London Strategic Model

building a complex hydraulic model of London's strategic assets, including more than 4,000km of mains, 70 service reservoirs and over 100 pumping stations

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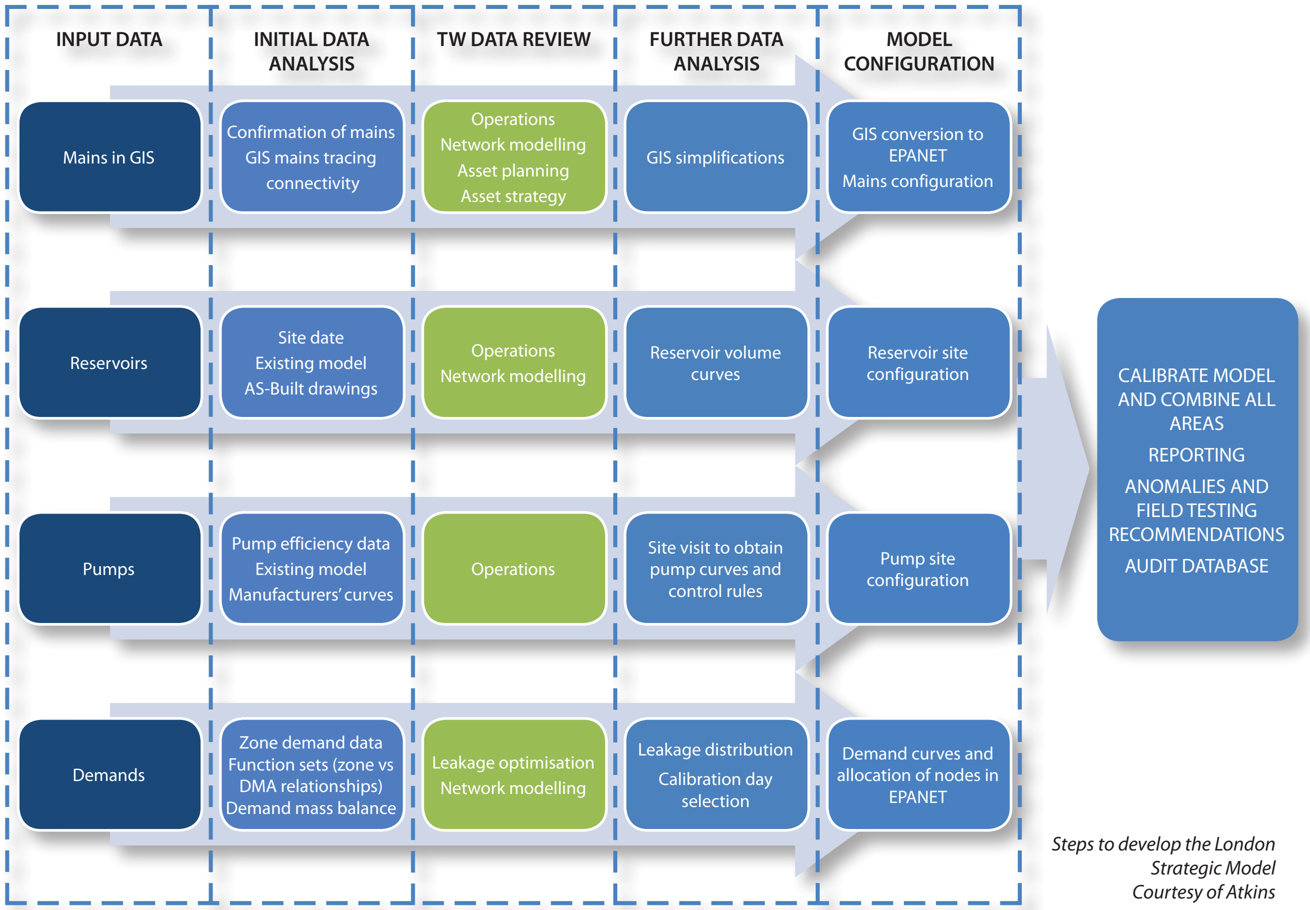
Thames Water, the UK's largest water service provider, supplies nine million customers in London and the Thames Valley. London's water supply comprises a complex network, including over 70 reservoirs and over 100 pumping stations. The population is growing and also changing in its distribution across London. Climate change and the associated environmental impact on water resources means the existing water supply network needs to be reconfigured to meet demand. Thames Water has upgraded their SCADA system and is developing a flexible operation to respond to events in real time. This, and the need to effectively plan the supply network for the future, will be based on a hydraulic model of the whole strategic network – the London Strategic Model. This paper describes the development of this challenging model, which involved collating over 57 million data point readings.



Steps to develop the London Strategic Model Courtesy of Atkins

Key project data and rationale

The London strategic network records in GIS include over 4,000km of mains ranging in size from 150mm for transmission and principal mains to 2.5m in diameter for the Thames Water ring main.

Divided into 76 Flow Monitoring Zones (FMZs), the network includes over 70 service reservoirs and over 100 pumping stations. Thames Water commissioned Atkins to build a strategic network model to include all strategic assets. Atkins produced a similar model in 2002 to reflect system changes over the previous decade.

Thames Water has made significant changes over the last decade, during which time the population has increased by 12% (up from 7.3 million in 2001 to 8.2 million in 2011, based on ONS Census data). A significant rise in demand to the east saw infrastructure built including refurbishment of twin 42" mains from Coppermills WTW and the new desalination plant in Beckton. Thames Water also invested in major capital schemes such as the Victorian Mains Replacement programme, pressure management and network reconfiguration to reduce leakage.

Further changes are expected as the population grows and shifts. Environmental pressures on allowable resource abstractions means the strategic network will have to change the way it works. Thames Water will need to adapt and reconfigure the network to meet these new challenges and provide a resilient and reliable supply.

In future, the network will need to be more flexible. Future operational scenarios may involve a number of different regimes, perhaps integrating with other water utilities in the South East.

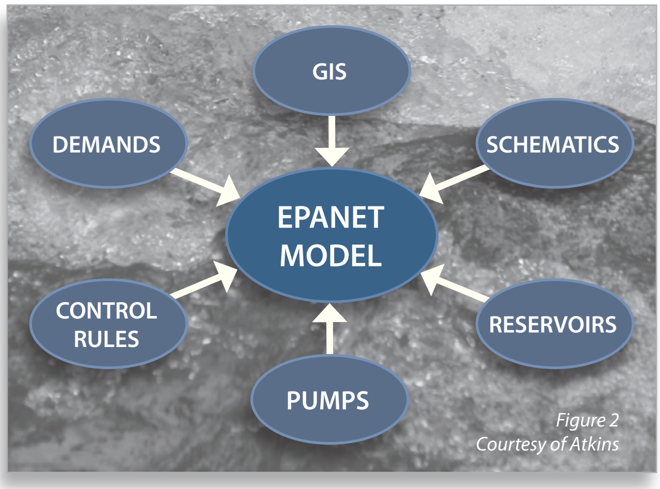


Figure 2
Courtesy of Atkins

Thames Water is upgrading their SCADA system to enable the network to be monitored and managed in real time. As such, the London Strategic Model will become an integral future part of Thames Water systems including real time monitoring, operation and reporting. The new model is required to reflect the system changes and create a model which provides a robust tool to predict system performance and leakage targeting.

The project started in late 2012 and is scheduled to complete in 2013. Other related projects such as risk of pipe failure modelling are being undertaken by Thames Water. They will combine with the hydraulic model to produce a powerful decision-making tool for targeting network improvements and rehabilitation needs.

The project objective was to produce a strategic network model, with a clear audit trail of the data used and calibration actions in two phases as follows:

Phase 1: Comprehensive collation and review of data (GIS mains/sites/demand and controls) to produce a verified strategic network model. Key outputs are:

- EPANET verified model.
- Audit database.
- Model construction report.
- Summary/location plans of anomalies identified during calibration.

Phase 2: Extensive investigation and resolution of the most significant anomalies identified under Phase 1 through field testing of pressures. Key outputs are:

- EPANET calibrated model.
- Updated audit database.
- Updated model construction report.

Project team collaborating with Thames Water

This project benefited from close working relationships developed between Thames Water and Atkins over the last 25 years. To undertake this comprehensive data collation, integration and model build exercise, a pro-active working approach with several Thames Water teams including Asset Strategy, Network Modelling Group, Assets Planning, Strategic Network Optimisation, Production and Leakage Optimisation was required.

Atkins' team modellers who worked on the 2002 models are now senior members of the management team, and bring a wealth of knowledge to the project.

This close working relationship enabled quick resolution of the issues arising from the data review by always talking to the right people, thus achieving programme efficiencies.

Technical description

The main model building blocks are illustrated in Figure 1 *(see page 1)* and the main steps in developing the strategic network model are illustrated in Figure 2 *(left)* as follows:

- Provision of input data.
- Initial data review and analysis.
- Review of data with Thames Water staff.
- Further data analysis.
- Model configuration.
- Calibration and reporting.

Each step was necessary to ensure all assets and system characteristics (e.g. mains including valves, reservoirs, pumps, controls and demands) to be modelled have been consistently checked and reviewed before they were all combined and the model calibrated.

Provision of input data

At the onset of the project, Thames Water provided the most recent GIS data of the strategic mains for each zone, which we verified to be representative and complete. GIS data included transmission (from distribution input (DI) to zonal meters), principal mains (from zonal meters to district metering area (DMA) meters) and all related assets and connectivity.

Thames Water provided work schematics with the most recent site data, comprising mains within the site boundaries, and details of pumps, reservoirs, water tanks and valves. Details of the site mains were available from the original strategic model (built in 2002), which were reviewed and amended as necessary.

Pump data comprised information from Thames Water's recent pump efficiency tests of the last 10 years, manufacturers' curves and the original strategic model. Control data was collated from interviews with Thames Water Operations and the Control Room, as well as operational flow data and reservoir level data. Control data represents the rules which determine whether or not a pump is on or off, and reservoir and control valve settings.

For calculating model demands, Thames Water provided historical flow data through the OMS and PIWADIS systems at 15 minute intervals. This included all zonal meters, reservoir, tank and other key bulk supply meters within each water resource zone for a one-year period (from 2011/2012). The function sets, as well as zonal schematics indicating the water balancing relationships between zones and DMAs, were also made available.

Initial data analysis

The strategic network was traced from site boundaries to DMAs to eliminate inaccuracies in connectivity from network GIS digitisation and asset tagging. Tracing and connectivity was carried out within the StruMap GIS environment. Atkins reviewed this against DMA and zonal schematics to confirm that all DMA meters are included and zones are discrete.

Atkins reviewed pump curve data (pump type, status, head lift and efficiency) to identify changes over the last 10 years; pumps with uncertain data; and needs for further pump data collection. The site visits were then organised to gather further pump data for the purposes of model build and calibration.

Demand balancing templates were used to ascertain DI, ZM and DMA flow data gaps and anomalies. The templates allowed dynamic modification during data review and importation into the model.

Review of data with Thames Water

After initial data analysis, Thames Water had the opportunity to review and accept key outputs from the project as it progressed. This ensured the model included key operational features and reflected the likely future operation of the network. Thames Water Production provided further pump data and Atkins visited sites to ascertain additional pump data.

Further data collection and analysis

Following completion of the mains tracing process and resolution of GIS anomalies, further GIS simplification improved efficiency of the model run. This included deletion of mid span nodes, capturing high and low elevation points on transmission main, and elimination of spurs and hydraulically less relevant loops on the network.

Following additional site visits, all pump data was collated ready to import into the model. Based on the analysis of pump flow, reservoir level and discussions with Thames Water Operations, Atkins prepared rule-based controls within an offline editor, which allowed Thames Water to edit and amend rules in the future.

The demand data was reviewed to calculate the average daily demand (ADD) for each zone and analysed to select the most representative calibration day (avoiding public and religious holidays, and major tourist events).

A single day was selected in October 2011 from which a single London model was created. An ADD for the whole of London was calculated to be approximately 2,000Mld.

Model configuration and conversion of GIS

Model configuration included conversion of GIS mains data and site data into EPANET software and verifying that all system characteristics, including boundary conditions have been set up correctly.

An EPANET data file was created by exporting the GIS data from StruMap GIS using a script developed by Atkins for the purposes of this project. The conversion script was written in StruMap Expression Evaluator using a programming language which can incorporate combinations of actions and specific functions to analyse entire data structure.

Boundary conditions comprised:

- ***Water treatment works***: Contact tank water level represented as a fixed head node source.
- ***Ground water abstraction works***: Pumping water level in the borehole or well.
- ***London Water Ring Main***: For individual area models, the ring main was modelled as a reservoir, representing the normal average operating level at the shaft. For the combined model, the ring main was modelled in full.
- ***Open/closed valves***.

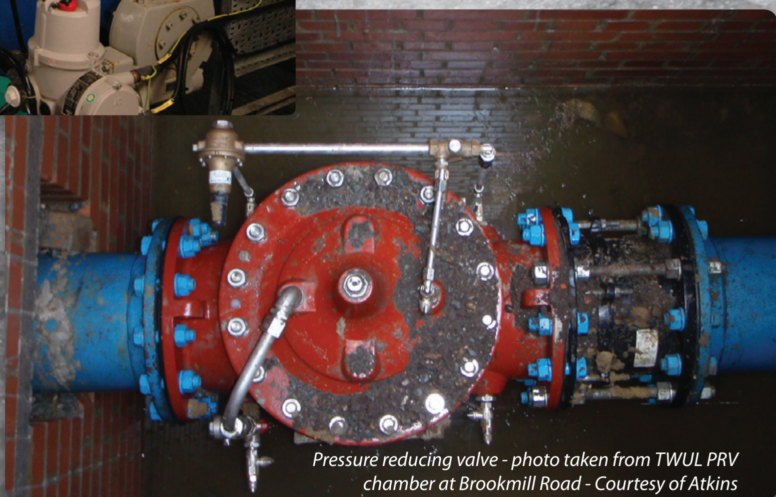
Generally, the model utilised the actual district meter flow profile allocated at the district meter nodal locations. Sometimes, where the DMA/FMZ is an integral part of the transmission system, strategically important mains were incorporated and the FMZ/DMA demands were directly allocated at single or multiple representative nodal points.

Calibration and reporting

Calibration under Phase 1 involved configuring levels, demands and controls to the calibration day, before adjusting to achieve good calibration. All calibration actions were documented in the modelling report.

EPANET produces calibration reports giving an indication of the quality of calibration of the model. The calibration reports in EPANET are utilised for grading in accordance with the following criteria:

Pumping shaft at TWUL Hampton WTW Courtesy of Atkins


Pressure reducing valve - photo taken from TWUL PRV chamber at Brookmill Road - Courtesy of Atkins

	Average modelled value	Instantaneous modelled value
Flow	+/- 10%	+/- 20%
Pressure/total head	+/- 2m	+/- 4m
Reservoir/tower level	+/- 100mm	+/- 200mm

Good correlation is defined by the average model value taken over 96 steps, 15min data values compared with average observed measurement being within the tolerances in the table above.

Poor correlation is defined by the calibration falling outside the criteria above.

In addition to the boundary conditions, existing pressures collected by Thames Water's SCADA system at approximately 300 pressure points were used initially to calibrate the model. More comprehensive field testing of over 2,000 pressure points is planned for Phase 2 of the project.

All calibration anomalies identified in Phase 1 were recorded to determine priorities for field tests in Phase 2.

Conclusions

Innovation in data processing: Analysing large data sets is challenging. Atkins developed bespoke applications and software to ensure consistent and efficient calculations.

For example, the selection of the calibration day and trunk main leakage calculation involved collating over 57 million data point readings. Atkins developed a set of templates and routines to efficiently derive a demand mass balance for the London trunk main system.

StruMap GIS Expression toolkit was used for network simplification, GIS clean up and conversion into EPANET. This advanced set of modelling skills was deployed jointly by Atkins and Thames Water.

This flexibility enables further data review and correction with minimal effort where several aspects of hydraulic calculation are considered simultaneously.

Adding value through asset and system knowledge: The model is calibrated to a high standard and is flexible enough for future operating scenarios to be easily tested. Key elements of the project's success:

- Exploiting available data and local system knowledge.
- Accessing data from a range of corporate systems and applications.
- Rigorous data collation, including data validation and audit trails.
- An in-depth knowledge of Thames Water's modelling group and operations teams.

Next steps

Field testing has been planned on approximately 2,000 pressure logger locations and is ongoing at present. The results will aid final model verification and resolution of anomalies identified in Phase 1 of the project.

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