SESSION CONTENT

- Introduction to modeling – 30 min
- Introduction to water supply system modeling – 30 min
  - Break – 10 min
- WSS modeling exercise – 45 min
  - Break – 5 min
- Introduction to sewerage modeling – 30 min
- Sewerage modeling exercise – 45 min

INTRODUCTION TO SEWERAGE MODELING

Aalto University – 2019-02-25

EUR ING PhD Markus Sunela

LEARNING OUTCOMES

- Describe the sewerage supply model structure
- Describe the difference and function of nodes and links
- List the most relevant model components, their most important parameters, results and uses for each
- List some applications for the model

QUESTION TIME (5 MIN)

Discuss in small groups of 2-4 persons. What do you think that makes a sewerage model? What components are needed? What parameters are important?

Think of the basic hydromechanics equations

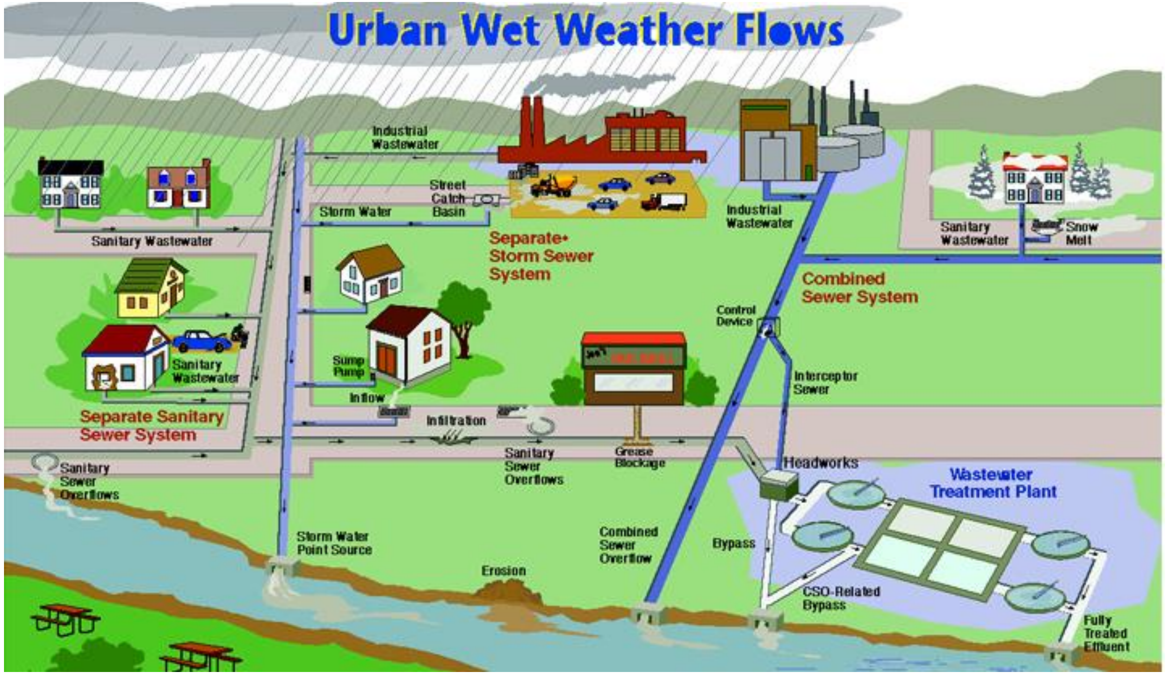
INTRODUCTION

- On this course *Fluidit Sewer* will be used as the modeling solution for sewerage. However, as the simulator in use, EPASWMM, is practically the same as in, for example, in *SewerCAD*, *MikeURBAN* and the free *EPASWMM*, the acquired skills can be applied to those other modeling solutions as well

- EPASWMM simulator is the most widely used and researched simulator
- The simulator is public domain and open source
- It can be used for modeling hydrological systems, open channel flow, pressurized flow and any combination of those, in irregularly shaped conduits
    - Sewer, storm water or combined sewer systems; other open-channel flow

URBAN WET WEATHER FLOWS

Reference: EPASWMM Builti-n Help



Water flows due discharges into the network (dry weather flows, runoff or infiltration), conduit slope (i.e. differences in water level elevations) and head differences generated by pumps.

Changes in the system are reflected slowly down-stream: as the water flows freely due to gravitation it takes time for the water to travel in the network, about an hour / km. Network empty of water at start.

Typical flow velocities in the pipes are 0.1-1.0 m/s (0.3 m/s avg).

SOME MODEL APPLICATIONS

- Tool for general planning
  - Capacity analysis
  - Capacity problems
  - Flood risk areas
  - Rinsing of the network
- Design and sizing of pumping stations and treatment plants
  - Designing the automation algorithms
- Leakage analysis
- Renovation planning
- Operational analysis: network, long transfer pipelines
- Energy assessments and optimization
- Quality analysis
  - Age, transfer time, H2S-O2 balance

SEWERAGE NETWORK MODEL

- Network modeling tools are usually map based – model components and results are presented on a map
- Catchments, conduits and junctions (manholes) are digitized or imported automatically along with their properties
  - Diameter, material, invert elevation, depth
- Pumps, dry weather inflows, leakage, pump characteristic curves, daily inflow patterns, tanks, weirs, outfalls and control algorithms are modeled too
- Typically a few days long simulation is performed, and the results of the last simulated day are reported using 1…60 minute time resolution

SEWERAGE MODEL COMPONENTS

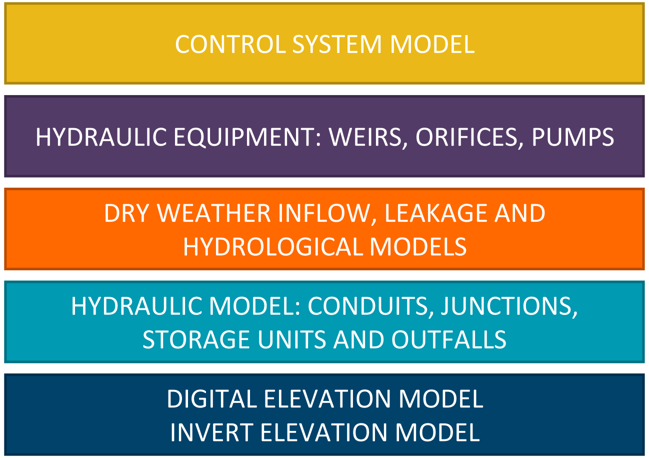
- Sewerage can be divided into five parts
    1. Hydrology – rainfall, runoff, infiltration, leakage
    2. Outfalls – release to nature or WWTP
    3. Sewer network and equipment
    4. Dry weather inflows – waste water producers
    5. Control system

- Water exists the model via **outfalls**

- Sewer network is modeled as a network of
    - **Conduits**
    - **Pumps**
    - **Weirs**
    - **Junctions** (manholes)
    - **Storage units** (tanks; pumping station wet wells)

- Waste water producers are modeled as dry weather inflows to junctions and leakage as direct inflows to junctions or using hydrological components

MODEL LAYERS



SEWERAGE MODEL STRUCTURE

- Like EPANET, EPASWMM supports practically all equipment and components present in sewerage and hydrological systems
- External inflows into the system, storage volume, water depth, pressure, head and flooding are modeled and solved as **node** component classes: junctions (manholes), storage units and outfalls (graph theory's vertices)
- Flow, velocity, water depth, volume, and head loss (or gain) are modeled and solved as **link** component classes, that connect two nodes: conduits, pumps, weirs and orifices (graph theory's edges)

PHYSICAL MODEL COMPONENTS

- Nodes – head
  - **Outfall** is an infinite receiving water body: head does not (practically) change, no matter what the flow
  - **Storage unit** is a finite tank: flow into or out of tank changes the head (level and volume)
  - **Junction** is a manhole, link crossing, a point where pressure is calculated and a point where water is drawn out of the system
  - All nodes can receive external inflows
  - Each model requires at least one outfall
- Link – flow
  - **Conduit** allows flow between nodes. Head losses are modeled based on flow, length, slope, shape, size, and Manning's roughness (n)
  - **Pump** produces energy into system; supports setting relative speed
  - **Orifice** is used for modeling orifices, holes in thin walls, through which water can flow from one node to another
  - **Weir** is used for modeling weirs, over which water can flow from one node to another (overflow chambers)

EPASWMM MODEL RESULTS

- Nodes
  - Head [m - above sea level]
  - Depth / pressure [m - water column]
  - Volume [m^3]
  - Lateral inflow (external inflow) [l/s]
  - Total inflow (lateral + flow from network) [l/s]
  - Overflow [l/s]

- Subcatchments
  - Rainfall [mm/h]
  - Snow depth [mm]
  - Evaporation [mm/d]
  - Infiltration [mm/h]
  - Ground water flow [l/s]

- Links
  - Flow [l/s] + flow direction
  - Velocity [m/s] + flow direction
  - Depth [m]
  - Volume [m^3]
  - Capacity (how much of the pipe is filled)

- All parameters solved as a function of time for all components
- Further results can be derived, for example statistical values (min, max, avg...), free capacity down stream, specific energy required for pumping, surface tension, flow capacity utilization...

PHYSICAL COMPONENT PROPERTIES

- Conduits
  - **Length** [m] (can be automatically calculated)
  - **Shape** (circular, filled circular, egg, rectangle etc.)
  - **Diameter/max depth** [m]
  - **Material/roughness** (n, unitless)
  - Minor loss coefficients: entry, exit, avg (unitless; optional)
  - Construction year (optional)
  - Start and end elevation relative to the node bottom
- Storage units (tanks)
  - **Invert elevation** [m] (NW; used for calculating level)
  - **Cross-sectional area** [m^2] or water level – area **curve**
  - **Depth** [m]
- Catchments
  - **Area** [ha] and **width** [m] (together define area + shape)
  - Percentages for **impervious**, **pervious** and zero-imp.
  - **Depression storage** [mm], **slope** [%] and **roughness**
- Outfalls (system boundary)
  - **Invert elevation / head** [m]
  - Type: **normal**, **fixed** or **time series**
  - Fixed stage (head) or head time series, if type requires
- Junctions / water discharge / geocoded demand
  - Waste water discharged (any node can accept in SWMM)
    - **Average (base) demand** [l/s]
    - Demand **pattern(s)**
  - **Invert elevation** [m] (can be automatically calculated)
  - **Depth** [m]
  - **Surcharge depth** [m] for pressure junctions
- Pumps
  - Pump and efficiency **curves**
  - **Startup and shutoff depths** [m], rel. to inlet node

NON-PHYSICAL COMPONENTS

- Patterns
  - Describe repetitive changes in a value relative to the average value
  - Can be used for water discharges
  - Two 24 hour patterns: **weekday** and weekend, and weekly and monthly pattern types
  - The average of coefficients should be 1 – this way the base demand modeled in geocoded demands or nodes represents the average value

- Curves
  - Describe relation of two variables
  - Different types
    - **Shape curve** for symmetric, closed conduits with custom cross section
    - **Volume curve** for non-right shaped tanks
    - **Pump curve:** one or three-point, or tabular; one or three point curve recommended
    - **Pump efficiency curve:** one or two point, or tabular curve; one or two point recommended

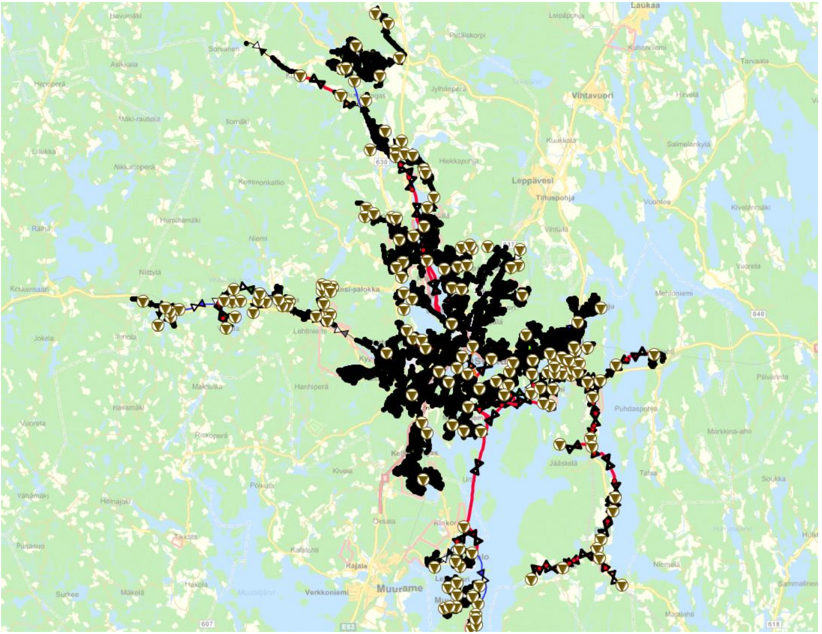
- Values can be pasted from clipboard (from Excel, for example) in Fluidit Water

NON-PHYSICAL COMPONENTS

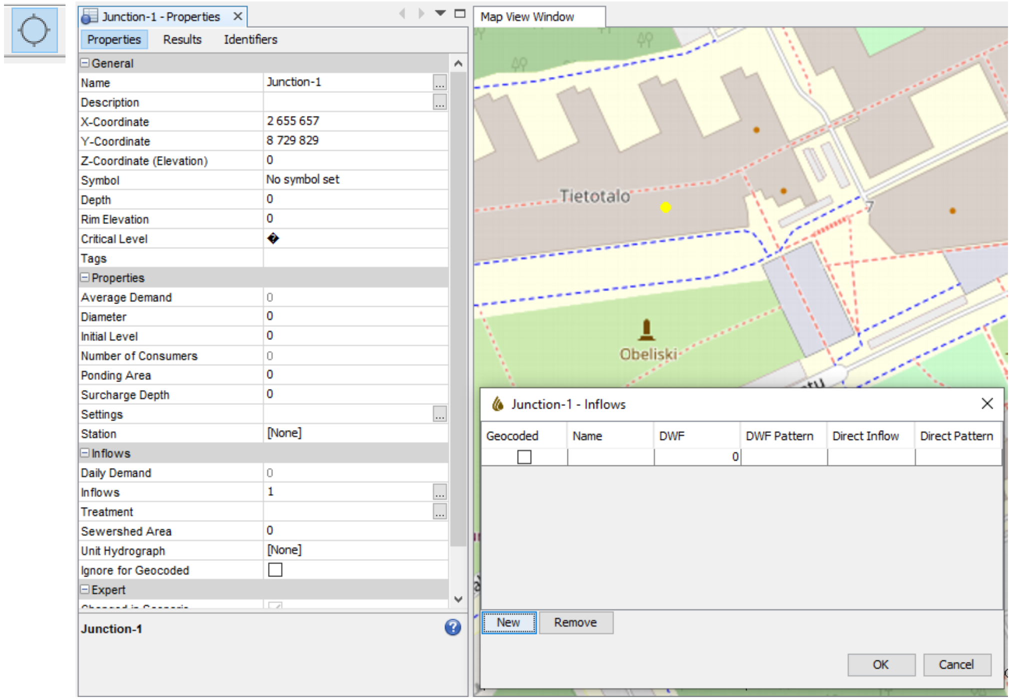
- Time series
  - Pairs of times and values
  - Describe time-varying measurements: inflow, **rainfall**, temperature, sea or lake levels etc.
  - Time can be expressed relative to simulation start, e.g. 01:25, or they can include date (M/D/Y), e.g. 12/31/2017 07:20
  - Time resolution can vary in one time series and the data can be sparse
- Unit hydrographs
  - Describes how rainfall turns into runoff and discharge into network
  - Alternative to using catchments
- Transects
  - Describe cross sections of irregular open conduits, such as rivers
  - Pairs of x, y coordinates

SEWER NETWORK MODEL - GENERAL

- Modern computational power enables precise and holistic, full-scale modeling
- E.g. Jyväskylä
  - 8700 manholes
  - 167 pumping stations
  - 8719 pipes
  - 675 km of network model
- In the past modeling and simulations included sewer mains only
  - Software was limited and difficult to use
  - Computer were slow
  - The value of full-scale results was not understood
  - Provided incorrect results in many cases due to the transfer times and storage volume



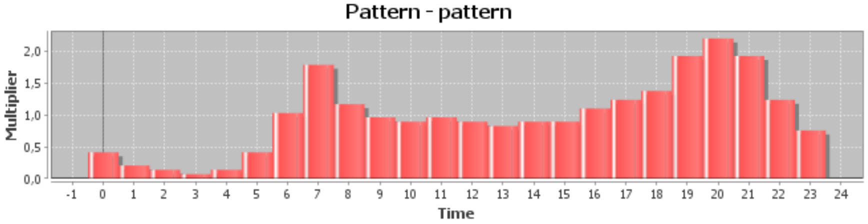
JUNCTION



- Junctions are to be added
  - Wherever a manhole exists
  - Whenever multiple links join
  - Whenever link type, or pipe size or material changes
  - Every along pipe lines 100…500 m
  - At otherwise critical or interesting locations, such as elevation extremes
- It is advisable to use the manhole numbering scheme in use at the utility or position numbers for junctions presenting SCADA measurements

MODELING WATER DISCHARGES

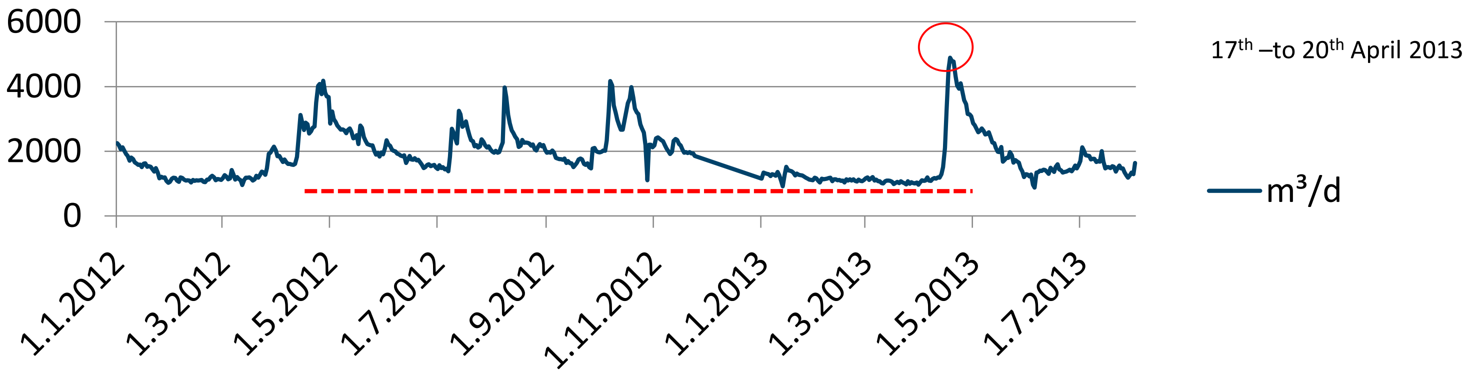
- In order to simulate a sewer model, it requires inflows
- Inflows originate from human activities or environmental sources (leakage)
- Inflow follows a certain pattern, which is related to the time of the day and day of the week
  - Water demand data from SCADA, measurements in network, pumping stations or WWTP
- Infiltration from the environment is related to natural properties, such as rainfall, snowmelt or ground water conditions
- There always leakage inflow in the sewer system
  - Model using constant (direct) inflows
  - Model using hydrological features (RDII)



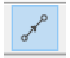
SEWER INFLOWS

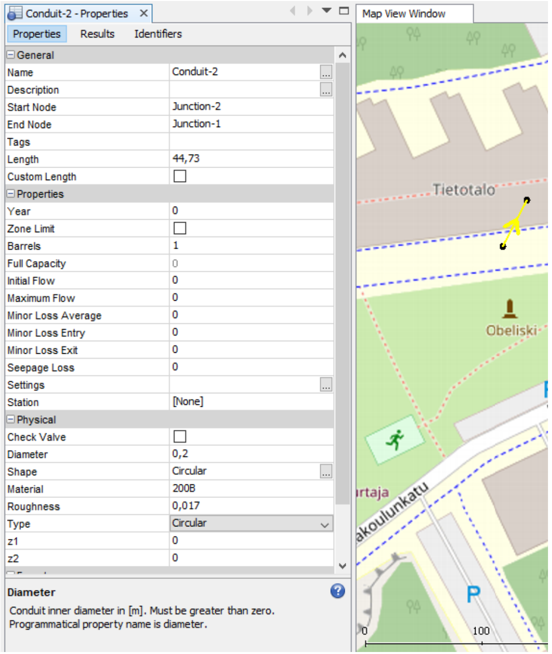
Typical average leakage water percentage in sewage network is 30-50 %

Though maximum daily flow can be more than five times the average due to leakage even in non-combined sewer systems



CONDUIT AND PUMP PROPERTIES



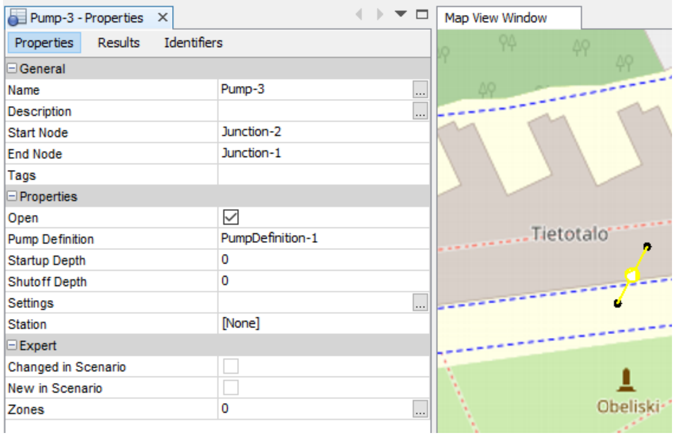


SELECT CUSTOM LENGTH CHECK BOX IF LENGTH IS SET MANUALLY

SET MATERIAL TO NONE TO MANUALLY GIVE *D* AND *n*

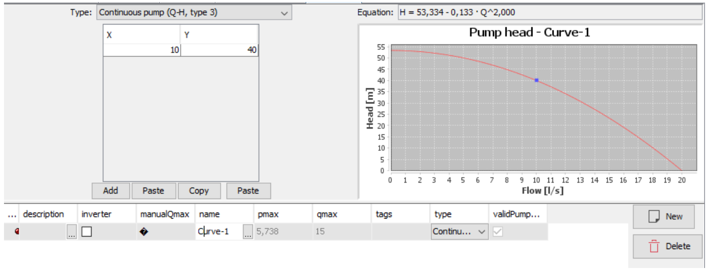
SPECIFY *Z1* AND/OR *Z2* IF CONDUIT IS NOT CONNECTED TO BOTTOM OF START OR END NODE (IN METERS RELATIVE TO THE NODE BOTTOM)

RELATIVE TO INLET NODE BOTTOM



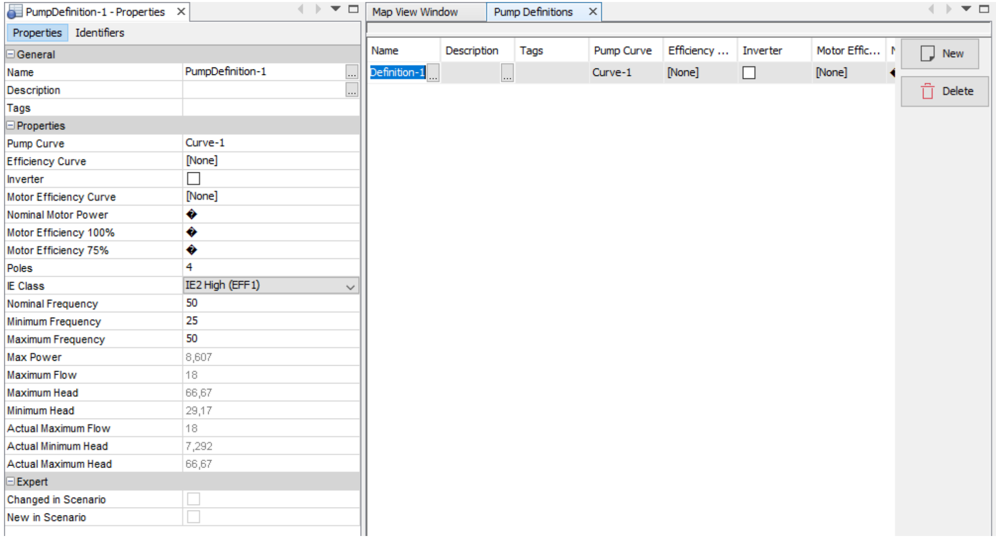
PUMP CURVES AND DEFINITIONS

Model->Curves…



CREATE PUMP (TYPE 3) AND EFFICIENCY CURVES

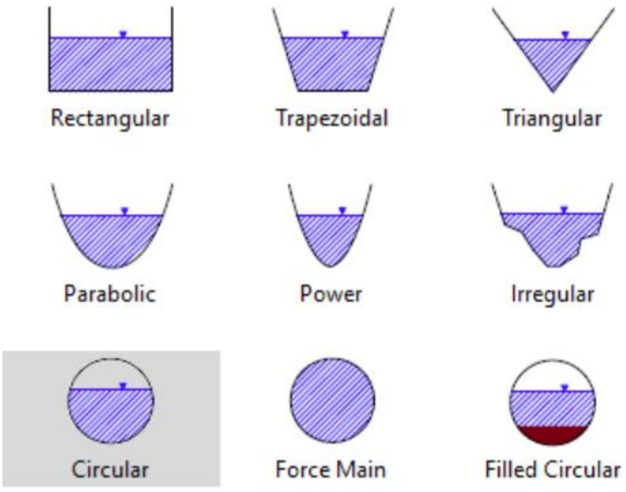
Model->Pump Definitions…



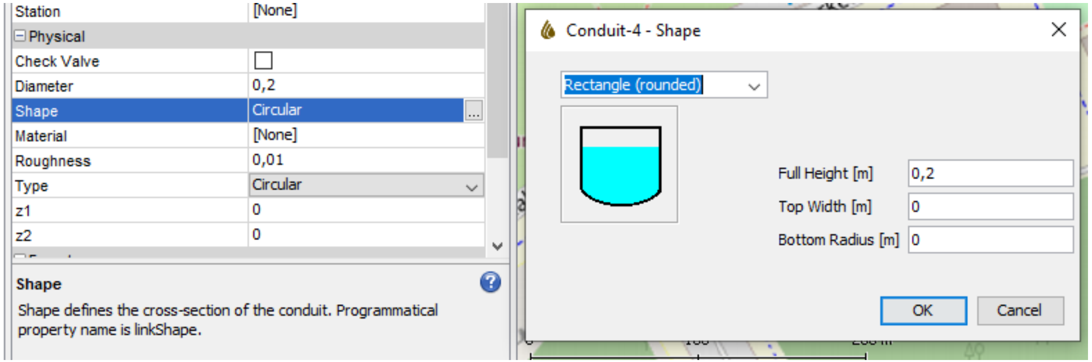
SET PUMP AND POSSIBLY EFFICIENCY CURVES

CONDUIT SHAPES

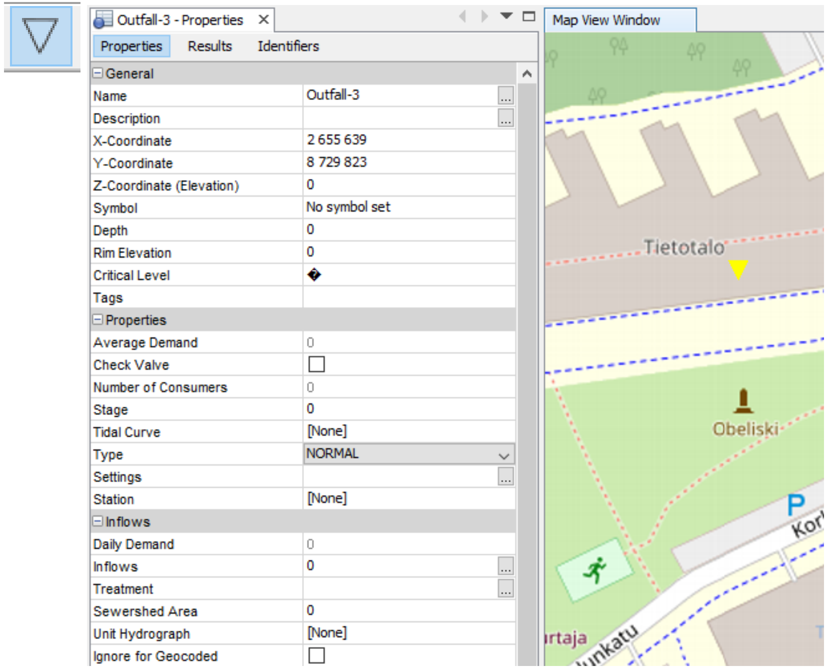
Some of the different pipe shapes

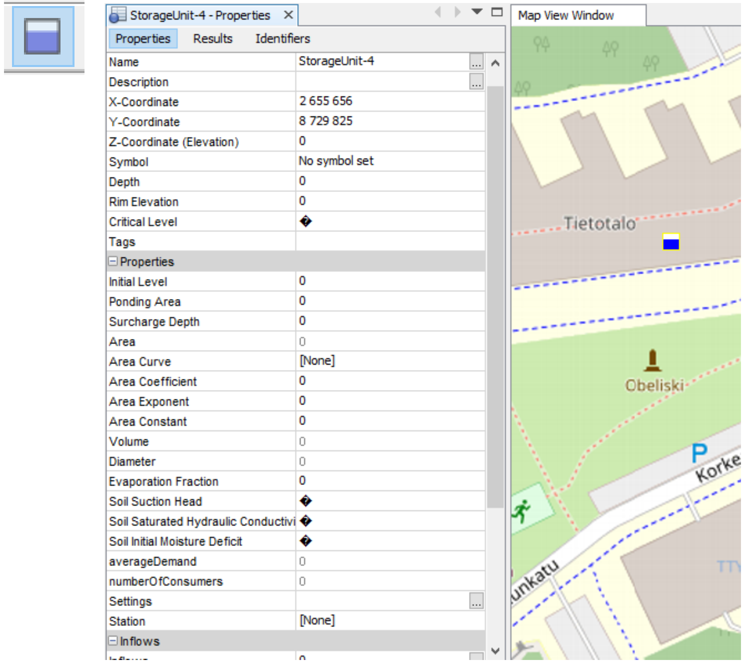


Pipe shape editor

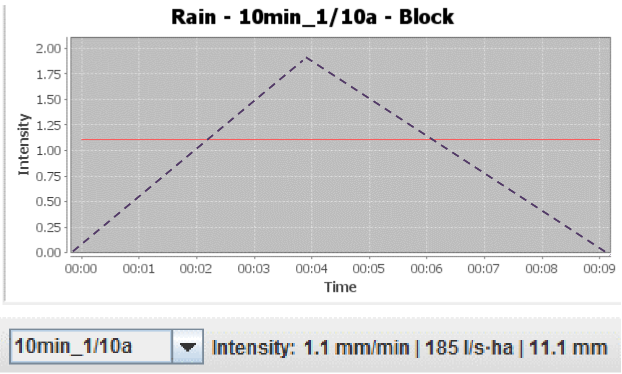


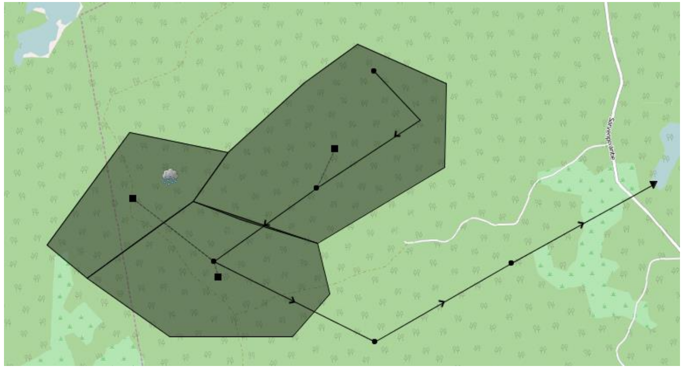
OUTFALL AND STORAGE UNIT PROPERTIES





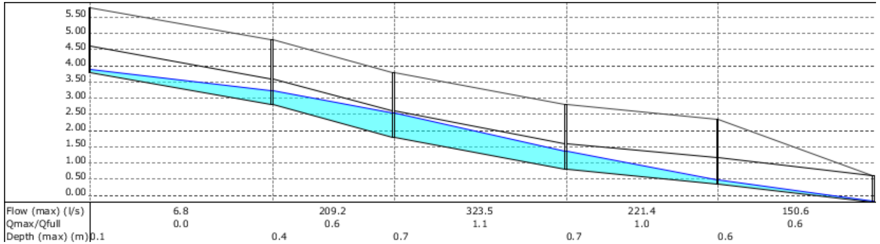
CATCHMENTS

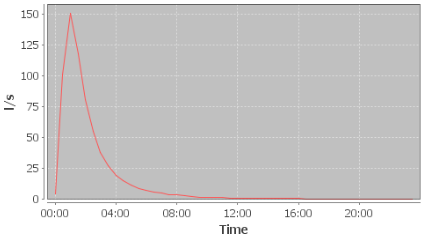




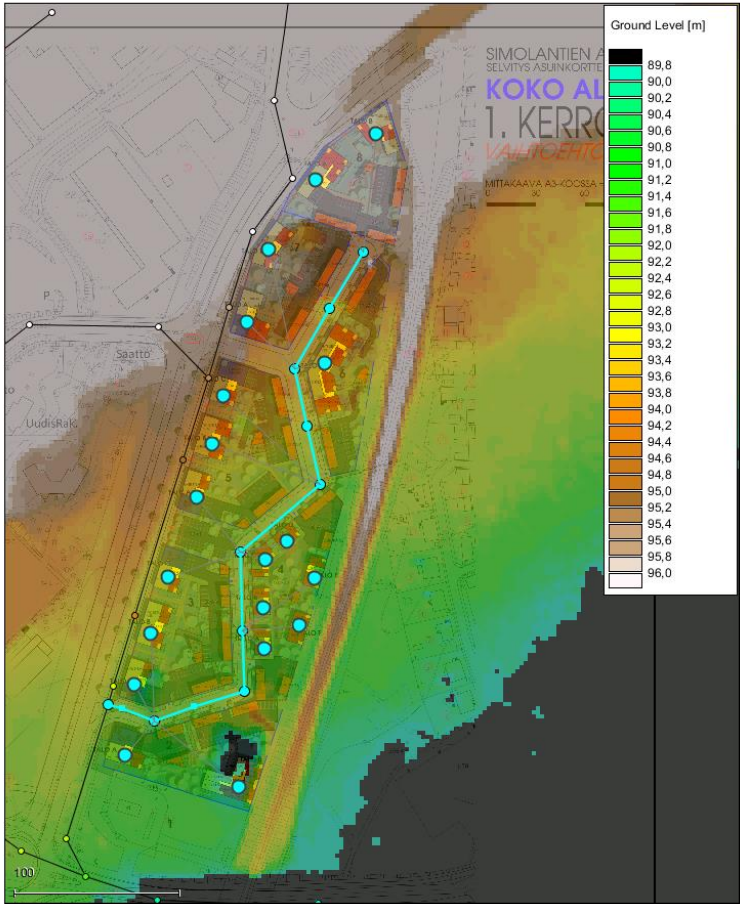
[ILMASTO-OPAS RAIN INTENSITY CALCULATOR](#)

http://www.alanasmith.com/theory-Derivation-Chicago-Storm.htm

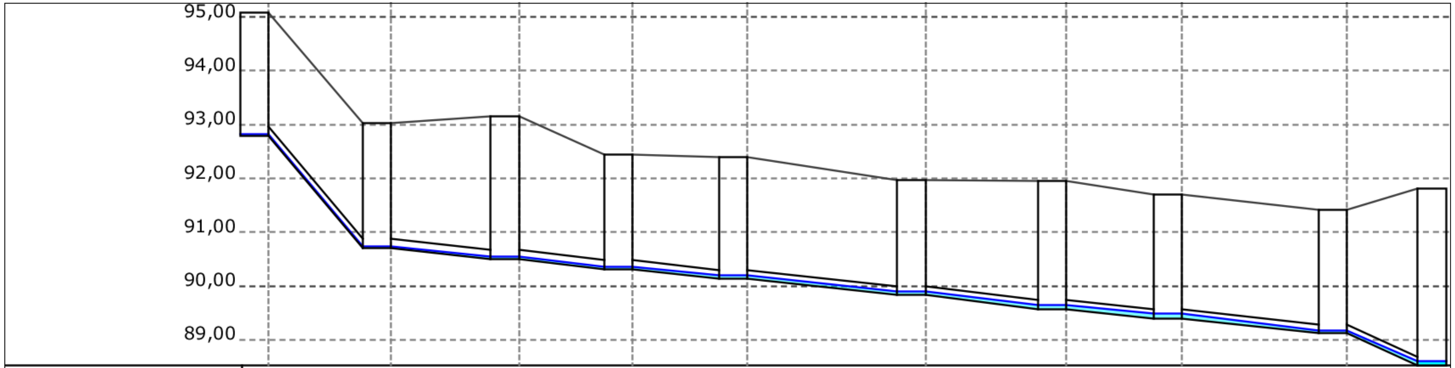




APPLICATIONS: GENERAL PLANNING



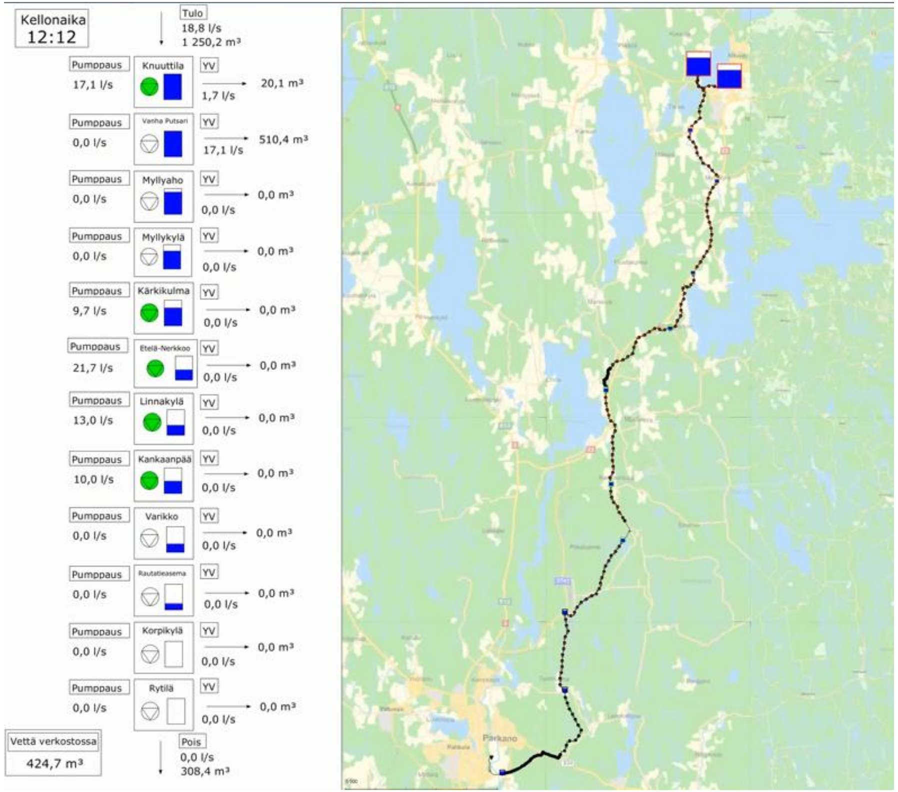
APPLICATIONS: GENERAL PLANNING



Qmax/Qfull		0,0		0,1		0,2		0,2		0,3		0,4		0,5		0,4		0,3
Diameter (m)		0,171		0,171		0,171		0,171		0,171		0,171		0,171		0,171		0,171
Slope (‰)		52,5		5,0		5,3		5,0		4,7		5,5		4,6		4,8		20,1
Flow (max) (l/s)		1,3		1,3		3,4		3,4		4,6		5,9		6,6		6,6		8,4
T (max) (N/m²)		8,3		1,3		1,6		1,6		1,7		2,1		1,9		1,8		7,3
Length (m)		40		42		36		36		63		48		37		58		30
Full Depth (m)	2,3		2,3		2,7		2,1		2,3		2,1		2,4		2,3		2,3	
Invert Elevation (m)	93,0		90,9		90,7		90,5		90,3		90,1		89,8		89,6		89,3	
Lateral Inflow (max) (l/s)	1,3		0,0		2,2		0,0		1,2		1,3		0,7		0,0		1,7	

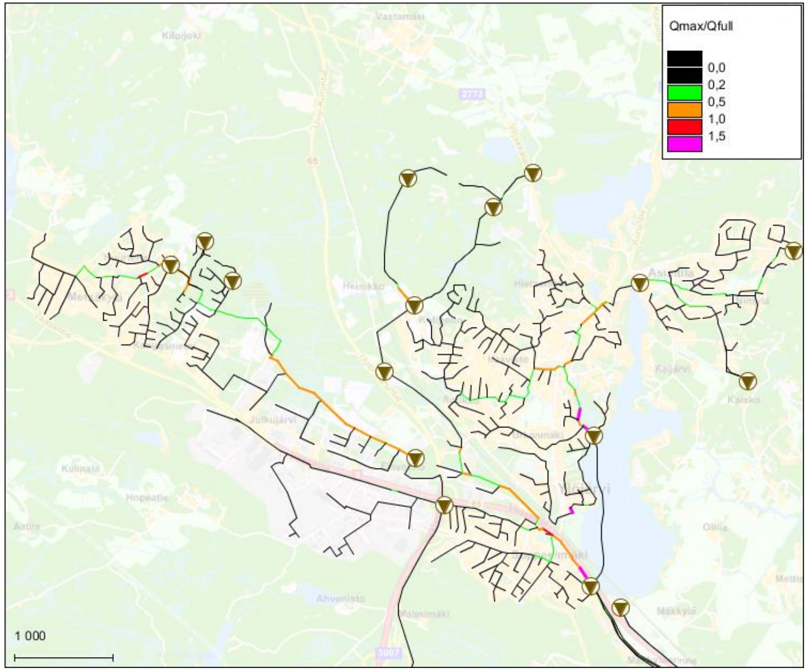
APPLICATIONS: OPERATIONAL PLANNING

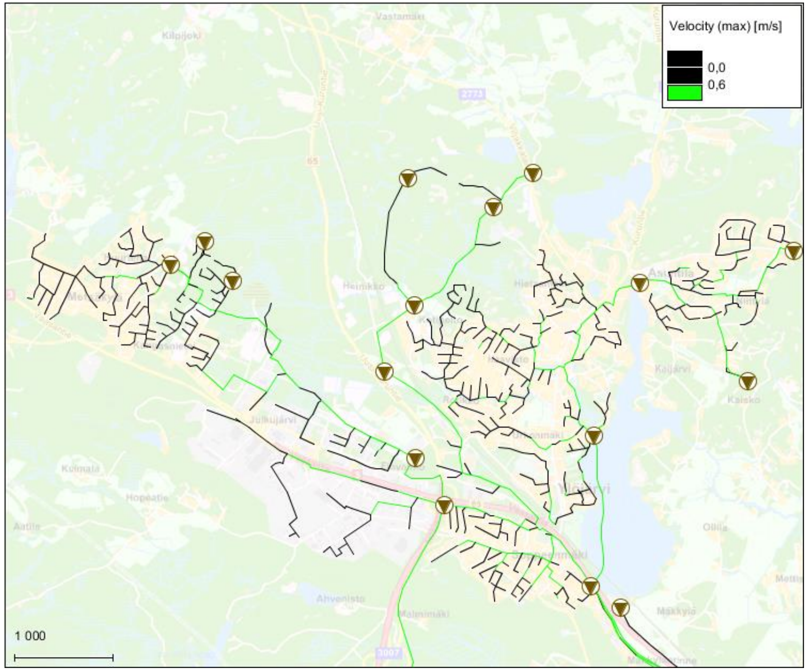
- Sewage water transfer line Kihniö->Parkano
- 33 km pressurized and gravitational pipeline
- 12 pumping stations
- Daily design flow 1250 m^3/d sewage water
- What should be the on and off limits in pumping stations in order for the line to work correctly?
- What is pumping station is going to flood first?
- How long does it take for sewage water to get from Kihniö to Parkano?



APPLICATIONS: CAPACITY ANALYSIS

For gravitational pipe networks we can simulate eg. Flow, velocity, max fill level or surface tension

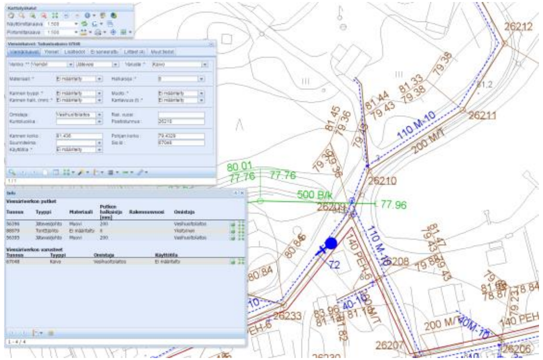




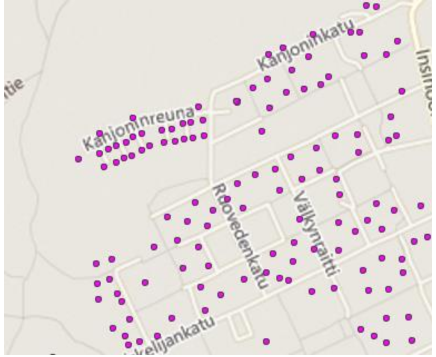
INPUT DATA REQUIREMENTS

- **Network map** with **invert elevations**, rim elevations, pipe sizes and materials: DWG, DXF, SHP, GML, WFS
  - In real coordinate system
  - GIS formats, like SHP or GML, preferred – enables automatic model construction
  - Should include both sewer and storm network, if combined network exists
- **Customer data** - client number, address or coordinates and billed volume
- **Pumping station data**
  - Volume, NW, HW; shape if non-right (drawings)
  - Pump data – number of pumps, pump QH and efficiency curves, start up and shut off depths
  - Flow or running time (one pump running + two pumps running in parallel) measurements
- **Waste water treatment plant data**
  - Daily and hourly inflows for a few years
- **Catchment data**
  - Typically generated semi-automatically
  - Only for areas with combined sewers or for the whole storm water system

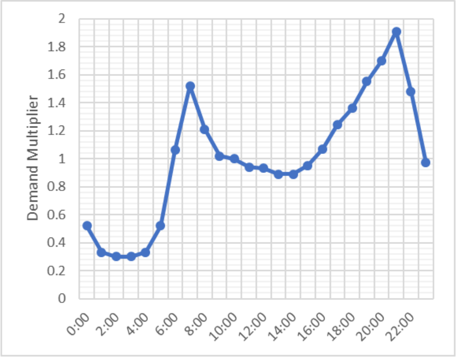
INPUT DATA REQUIREMENTS



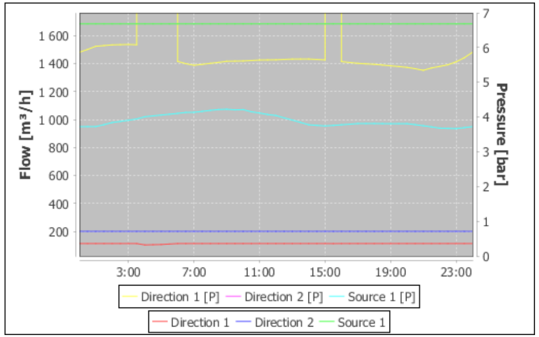
NETWORK MAP



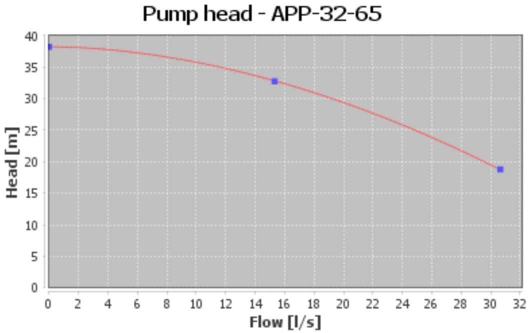
WATER USERS & USAGE



WATER USAGE PATTERNS



MEASUREMENTS



PUMP CURVES

LINKS AND ADDITIONAL INFORMATION

- EPASWMM (Open source https://www.epa.gov/water-research/storm-water-management-model-swmm
- QGIS (Open source GIS application: www.qgis.org)
- GRASS (For manipulating raster images, generate sub-catchments from height model automatically: https://grass.osgeo.org/)
- Finish NLS background maps, DEMs (https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta)
- Grundfos Product Center pumping stations sizing software (https://product-selection.grundfos.com/)
- Finnish geology institute, soil information WMS interfaces, (http://www.gtk.fi/tietopalvelut/rajapintapalvelut/)
- RIL-237-1/2 Vesihuoltoverkkojen suunnittelu and RIL 124-1 Vesihuolto 1 ja 124-2 Vesihuolto 2
- GIS information(Map Window) (http://www.paikkatietoikkuna.fi/web/fi/avoin-paikkatieto)
- Windows Phone / Windows 8 and 10 free hydraulic sizing software (”Hydraulic Calculator”) by Markus Sunela