

The Optimatics Letter

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Advances in Optimization for Water Distribution System Design & Operations

Toronto/York State of the Art JOS

The City of Toronto and the Region of York have collaborated on the planning for their future water infrastructure needs since the mid-1970s. Toronto and York recently took their historic collaboration a step further by undertaking a state-of-the-art Joint Optimization Study (JOS).

Joint Optimization Study Goal

Toronto currently supplies most of the Region of York's demands by pumping water north in a series of lifts from four water treatment plants on Lake Ontario in the south. In the future, increased demand within the City and the fast-growing Region of York will require that existing treatment capacities be increased and other supply sources brought on-line.

The goal of the JOS was to identify near-term (2011) and long-term (2031) water supply and infrastructure plans to meet future demands (under various conservation assumptions) in the most cost-effective manner.

The JOS began with Earth Tech Canada being selected to update and combine the individual hydraulic models of Toronto and Region of York into a single model. An extended period simulation (EPS) model was prepared using H2ONET for different demand conditions, assuming with-conservation and without-conservation demands for Toronto and Region of York separately.

As the model neared completion, the next step was to get the specialty optimization team on board. Toronto-York and Earth Tech selected Optimatics to provide its expertise for the next JOS phase. The work plan called for Optimatics to utilize its Optimatics GA (OGA) to optimize a series of maximum day EPS demand scenarios. It was agreed that the optimization would consider both future capital improvement and system operating costs to minimize the overall project life-cycle costs.

A State-of-the-Art Optimization

The Toronto-York JOS represents the most advanced analysis that Optimatics has undertaken to date. The joint water system is very large and has many future supply and facilities options as well as system operating options. Toronto's existing facilities include 18 pump stations with 120 pumps having an installed pump capacity of 9,100 ML/day (2,404 MGD), with 10 reservoirs and 4 elevated storage tanks serving 12 pressure districts. The City has some 490 km (305 mi) of transmission mains ranging from 300 mm-2,500 mm (12"-96") in diameter.

The Region of York receives about 75% of its water from Toronto via 13 interconnection points. The balance of water demand is met from wells and from Lake Simcoe in the far north. The southern and central York system includes 187 km (116 mi) of transmission mains, 11 pump stations, 9 reservoirs and 13 elevated tanks.

Average day water demand for Toronto-York is about 1,500 ML (395 MGD) with average day pumping of about 2,900 ML (766 MGD). A large demand increase is expected for the Region of York over the next 25-30 years with a doubling of population to 1.2 million. Long-term average water demands for Toronto-York are forecast to increase by some 25% or 380 ML/day (100 MGD).

(Continued on page 2)

The Toronto-York Joint Optimization Study represents the most advanced optimization analysis that Optimatics has undertaken to date.

Optimatics Goes Global with Its GA Services

Since 1995, Optimatics has completed dozens of consulting studies in the U.S. and Australia. In late 2003, Optimatics took steps to begin offering its specialized consulting services in optimization of water systems to clients in Europe and the United Kingdom. Optimatics now has two contracts underway in the U.K.

Optimatics' U.S. operation was also expanded with Mike Canning, P.E. joining our Chicago office as Regional Manager to handle studies in the eastern states. At the same time, Frey Water Engineering effectively merged with Optimatics so that consulting services could be offered under just the Optimatics name.

JOS Optimization Approach

In spite of the large size and complex operation of the Toronto-York joint system, the JOS aimed to develop low-cost optimized solutions that fully met Toronto and York’s design and performance criteria. The JOS optimization would have to identify the best mix of water supply options, new pipe, storage, pump and valve facilities options, and operational settings, pumping hours, etc. to minimize project life-cycle costs. The optimization was thus formulated to find the optimal balance between future capital improvement costs and lifetime operating costs over the project design life.

The OGA optimization was first applied to the year 2031 maximum day EPS model using with-conservation demands for both City of Toronto and Region of York. To the existing system model, the following possible choices (for locations and sizes or capacities) were added as capital improvement decision variables:

- 2 WTPs (Clark & Horgan) for upgrade
- 1 Region of Peel supply point
- 385 new pipe alignments
- 12 new storage facilities
- 14 existing storage expansions
- 10 new pump stations
- 26 PS upgrades or expansions
- 6 new control valves

In addition to these capital improvement choices, the OGA model was formulated so that a range of operational decisions could be evaluated/selected in the same optimization runs. The allowable operational decisions for included:

- supply rates from the 4 WTPs
- supply rates for the Peel supply point
- on/off decisions for new pumps
- setting decisions for existing pump sets

OGA Optimization Search

After adding all of the OGA future facilities choices into the existing Toronto-York system EPS model, the resulting model had nearly 3,000 pipes, 52 storage facilities, 166 pumps and 184 valves. (Figure 1 presents a layout showing the existing system in the background with new pipe decision choices highlighted.) In a series of dozens of preliminary and interim runs, the OGA searched for the best mix of capital improvements and operational choices to minimize project life-cycle costs.

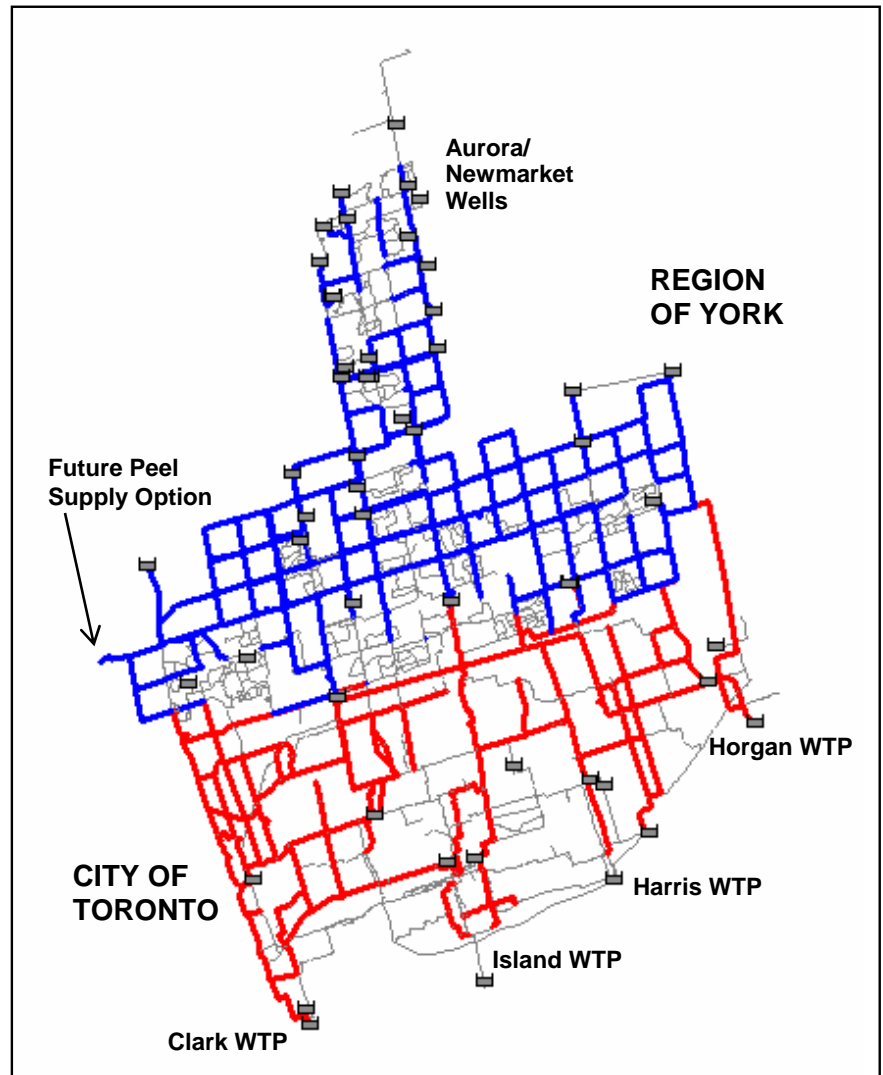


Figure 1. Allowable New Pipe Alignments —The different shades or colors distinguish between the Region of York and City of Toronto new pipe choices. A total of 385 new pipe choices were considered in the OGA optimization search.

Capital improvement and operating costs were input into the OGA for the range of allowable values. Capital costs were estimated for each of the capital improvement decision choices listed above. Estimated costs for pumping operations were prepared based on recent data for Toronto and York. Pumping costs utilized on-peak and off-peak rates taking into account energy and demand charges. (Different source water costs could have been included in the analysis but were not in this case.)

The OGA optimization search process entailed creating an initial “population” of trial solutions with each solution consisting of a mix of the allowable facilities and operating decision variables. Each of the 200 initial trial solutions was then run in the Toronto-York simulation model and its hydraulic performance evaluated.

The “fittest” solutions were those that had a low life-cycle cost and good hydraulic performance, i.e., those closest to meeting minimum and maximum pressures, maximum velocities, and adequate turnover of storage (to maintain water quality) over the EPS day.

Based on a natural selection or “survival-of-the-fittest” process, the OGA manipulated successive generations of trial solutions to breed into the population the desirable characteristics of low cost and good hydraulic performance.

For the above optimization search to succeed, it was critical that the OGA model be properly formulated to the customized Toronto-York hydraulic model and that appropriate GA search parameters be selected to effectively guide the search.

JOS Optimized 2031 Solution

A total of more than 25 million trial solutions were simulated in a series of OGA runs. Three distinct 2031 and 2011 scenarios for the Toronto-York system were optimized.

Figure 2 presents the preferred optimized solution for the 2031 with-conservation scenario for Toronto and Region of York. The estimated capital cost of the 2031 improvements was \$1,124 million (Canadian) to cover the new Region of Peel supply point, two WTP upgrades at Clark and Horgan, and pipe, storage, pump station and valve costs. The estimated pumping costs for Toronto and York over the project life were estimated at C\$21.3 million per year.

Toronto-York JOS Outcome

In creating the Joint Optimization Study, the City of Toronto and Region of York water utilities were motivated to utilize a state-of-the-art optimization technique to analyze the widest range possible of facilities alternatives and system operations options. They desired

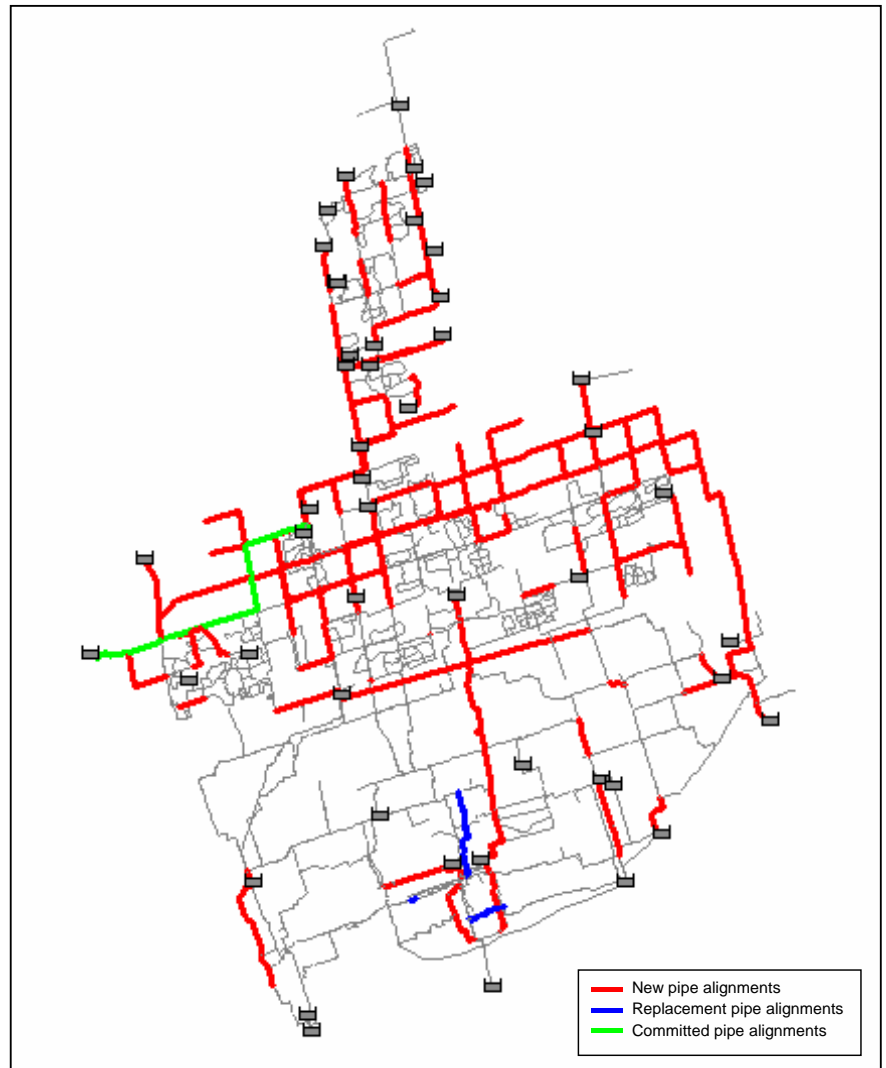


Figure 2. Preferred 2031 With-Conservation Optimized Solution — An optimal mix of water supply, new pipe, storage, pump and valve facilities locations and sizes and operating setpoints was selected from among the allowable choices to minimize project life-cycle costs considering capital improvement costs and lifetime pumping costs.

an optimization approach that would minimize project life-cycle costs since annual pumping costs are significant and future energy rates are uncertain. We are happy to report that Toronto and York were pleased with the outcome of the JOS as evidenced by the quote shown on the back cover from Toronto’s JOS Project Manager Gordon Mitchell.

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We used GA optimization to determine optimal future supply infrastructure requirements for Toronto and our neighbour, the Region of York to the year 2031. The technique proved to be a cost-effective method of evaluating hundreds of variables to determine the best solution. We certainly could not have evaluated a fraction of the options considered using traditional design techniques.

Gordon Mitchell, P.Eng.
Senior Engineer, Water Supply
City of Toronto Water Supply

The City of Toronto-Region of York Joint Optimization Study (JOS) must be considered a BEST PRACTICE for water system planning.