

The Optimatics Letter

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Optimizing a Main Replacement

EPA's 1997 Drinking Water Infrastructure Needs Survey collected and analyzed data from 4,000 community water systems. Needs were documented by the water systems' capital improvement plans and engineering reports. A total of \$138 billion for current and future infrastructure needs for the 20-year period 1995-2014 was identified.

Breaking this total figure down, the EPA reports the single largest category of need is the installation and rehabilitation of transmission and distribution systems—\$77.2 billion or 56%. Most needs in this category involve the replacement of existing pipe. Either the pipe has exceeded its useful service life or it is severely undersized and must be replaced.

Water districts and utilities realize that sound transmission and distribution systems are critical to protecting the public from contaminants that cause acute illness. Pipe deterioration may also result in reduced hydraulic capacity and decreased reliability. For these reasons, it has become standard practice for water utilities to have a main rehabilitation/replacement program in place.

The question we'd like to address in this issue of *The Optimatics Letter* is how optimization can be used to drastically reduce the cost of main replacements while at the same time improving a system's hydraulic performance.

The Lyons Road Main Replacement

The Lyons Road Project in South Australia represents the type of main replacement problem that faces nearly all water utilities. SA Water found that its 900 mm steel main (installed in 1920 and concrete lined in 1958) running from Hope Valley Reservoir along Lyons Road and North East Road was exhibiting frequent breaks and excessive leakage due to severe external corrosion. The question was what replacement and/or improvement solution was best?

In May 1999, SA Water prepared a report to evaluate options for the Lyons Road Main. The report concluded that 3,400 m (11,150 ft) of the main, not its full length, should be replaced. Also, a 900 mm main would not be required, but rather a 525 mm concrete-lined ductile iron pipe would be sufficient based on a preliminary hydraulic simulation.

SA Water's preliminary solution, shown in Figure 1, had an estimated capital cost of Aus\$3,190,000 (US\$2,200,000) for the main replacement based on updated unit pipe costs. After further review, the solution was found not to strictly meet the desired minimum allowable residual head of 20 m at peak instantaneous demands for all nodes in the northern portion of the El. 103 zone.

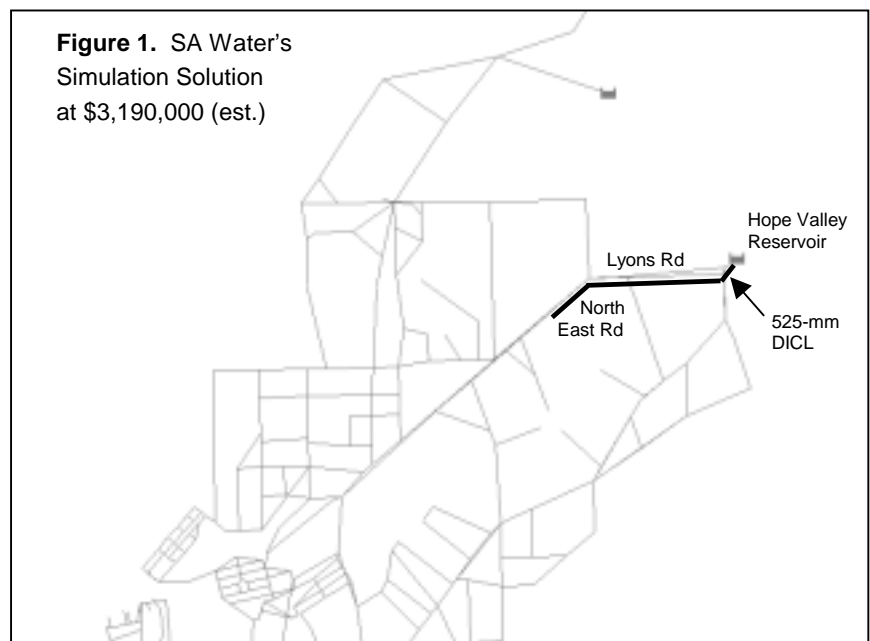
Optimatics GA Optimization Review

SA Water suspected that its solution could be improved on using the Optimatics GA, based on their experience on previous projects. A series of OGA runs were thus conducted to

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Optimization can be used to drastically reduce the cost of main replacements while at the same time improving a system's hydraulic performance.

Figure 1. SA Water's Simulation Solution at \$3,190,000 (est.)



identify alternative solutions. The OGA was formulated to search for the optimal locations and sizes for duplicate (parallel) pipes. Duplicates for all existing pipes in the northern area of the El. 103 zone were considered, as well as additional connections using new pipes to form loops.

An interesting feature of the OGA analysis was that the 3,400 m of 900 mm main to be replaced was input as separate pipe sections between major street intersections. If only certain new pipe sections are required to connect up other pipes in the system to provide adequate flow and residual head, then the OGA was allowed to replace only that portion of the main.

The OGA did in fact identify limited pipe sections for replacement rather than the entire 3,400 m main. Figure 2 shows the preferred OGA solution which replaces the 900 mm pipe from Hope Valley Reservoir to the Lyons Road connection (285 m), and replaces 770 m of 900mm pipe with 750 mm pipe along North East Road.

The OGA determined that no replacement pipe along Lyons Road was necessary. The OGA solution thus achieved significant cost savings. The estimated capital cost of the optimized solution was Aus\$1,450,000 (US\$1,000,000) which is less than half the SA Water solution cost. For this particular solution, the OGA was required to attain residual heads at least as high as existing heads, which also is better performance than the SA Water solution exhibited.

Improved Hydraulic Performance

In conjunction with the optimization of the Lyons Road area, hydraulic performance in other parts of the El. 103 zone was checked to ensure that residual heads did not drop lower than existing levels. Two nodes in the south-eastern area did exhibit problems—nodes 10060 and 11320 in Figure 2.

A series of OGA runs identified six options for new parallel pipes that would maintain residual heads near existing levels. The six solutions are illustrated in Figures 3A-3F with their corresponding capital costs.

Table 1 presents a detailed comparison of the six low-cost options. Option D keeps the residual heads at or above existing levels at a cost of Aus\$228,800. If a small reduction in

residual head is allowed, then Option A may be selected with a cost of Aus\$146,900.

It should be noted that had the client indicated that existing residual heads should be increased to 20 m in the area, it would have been a simple matter to re-run the OGA with that constraint in place to identify additional low-cost alternatives.

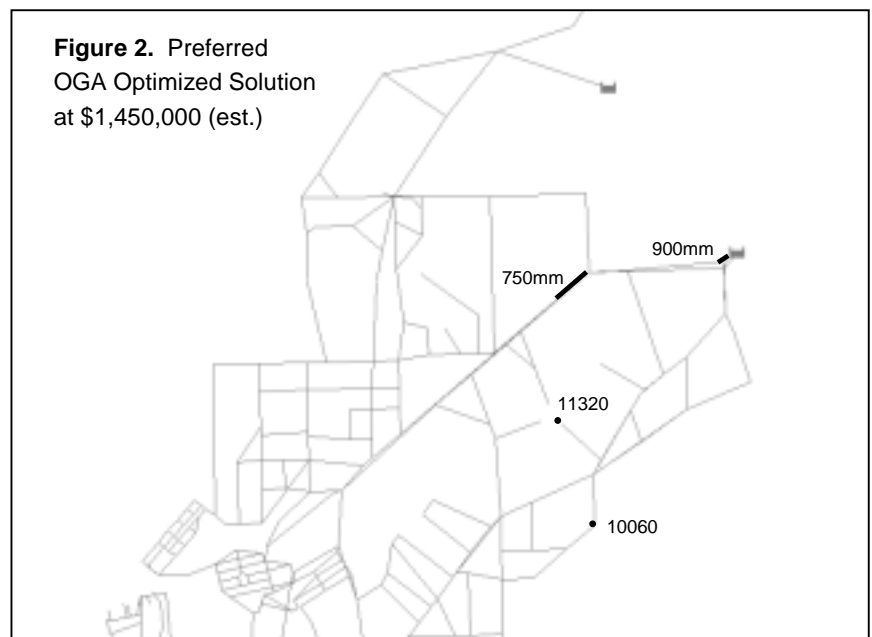
Optimization & Main Replacement

In recent years, many water utilities have begun taking seriously the challenge of main rehabilitation and replacement. Sophisticated analysis and decision support tools are being used to plan and budget their programs.

Utilities use reactive evaluation (where leaks, breaks and red water complaints prompt remedial action) or predictive evaluation (where deterioration is predicted and preemptive action is taken). In either case, the utility develops a prioritized list of mains to be rehabilitated or replaced.

With millions of dollars at stake, optimization represents the next logical step for a utility. Rather than simply replace a main with a new pipe of the same size, a utility like SA Water can view the required work as an opportunity to improve the performance of its system by optimizing replacement options based on a broader hydraulic analysis. As the utility completes work on its prioritized list of mains, optimization will help improve system hydraulic performance while expenditures are hopefully drastically reduced.

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Comparison of Six Optimized Improvement Options for Southeast Area

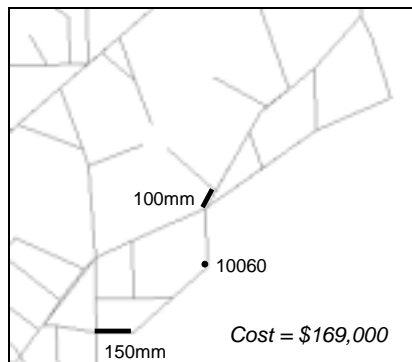


Figure 3A. SE Area Option A



Figure 3B. SE Area Option B

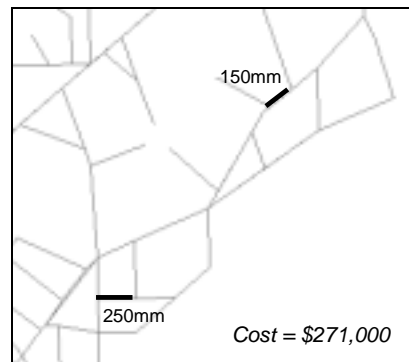


Figure 3C. SE Area Option C



Figure 3D. SE Area Option D



Figure 3E. SE Area Option E

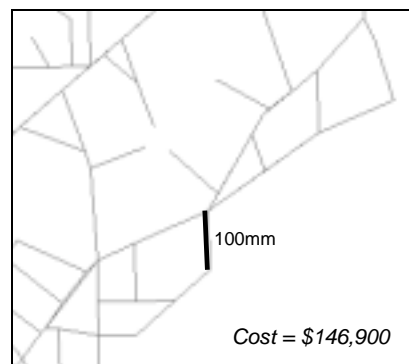
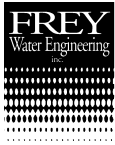


Figure 3F. SE Area Option F

Table 1. Residual Head & Cost Comparison for Six Southeast Area Options

Option	Cost (Aus.\$)	Residual Head (m)	
		Node 10060 (WATSYS node 60)	Node 11320 (WATSYS node 1320)
<i>Existing System</i>		19.19	18.83
Option A	\$169,000	18.79	24.18
Option B	\$270,000	19.18	18.79
Option C	\$271,000	19.29	18.80
Option D	\$228,800	19.19	24.20
Option E	\$210,800	18.91	18.79
Option F	\$146,900	18.90	18.03

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