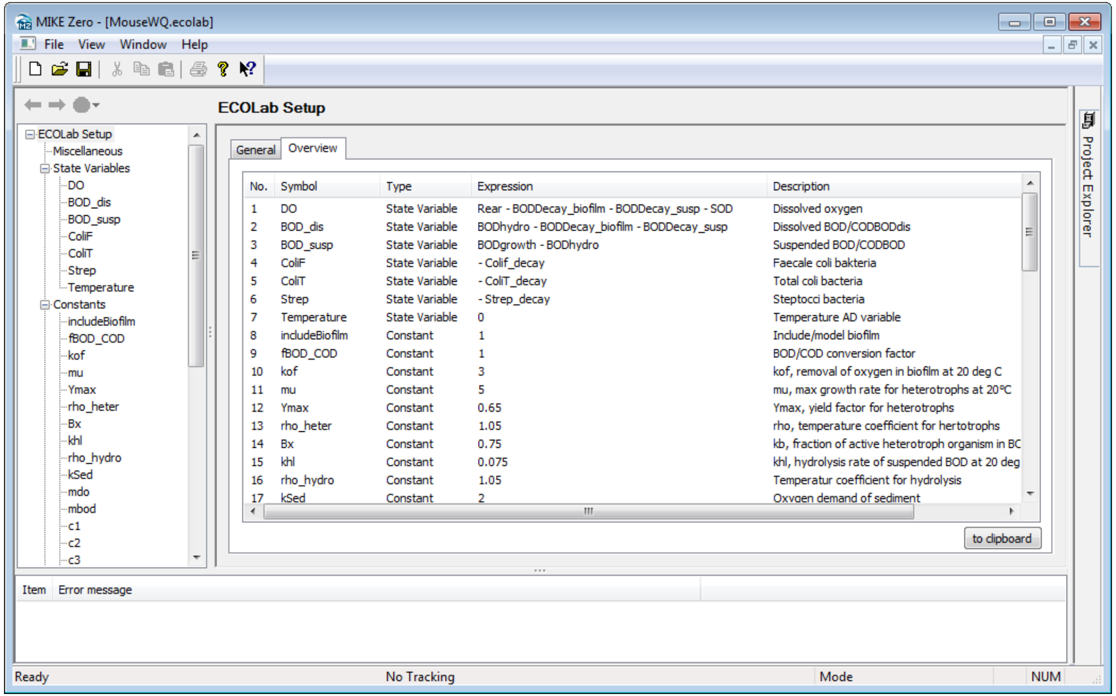
# MOUSE WQ (Biological Processes) ECO Lab Template

- MOUSE WQ Process Model as ECO Lab Template
- Template can be used with MIKE 1D
- MIKE1DWQ.ecolab

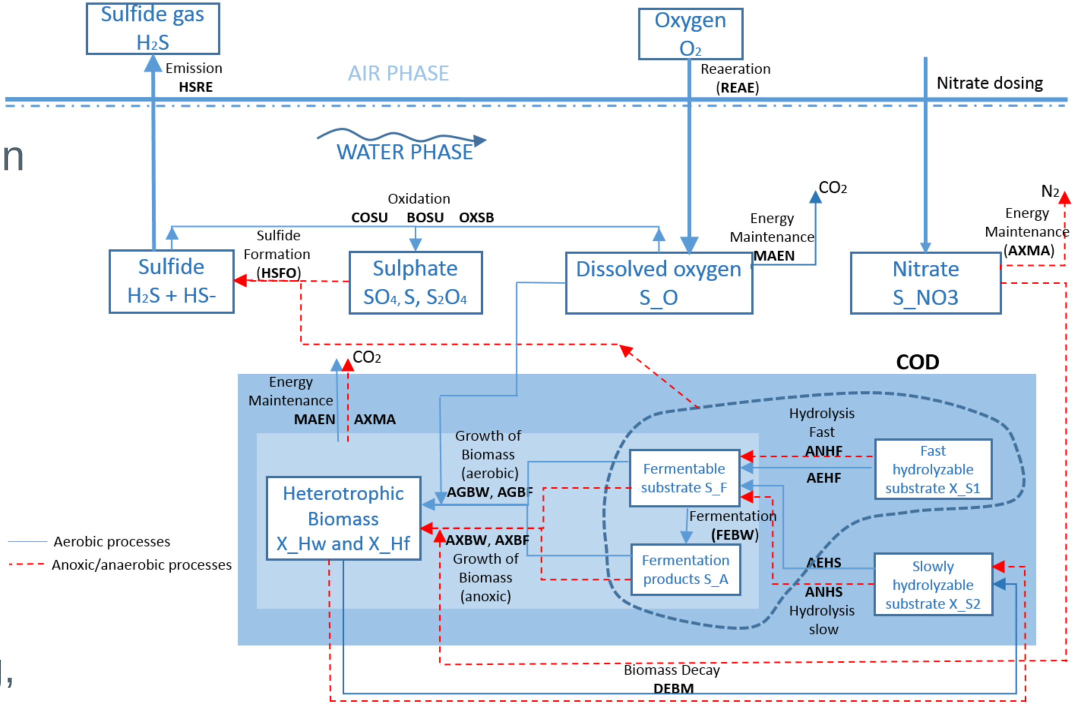


# Hydrogen-Sulphide (H2S) Modelling
## (WATS – Wastewater Aerobic / Anaerobic Transformations in Sewers)

- The ECO Lab H2S WATS template represents state-of art modelling of hydrogen sulphide in wastewater network – both in gravity and force mains sections

- H2S_module_WATS2013.ecolab

- Results can be used for risk mapping and sizing mitigation options such as chemical dosing, oxygen injection for controlling corrosion and odour

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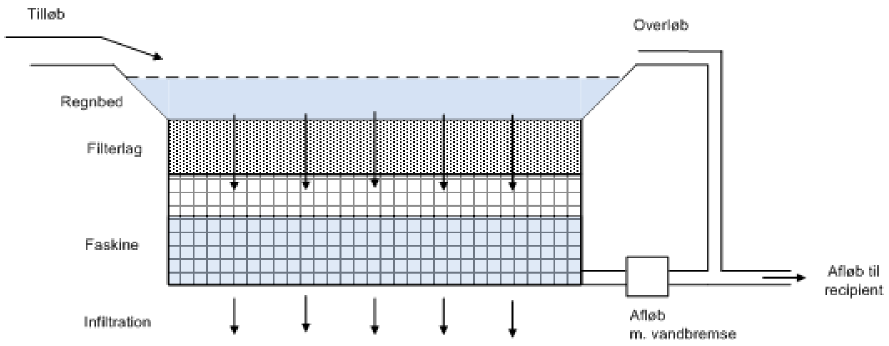
# Modelling of Storm Water Quality – Treatment Processes

- Selected constituents
  - SS
  - Dissolved COD
  - Ammonia
  - Total-N
  - Dissolved P
  - **Total-P**
  - Heavy metals
  - E. Coli ?

- Generic Treatment Processes
  - Sedimentation
  - Sand filtering
  - **Adsorption**
  - Infiltration
  - Biological processes

# Water Quality modelling of LID technologies

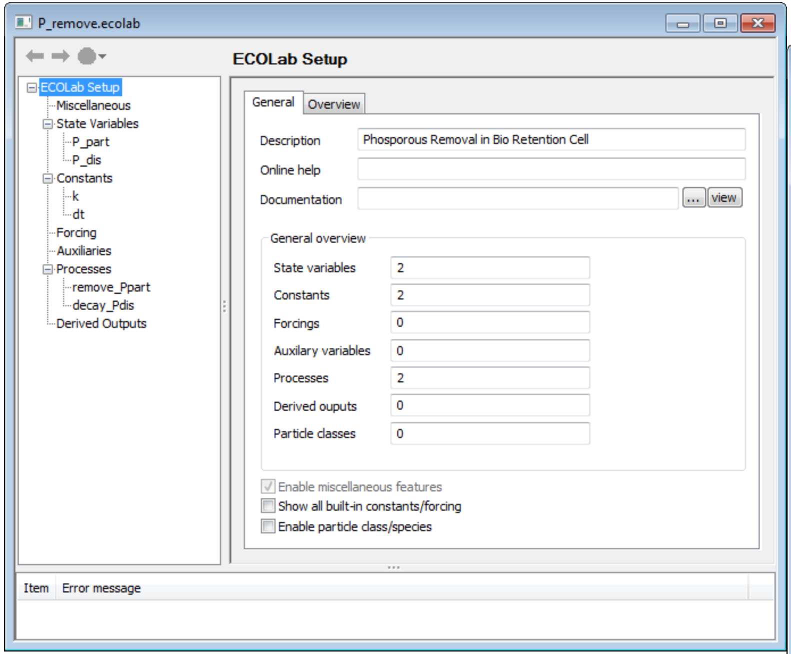
- Stormwater basin/pond
- Sand filter
- Adsorption filter
- **Bio-retention cells**
- …

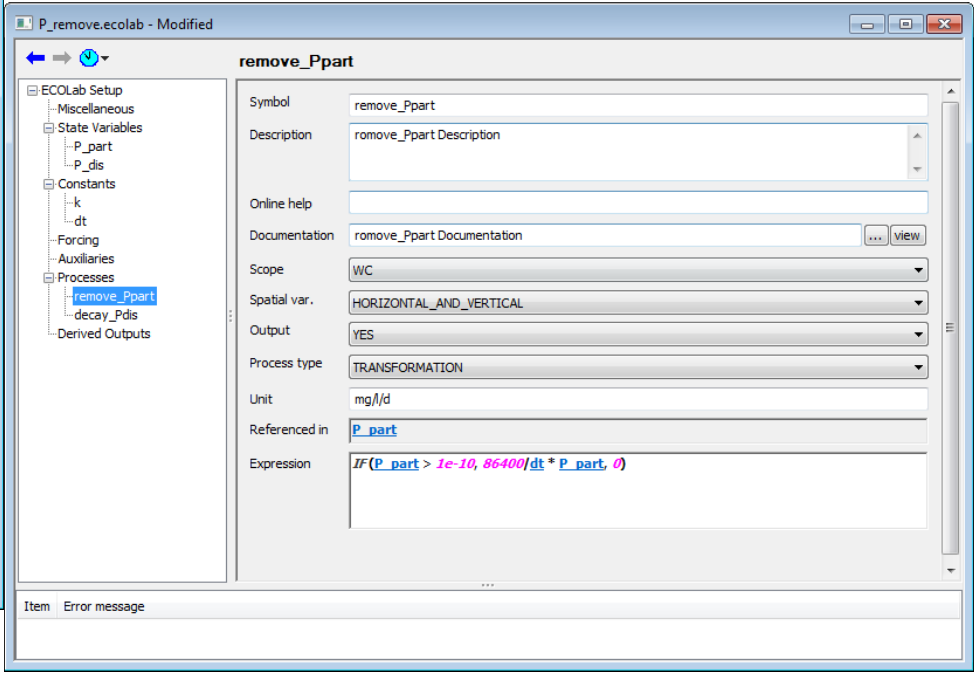



Example of a treatment process – removal of phosphor in filter layer:

C_out = C_in * $e^{k*t}$ , t = concentration time

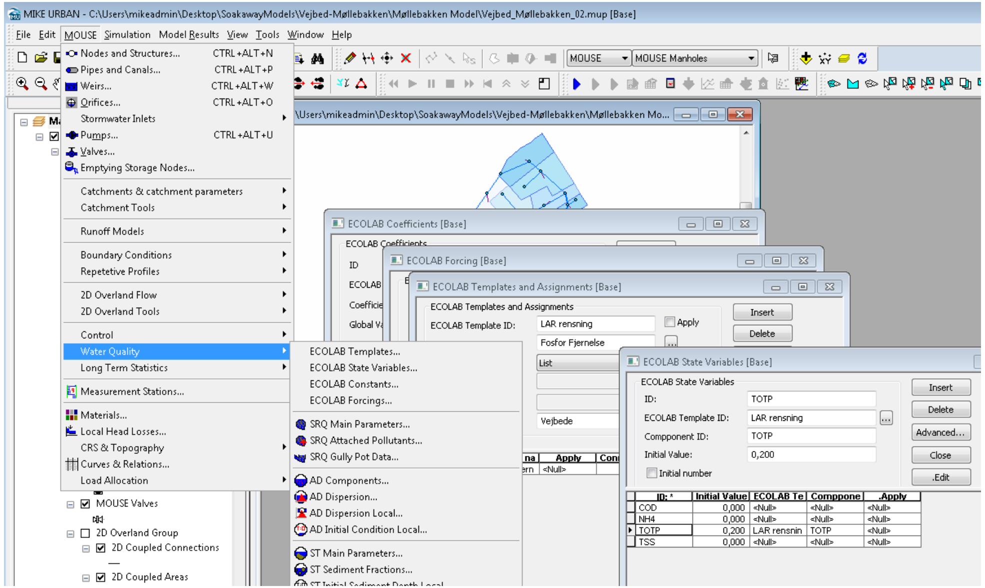
# Storm Water Treatment Template for Phosporous Removal



# Modelling of water quality in MIKE URBAN - **ECOLAB**

- ECOLAB
  - Template based and user configurable!
  - Soakaway-Template with simple treatment process description for i.e. phosphorous removal (NOT installed)



# Conclusion

- Screening Level
  - LID Concept (Hydrology)

- Detailed Level
  - Soakaway (Hydraulics)
  - Soakaway (Hydraulics) + Treatment (Advection-Dispersion + ECO Lab)

# Ongoing - storm water modelling for green cities

- Student Applications
  - 2 * Master Thesis at DTU, Denmark
  - 1 * Master Thesis at Calmers University of Technology, Sweden

- MIKE Seminar the 10 March, 2016, Hørsholm

- DHI Academy training course (2 day). “Modelling of storm water for green cities”. September 2016, Hørsholm

# Thank you – any questions / spørgsmål?

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