The Optimatics Letter

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A Paradigm Shift to Optimization

The paradigm shift or radical change in approach described in this article is the move by utilities from relying on a simulation modeling approach to plan and operate water and wastewater systems to the use of an optimized decision support approach to identify superior capital improvement and operating solutions.

Simulation's Limitations

Simulation modeling of water systems has been in widespread use for more than 20 years. Today's simulation models are sophisticated analysis tools capable of accurately representing flows, pressures, water levels, pumping, etc. in water transmission/distribution systems and wastewater collection systems under a range of loading conditions.

The leading software packages include versions that combine simulation modeling features with GIS integration and functionality. Other advances include feature-rich controls, powerful user interfaces and limited optimization capability. As for computational methodology, most of the simulation models utilize or have the option to utilize the standard EPA hydraulic solvers EPANET and SWMM5 at their core.

No matter how sophisticated these simulation models, their primary purpose is to simulate how water systems perform under different conditions. Simulation models simulate—they assist a modeler or planner to identify capital improvement or operating solutions only to the extent of making it easier to perform trial-and-error analyses and review results for different solutions input by the user. Modelers rely on engineering judgment and trial-and-error to develop a handful of solutions for them to evaluate.

Value of Moving to Optimization

An optimized decision support approach using powerful, water-specific optimization tools is fundamentally different from a simulation approach. Optimization tools such as Optimatics' Optimizer WDS and Optimizer WCS, developed for distribution systems and collection systems, are able to guide the modeler or planner to identify superior, low-cost solutions. Using an optimized decision support approach, the user elevates his role to one of directing the software to find a range of near-optimal solutions rather than trying to solve the problem himself. Engineering judgment, of course, remains a key factor but importantly the modeler avoids getting bogged down in the details of creating a trial solution, running it, analyzing the results, repeating those steps and then ultimately manually calculating the cost of a preferred solution.

The optimization modeler still performs a deficiencies analysis to see where there are problems in the system, and then adds all possible capital improvement and operating options into the model as decision variables to be considered. The optimization search mixes and matches the improvement and operating options to create hundreds of thousands of trial solutions that are run individually in the hydraulic simulation model. This is done automatically by the software which proceeds to evaluate each solution's hydraulic performance and cost simultaneously.

This optimization process frees the modeler and project engineers from the drudgery of repeated trial-and-error testing while it encourages innovation and out-of-the-box thinking. The process welcomes input and ideas from the utility's Planning, Engineering and Operations groups—in fact obtaining this wide-ranging input is critical to achieving the best overall solution for the utility.

Figure 1 shows the full range of pipe, pump, tank, and valve decision options input for the build-out demand case for City of Bend, Oregon's Water Master Plan. Figure 2 illustrates how few of these many improvement options were selected to be included in this particular optimized solution. Once formulated, the optimization search "evolves" several unbiased, defensible, near-optimal solutions for consideration by the utility decision-makers.

Is the optimized solution in Figure 2 a "black box" solution that cannot be trusted because the utility does not understand where it came from? On the contrary, the process used is simply an automated trial-and-error process that takes advantage of today's available computing power. This genetic algorithm approach has been called "trial-and-error on steroids" which is a pretty accurate description.

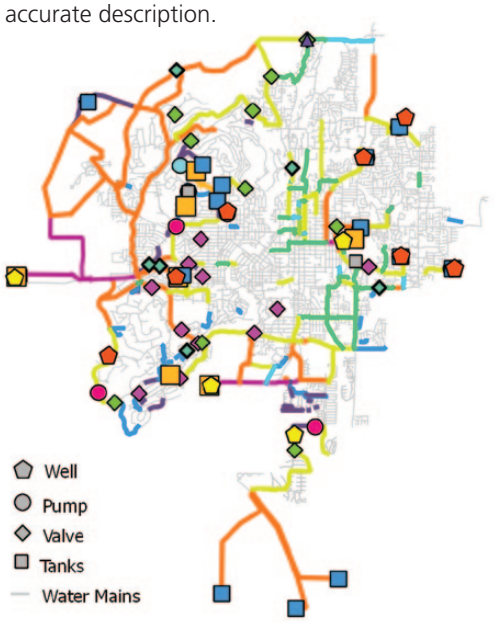

Figure 1. Bend system highlighting vast number of pipe, tank, pump and valve options in Optimizer.

Figure 2. Bend optimized improvements are a small subset of the wide range of options in Figure 1.

Evidence of a Paradigm Shift

Labeling the shift from utilizing simulation models to using an optimized decision support approach as a paradigm shift is subjective. The evidence we would cite is the strong interest being shown by utilities and consultants to utilize optimization to attain better solutions. Some examples include:

- East Bay Municipal Utility District's West of Hills Optimized Master Plan
- City of Bend's Water Master Plan and Seasonal Operations Optimization
- Las Vegas Valley Water District's Daily Operations Optimization Tool Assessment
- San Antonio Water System's New Source Water Integration Optimization
- Murray Darling Basin Authority's River System Drought-Inspired Optimization Tool (Australia)
- SA Water's New Desalination Plant Source Integration Optimization (Australia)
- South Central Connecticut Regional Water Authority's Service Area Improvements Optimization
- San Diego Water Area Cast Iron Main Replacement Optimization
- Johnson County Wastewater's Turkey Creek Basin Plan Optimization
- City of Fort Wayne's Collection System Real-Time Control Evaluation RFQ

In speaking with utilities and consultants over the past year, we have observed an increased awareness of what optimization is and the value that it brings. **Pam Elardo**, Division Director at King County DNR in Seattle, had a great quip saying the move from traditional simulation to optimization was *"like moving from the slide rule to the calculator."*

Greg Baird, former CFO for Aurora Water in Colorado, now writes the Money Matters column for AWWA Journal. Greg has a laser focus on the issue of affordability for customers and utilities. In his December 2010 column Greg lists strategies for minimizing rising water costs, including: *"Conduct on-going optimization decision support analysis on hydraulic models for comprehensive planning, operational efficiency reviews, cost allocation verification, and 'green' alternatives analysis using advanced techniques such as genetic algorithms."*

Finally, the **Partnership for Safe Water** (PSW) announced on January 13, 2011 an invitation for charter membership through March in PSW's new Distribution System Optimization Program saying: *"PSW's optimization programs identify opportunities for improvement in water system operations…"* PSW held a National Conference on Water System Optimization in Hershey, PA with AWWA that attracted at least one paper on optimized decision support of water systems. We anticipate the Program will advance further into the use of formal optimization tools to enhance system operations and water quality performance.

Educating Others on Optimization

In 2010 we had the chance to meet **Dr. Dennis Lai** and Steve Allbee, two key leaders at U.S. EPA. Dennis is at the Urban Watershed Management Branch and has led advances in collection system and storm water research with the SSOAP and SUSTAIN projects. Dennis is an optimization pioneer known globally for his landmark paper applying optimization to the New York City Tunnels problem (Lai and Schaake, 1969, *Linear Programming and Dynamic Programming Applications to Water Distribution Network Design*. Report 116, Department of Civil Engineering, MIT, Cambridge).

Steve Allbee as EPA's Project Director of Gap Analysis has highlighted critical funding needs for water and wastewater infrastructure for many years with a focus on asset management. His presentations have called for the application of best practices, innovation leading to productivity gains, and sustainable rates pricing.

We had the chance to demonstrate Optimatics' Optimizer WCS software to Dennis and Steve who expressed appreciation to see new technology that could positively impact utility costs and customer rates. [Note that we are not implying any endorsement by them or by EPA.]

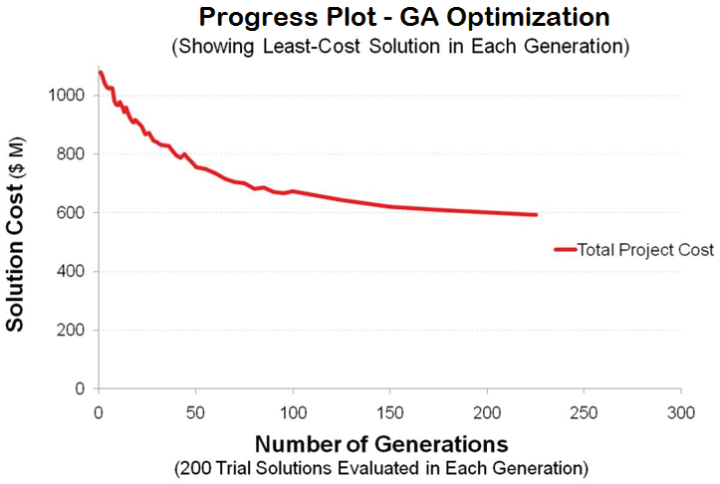

Figure 3. Optimization search progress plot when using a pure genetic algorithm computational approach.

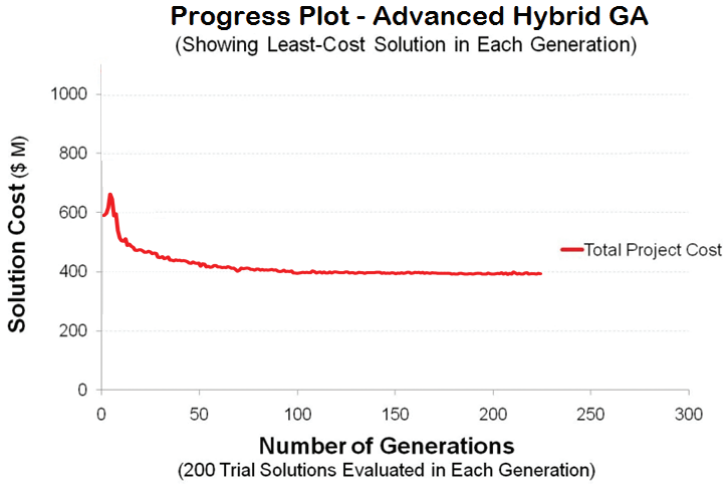

Figure 4. Optimizer WCS search progress plot using an advanced hybrid genetic algorithm computational approach.

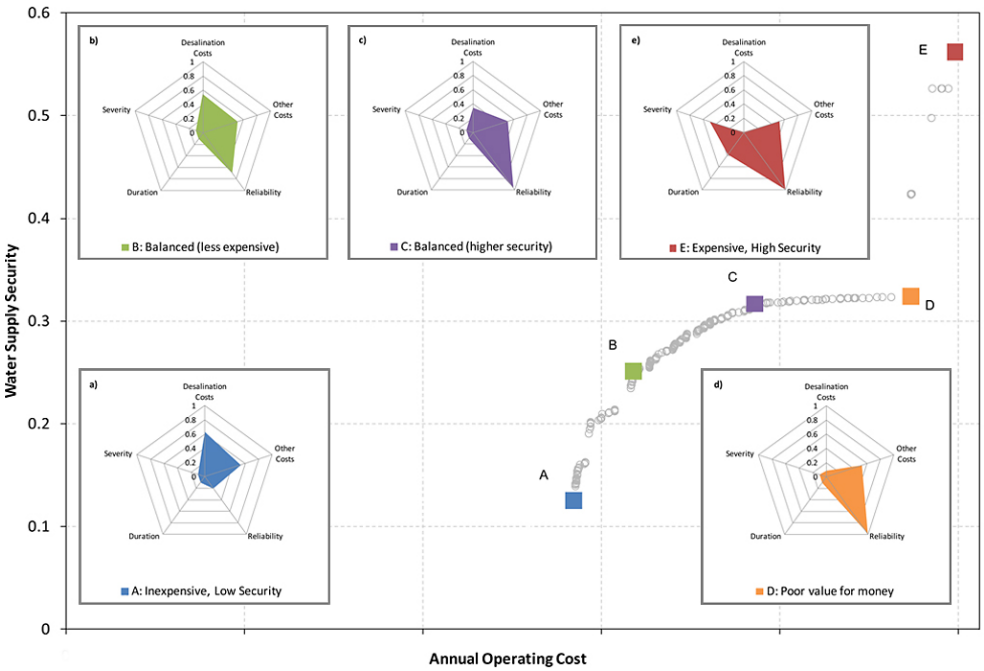

Figure 5. This example curve illustrates the trade-off between Annual Operating Cost and Water Supply Security for Melbourne Water. Utility decision-makers might prefer a solution near B or C with good trade-offs or solution E with high security.

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For further information about Optimatics and back issus of 'The Optimatics Letter' please visit our website at:

www.optimatics.com

Latest Optimization News

Rather than attempt a broad coverage of the optimization field, we will just mention three exciting developments at Optimatics. **First**, we have upgraded our previous-generation Optimizer WCS genetic algorithm software by adding implicit linear programming, heuristic analytical refinement, logic adjustors, and detailed engineering checks. The advanced hybrid genetic algorithm optimization search is far more efficient as shown by comparing the plots in Figures 3 and 4. Both the speed of the collection system planning process and the quality of the solutions have been improved.

The **second** bit of news is Optimatics development and application of multi-objective optimization on a major project in Australia. Based on the ubiquitous NSGA-II algorithm, our software directly outputs an optimal trade-off curve that provides utility decision-makers with the information they need to choose their preferred balance point among two or more objectives. Figure 5 plots the optimal trade-off curve found for Melbourne Water's Water Supply Security Project. The radar charts for solutions A-E are particularly helpful to decision-makers in comparing different operating strategies. They were used as part of a multi-criteria analysis to evaluate the relative merits of each strategy.

The **third** development to highlight is Optimatics' move to train selected utility and consultant staff to apply our Optimizer WDS and Optimizer WCS software. To date we have licensed versions of Optimizer WDS to SA Water and Allconnex Water (Australia) and Veolia Water Central (UK) to enable utility staff to gain experience formulating and running the software and evaluating solutions. We have also licensed reader-only versions of Optimizer WCS to Hunter Water (Australia) and North Shore City Council (New Zealand). Based on positive feedback on these projects and our recognition that the industry needs to make the transition to using optimized decision support software, Optimatics foresees the Optimizer tools soon helping more utilities realize cost savings and achieve superior hydraulic solutions.

Afterword

Some of you may realize this issue of The Optimatics Letter comes after a long respite. The previous issue No. 22 was sent in Winter 2005. Our apologies go out to anyone who missed this quarterly dispatch. It was a recent visit with one of our former readers **Kevin Hunt**, General Manager at Municipal Water District of Orange County, who inspired us to have another go at this. Thanks Kevin.

Finally, we would be happy to receive any questions, comments or feedback you'd like to offer. In the coming months we have a number of optimization case studies to report on, but if you have a request for a specific topic please let us know by emailing jeff.frey@optimatics.com.

The Optimatics Letter

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Please pass this newsletter on to key staff involved in water system planning and operations.

Also, please call, fax or e-mail us to update names & addresses or to be removed from the mailing list.

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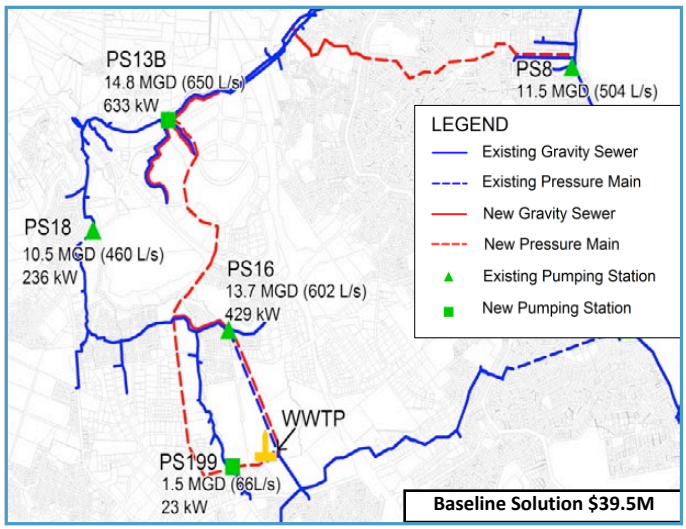
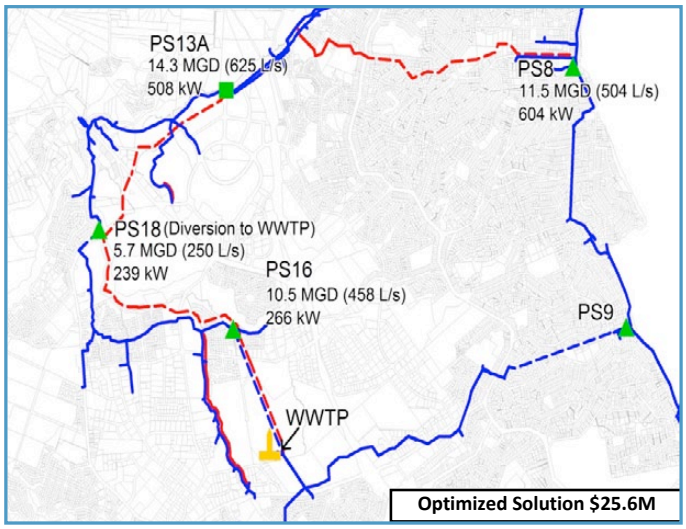
As systems age and budgets contract, utilities are moving from a traditional simulation-only approach to an optimized decision support approach to achieve results like this: $13.9 million (35%) in capital cost savings.



The City's collection system improvement plan had been approved and construction of the PS13B pressure main had begun when the City decided to see if Optimatics' Optimizer WCS hybrid genetic algorithm optimization could in fact save them precious capital.



The Optimizer WCS study evaluated many thousands of alternative sewer, pump station, storage and I/I removal combinations to mitigate overflows. The optimized plan achieved $13.9 million in capital cost savings plus a 10% reduction in projected lifetime pumping energy costs.