MESOPOLIS

A Virtual City for Water Distribution System Research Applications

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Procedural Documentation

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Overview

This document outlines some of the basic steps I went through in designing Mesopolis' water distribution system from scratch.

The initial layout of the city was drawn over a topographic map in ArcGIS. A basic network or grid of "roads" split Mesopolis into polygons which were each assigned an attribute denoting land-use type and density (e.g. high-density residential, medium-density commercial, low-density industrial, etc.). The land-use type of each polygon was then used to estimate an average water demand in gallons per day for that polygon, in accordance with the average values in gallons per day per acre from Mays' Water Distribution Systems Handbook. Each polygon was labeled with its total demand in gallons per day and exported as a map for use in EPANET.

Once the map was imported as a backdrop EPANET and adjusted to the proper scale, I placed a series of intermediate nodes at each road intersection. These would serve as connectors for the grid of water mains. Terminal nodes were placed in the middle of each land-use polygon and assigned a demand in gallons per day that matched the label on the map. All the nodes were finally connected using a system of pipes, pumps, and valves to create the water distribution network.

Naming conventions

Nodes

Intermediate node (no demand)	IN
Terminal node (aggregated demand)	TN

Pipes

Water main	MA
Service connection	SC
Tank connection	TC

MAs connect INs to one another, and SCs connect INs to TNs. TCs connect tanks to INs.

Node Elevations

To assign elevations to every node in EPANET, I first exported the network as an .inp file, used the program epa2GIS (http://www.zonums.com/epa2gis.html) to create a shapefile containing the junctions/nodes, and imported that shapefile into ArcGIS. An elevation field was added to the attribute table for the nodes and filled with elevations that were interpolated using ArcGIS' Spatial Analyst. Finally, the original .inp file was opened using Microsoft Excel, and the elevations were copied from the ArcGIS attribute table into the Excel document and matched to the proper nodes. The .inp file was then saved and reopened in EPANET.

Pumps

Mesopolis is hilly, and requires that we split the WDS into pressure zones by elevation by means of a series of pump stations. Each pump station pressurizes the flow it receives from a lower pressure zone so that a wide range of elevations will have 35-80 psi. Each pressure zone is assigned a letter, with A being the base pressure zone of the system, and F at the top of the east mountain. Pumps are generally named "location-XY", where X designates the pressure zone it serves (from A to F), and Y is the pump ID for that specific pump station. So eboost-B3 is the 3rd pump at the eboost-B pump station, which pressurizes water for the B pressure zone.

Pump curves are obtained from ePrism. To find an actual pump that provided the necessary flow/head combination, I'd first create a fake pump curve in EPANET that gave the results I wanted. Then I used ePrism (http://eprism.gouldspumps.com/prism/pss.htm) to find a pump with a similar flow/head relationship, and pick a series of (flow,head) points along the curve to put into EPANET. For energy calculations, I also created efficiency curves for each pump in EPANET.

Valves

All valves in the system act as pressure-reducing valves (PRVs) on downhill sections of pipe. They are named "locationPRV-XY" where X is the uphill pressure zone and Y is the downhill pressure zone. These PRVs dissipate energy in the flow in order to bring downhill pressures within acceptable limits.

Tanks

All tanks are water towers, except the "hillside-tank"s, which are ground-level storage tanks installed higher up in the mountains than the houses which they serve.

Many tanks (e.g. w-tank) are connected with separate inflow and outflow pipes. This configuration allows us to write rules that control flow into or out of the tank explicitly - if only one pipe were connected to the tank, the direction of flow would be out of our control. Notice that w-tank's inflow pipe (TCw-tankCV1) has a check valve restricting flow out of the tank. Since EPANET's rules can't open or close a check-valved pipe, there has to be a second, controllable pipe (TCw-tankin) connected to the check-valved pipe. That's the pipe that the rules will open and close. The same pattern is followed with the outflow pipes.

Rules and controls

(Maximum day demand vs. Average day demand)

A series of complex controls govern the status of pumps and tanks in the system (the basics of rules and controls are spelled out in EPANET documentation).

However, a different set of controls must be used in the maximum day demand (MDD) scenario than in the average day demand (ADD) scenario. when switching from ADD to MDD, EPANET must first import the MDD controls (under File, Import, Scenario). Then, EPANET's demand multiplier (under Options, Hydraulics) must be changed from 1.0 to 2.5 to reflect the increased demand. To ensure that the system starts at a relatively stable condition, one must check the initial values of all tanks to make sure they are set correctly. This is explained below.

Commenting conventions

In EPANET, each tank has a comment in the Description property. For example, wres-tank's comment is "110/109 mdd, 118/107 add, 2kgpm/2hr."

This means that in an MDD simulation, the initial level should be set to 110. For that scenario, the tank's lowest level at any time of the day will be 109. Likewise, for an ADD simulation, the initial level should be set to 118, and the lowest value for that scenario will be 107. Since wres-tank's diameter is 100, and its minimum level is 103, this means that the tank will always have a minimum reserve of 3,900,000 gal. In other words, regardless of the time of day, wres-tank can always provide at least 2000 gpm of fire flow for 2 hours.

Notes on opening EPANET .inp files with Excel for editing

EPANET saves .inp files in a quasi-tab-delimited format. It's just non-standard enough to make them difficult to edit with Excel. To make matters worse, EPANET can't seem to open .inp files if they are actually tab-delimited. Instead, they must be tab+space-delimited. This is time-consuming to do by hand, or even with Excel. I've found an easy way to convert between the two formats using Notepad++ (http://notepad-plus.sourceforge.net):

EPANET to Excel

1) Export .inp with EPANET; open with Notepad++.
2) Replace regular expression `[\s\t]*$` with nothing.
3) Replace regular expression `^[\s\t]` with nothing.
4) Replace regular expression `\s*\t` with `\t[space character]`.
5) Save as .txt, open with Excel as tab delimited file.

Systematically renaming junction/pipe elements in Excel

1) Create new element names in column K, to the right of the original junction and pipe definitions. For example, you could build the names by using CONCATENATE() inside IF(), along with a column of numbers that go from 0001 to 9999. Right-click the 0001-9999 cells and format them using a Custom format of "0000". This will pad the numbers with leading zeroes.
2) Everywhere else in the spreadsheet, put something like VLOOKUP([cell_containing_old_name],$A$1:$K$999,11,FALSE) in column K, where $A$1:$K$999 is the original block of old-names/new-names. This tells Excel to find the new names corresponding to each old name in the spreadsheet – for example, this will help you easily update all the junction names in the link definitions section of the .inp file. It is **crucial** that every occurrence of an old element name is changed to reflect the new element name specified in step 1.
3) From the bottom of the spreadsheet up, copy and paste chunks of new element names over the old names using Paste Special, Values. Start with [VERTICES], then [COORDINATES], etc., and move to the top. Mesopolis_edit_example.xls is a working example of this process just before this step is taken.
4) Sort rows to make things easy to find in EPANET.

Excel to EPANET

1) Save as tab delimited .txt and open with Notepad++.
2) Manually edit rules and controls in Notepad++ to reflect element name changes.
3) Replace regular expression `[\s\t]*$` with nothing.
4) Replace regular expression `\t` with `\t[space character]`.

5) Replace the double-quote character " with nothing.

6) Save and open .txt with EPANET.

Pipe Roughnesses

Year Installed	mft of roughness
1910	18
1920	15
1930	10
1940	5
1950	3
1960	2
1970	1.3
1980	0.11
1990	0.1

In EPANET, use Group Edit to assign a year installed Tag to a cluster of pipes (e.g. 1980); then use Group Edit again to set a roughness (e.g. 0.1 mft) based on the Tag. For some reason, roughnesses smaller than 0.1 mft will create an unbalanced system and EPANET will complain. Under Browser, Map, view links by roughness and set the legend to limits of 0.11, 1.2, 1.8, and 5.1.

High-Resolution Zones: In progress

Eventually, the Mesopolis model will have multiple high-resolution zones with a much higher level of detail -- the system will be fully described and simulated down to the individual service connections. Of course, it doesn't make sense to model Mesopolis at this level of detail throughout the city, so we will focus on just a few areas of interest, e.g. the port, the mountains, or the abandoned industrial district.

This phase of the Mesopolis project is just beginning development.