

Design water distribution for a new district

Files you should turn in:

1. Fluidit Water model file (.fwat)
2. Report (+ optionally other files such as calculations done in MS Excel)

Grading:

Models (1 - 70 points)

Report (1 - 70 points)

To pass you have to turn in both files. In the report please explain the steps and phases along with the calculations used to find the parameters for the model you conducted during the modeling. The grade will be the average of model and report grades.

Minimum requirements for a passing grade:

Model: Task has been modeled and the simulation runs through.

More points for:

- Results are good, no continuity error greater $< 10\%$
- Available information is used thoroughly (elevation model, background maps, visualizations, etc.)
- Components of the model have the correct parameters (manholes, pump curves, etc.)
- Sizes of the pipes and pumps are near optimal

Report: All the task phases have been described shortly.

More points for:

- All the task phases have been described thoroughly and analyzed
- Sources are clearly mentioned when describing the choices for the parameters and basis for calculations
- Figures available in the model software are used in the report (capacities, flows, etc.)
- Feedback is provided regarding the model work
- Improvement suggestions on preliminary design?

Demo models, including examples for visualisations, setting up pumps, and software Wiki are accessible at [Fluidit Support page](#). Log in with username/password provided.

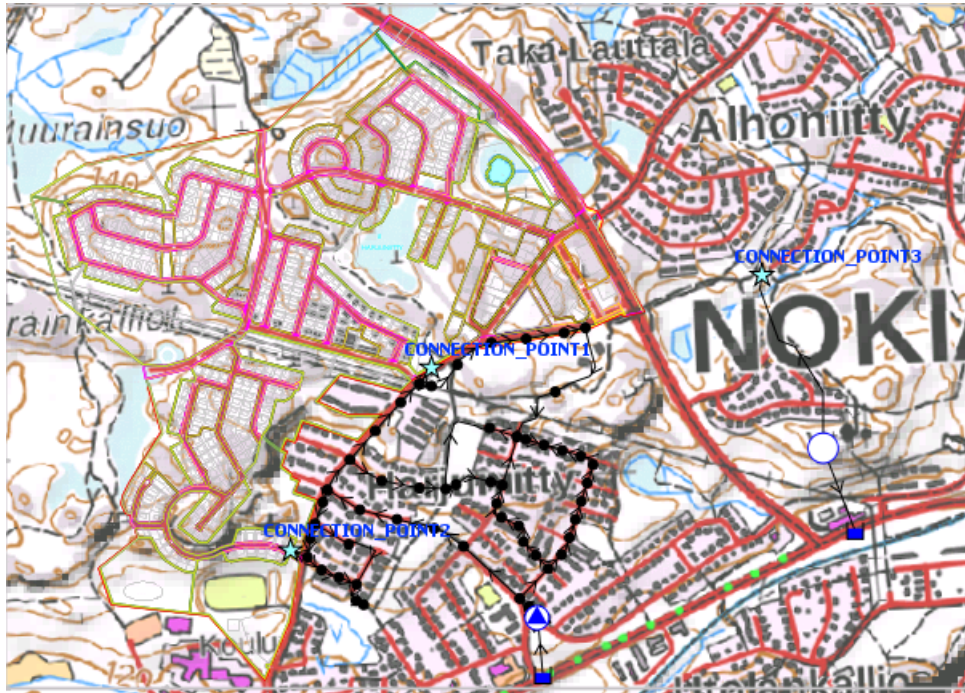


Figure 1: Map of Nokia water supply.

This exercise is based on a real project. The exercise will teach you (1) how to build and extend a water distribution system model, (2) how to analyse the results, and (3) how to design network and pumping.

Begin with downloading the materials. Open *nokia.fwat* model file. The model contains part of the real network of city of Nokia (Harjuniitty district) along with the pressure booster station feeding the zone. File *master plan.dxf* contains a master plan for a new district "Tähtitarha". The file can be added as a background layer into the model by right-clicking the *Background Layers* element in the model tree and choosing *Add DXF Layer ...*

Your tasks are to:

1. Model the water demand at the new area. The recommended way is to add a *geocoded demand* for each lot, and then estimate the water demand for each lot based on the number of inhabitants.

The markings on the master plan show what kind of buildings there will be: **AK** means block houses, **AR** row houses, and **AP** and **AO** villas. Everything with **Y** in it, is some common building, like school. *The roman numbers specify the number of floors in the buildings and the Arabic numbers show the floor area.*

For villas, it can be assumed, that every lot will have a two-storey villa with 3-4 people living in it. For the other areas, it's up to you how to estimate the inhabitants. One way, besides the floor area [m^2] given in the plan, is to approximate the areas by holding down the ALT+SHIFT keys and clicking on a map – the area of the polygon will be shown in the lower right corner of the program.

You can use demand pattern "Harjuniitty" for the demands. Don't forget to connect the geocoded demands to the network junctions (use *Tools* → *Demands* → *Update Geocoded Demand Junctions*).

2. Design the preliminary network for the new district. Start with pipes 160PEH17 for the main pipes and 110PEH17 or 63PEH17 for the final lines. Recommended pipe sizes range from 63 to 225 mm of PEH17 pipes.
3. Connect the demands to the network by using *Tools* → *Demands* → *Update Demand Junctions* ...
4. Add also some 8 % of leakage. This can be done 1) by dividing the amount [l/s] equally to the junctions by selecting all junctions in the new district and then using *Tools* → *Demands* → *Assign Demand to Junctions* ... or 2) using the *Tools* → *Demands* → *Assign Leaks* ... tool, which enables to model the leakage as *emitters* (pressure dependent) or *constant demand* – both will be assigned relative to the pressure, pipe diameter and length. The tool works by ticking the area one wants to work with, and then setting the *Total* value in m^3/d and clicking *Assign*. It typically needs a few iterations.

Demand multiplier of 1.8 can be used for maximum day simulations. The value can be set in *Scenario object's properties* (click on the scenario *Base Scenario* in the model tree and modify its properties).

5. Design a new pressure booster station and the pipe line that connects to the new area the existing network at junction CONNECTION_POINT3, East from the new district, marked with a cyan star. Try to follow the existing roads with the pipe. Choose the constant pressure setting for the pump battery representing the new booster station, so that sufficient pressure is ensured in all junctions.
6. Refine the network pipe sizes and pressure booster station setting iteratively to ensure sufficient minimum pressures at each location, try to keep maximum unit head losses in 1-5 (8) m/km range and maximum velocities $< 0.3 - 0.8m/s$. The booster station's outlet pressure should not exceed 80 m .
7. Present the working regime (flow and head range) and energy consumption for the booster station
 - (a) during normal operations (average day, water possibly flowing from other directions too), and
 - (b) in the worst case scenario, where all the water to the new area is delivered via the station during maximum day.
 - (c) Use Grundfos WebCaps (<https://product-selection.grundfos.com/> - use international product range and 50 Hz; note the units! Model has l/s flow.) to see what kind of pumps they'd offer for this kind of working area (two pumps can be used in parallel for the worst case-scenario – specify the maximum head & flow as the duty point). Note the pump's nominal motor power.
8. Also, asses the need for another pressure booster station for the new district that connects to the Harjuniitty district at either CONNECTION_POINT1 or CONNECTION_POINT2, and design it. Present the the same results as in 7) for the another station. Explain, why you chose to build or not to build another booster station, and why you connected it to the point you did. Can the whole new district be fed from the other station? Check that HARJUNIITTY pump battery works within its allowed range.

9. Present yearly

- (a) investment costs (annuity method; interest 5 %; 50 years investment period) based on the cost of pipes as reported by *Fluidit Water* and the cost of any new pressure booster stations (à 50 000 eur + cost of pump 250 eur/kW – based on pump’s maximum electrical power it can use)
 - (b) energy costs for the current Harjuniitty pressure booster station and any new stations you have planned under *the average scenario* (i.e. scenario demand multiplier 1.0)
 - (c) yearly pressure booster maintenance costs (10 % of the station investment)
 - (d) total cost of the plan
10. Analyze the different cost components: what affects the costs most? Can the plan be made cheaper? How it would affect the reliability of the water supply?
11. For additional level of optimization, find appropriate chlorine dosage that will result in sufficient chlorine residual in all parts of the network without compromising disinfectant efficiency and taste and odor deterioration; also, model the water age.

Initial water quality can serve as an input for tanks, reservoirs and junctions. Water quality input for pipes includes:

- (a) Bulk reaction coefficient
 - i. Positive value for growth reactions
 - ii. Negative value for decay
- (b) Wall reaction coefficient (not used here)

Residual chlorine is modeled using bulk decay rate coefficient, which describes the decay of chlorine in water due to its reaction with natural organic matter. For water safety, residual chlorine concentration must be sufficient for disinfection and at levels for minimal formation of disinfection by-products.

- (a) Determine the initial chlorine concentration if the bulk decay rate coefficient is – 0.1 (Bulk reaction coefficients can be estimated by performing a bottle test in the laboratory, so if you assume a different value, justify it clearly in the report).
- (b) Add the reaction order and bulk decay rate coefficient via *Model* → *Chemicals* → *New*.
 - i. Set only the Global Bulk and Tank Coefficients, leave other Global Coefficients at 0; set the Reaction Order Bulk and Tank to first-order reaction rate.
 - ii. Set the initial concentration where chlorine is fed to the end junction of the pump battery, and could be assigned via *Junction Properties* → *Quality Parameters*.
 - Quality Parameters for the junction should be “Source.Qual.” = concentration you want to set (for example 1 mg/l) and “Source Type” = “Set Point”.
- (c) Water age is added the same way as chemicals described above: *Model* → *Chemicals* → *New*. Here, the Reaction Orders stay at 0 while Global Bulk/Tank/Wall Coefficients are set to 24 (h) to represent the time water stays in the network. It might be useful to add the units via *Model* → *Chemicals* → *Chemical unit*.

NB! When you make new results (including new Chemicals or Age), you need to reopen the model before they appear in ”Results”-lists.

NB! Use long enough simulation times to allow chemicals to spread in the network.

12. Create a rule-based control for a pump, which would operate based on time of the day. Controls are statements that determine how the network is operated given the certain conditions. By controlling water distribution, it is possible to distribute water in ways that respond appropriately to demand in the water service area. Controls can be implemented under *Scenario Properties*.

A rule-based control is based off the following scheme:

```
RULE ruleID
IF condition_1
AND condition_2
OR condition_3
AND condition_4
etc.
THEN action_1
AND action_2
etc.
ELSE action_3
AND action_4
etc.
PRIORITY value
```

Please refer to the appendix of EPANET Controls manual (attached as a separate document in the project folder) for instructions how to implement controls.

NB! There is a Python-controlled (level-compensated flow control) pumping into the water tower, which is an actual tank: this is a better and more realistic representation. Everybody is encouraged to take a look at Python-controls under *Model → Python Control Stations*, which represent how complicated controls can be made. You could comment on them but it is *not* compulsory, and there is no need to change them.

13. Document your design and present the results in a concise report. Attach the model and any spreadsheets or other materials you used.