

The Optimatics Letter

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San Diego Main Replacement GA

The City of San Diego faces a two-pronged infrastructure challenge as it seeks to provide continued excellence in water service to its customers. The City continues to undergo rapid growth in many areas of the system, while at the same time facing an accelerating need for rehabilitation and replacement of aging transmission and distribution mains.

Over the coming years, these challenges could place a significant strain on the water system infrastructure if proper planning and execution of capital projects are not accomplished in a timely manner. The San Diego Water Department, Water Policy, CIP Finance & Planning Division (SDW) is responding to this challenge by applying optimization analysis to help identify the most cost-effective and hydraulically appropriate planning solutions.

This article describes a cutting-edge genetic algorithm (GA) optimization study of pipeline replacement options that SDW recently completed.

San Diego's Water System

The City of San Diego water system serves approximately 1.4 million people with an average daily production of 210 MGD from three water treatment facilities. To meet increased future demands, the Miramar Water Treatment Plant in the north will be expanded from 140 to 215 MGD, while the Alvarado WTP serving the center and western areas will be expanded from 120 to 150 MGD. The Otay WTP in the south will be upgraded at its current 40 MGD capacity.

The treatment plant expansions and other capital improvements in SDW's 1998-2006 CIP are sized to meet projected year 2030 demands of about 277 MGD average day. The current CIP contains \$772 million in projects, and the next CIP is estimated to be at least as large.

SDW currently purchases 90% of its water from the San Diego County Water Authority

(CWA), with the remainder coming from local runoff that is captured in six lakes. CWA treated water is supplied via five connection points throughout the City system with hydraulic grade lines (HGL) of 780-873 ft. CWA raw water is supplied via five other connection points with HGLs of 618-815 ft.

SDW's Pipeline Replacement Plans

The Alvarado WTP service area covers about one-third of the SDW system extending north and south from Interstate 8. The area is generally built-out with a network of large transmission pipelines carrying water throughout the major 645 and 536 pressure zones.

One critical pipeline nearing the end of its useful life is the 70-year old Otay Second Pipeline shown in Figure 1 running to the southeast corner of the Alvarado area (see back cover). Based on the results of a condition assessment study, SDW made plans last year to replace 3.5 miles of the Otay Second Pipeline with 48-inch steel pipe.

SDW initially thought to have its Otay Second Pipeline replacement plans reviewed using Optimatics GA (OGA) optimization. It was later decided that the OGA model, once set up, could also be used to optimize options for other aging pipelines in the Alvarado service area.

(Continued on page 2)

San Diego faces a two-pronged infrastructure challenge: to meet the demands of rapid growth and to take timely action to rehabilitate and replace aging pipelines.

Don't Miss an Opportunity to Optimize

Over the past seven years, Optimatics/Frey Water Engineering has had the good fortune to optimize water distribution and irrigation systems for numerous clients. San Diego Water is a client that was looking for a long time for an opportunity to apply optimization on a trial basis to its system. SDW is pleased with the results of its Optimatics GA study of the Alvarado service area, and is now proceeding with a second OGA study—a Water Master Plan for the North City area.

The opportunity for a water utility to optimize its system does not come around every day or even every year. Given the tremendous potential payoff, it makes sense for a utility to take advantage of its very first opportunity to optimize.

Optimization Study Scope

The OGA study scope was thus revised to develop a comprehensive rehabilitation and replacement (R&R) plan for major pipelines throughout the Alvarado service area, namely the Trojan, El Capitan, Otay First, Otay Second, Texas Street, 30th Street and Thorn Street pipelines (shown as heavy solid lines in Figure 1).

It was decided that each of the seven aging pipelines would need some R&R action prior to the 2030 plan year. The R&R choices for the OGA were then (1) to abandon, (2) to structurally re-line, or (3) to replace each pipeline section.

To complement the R&R actions selected for the existing pipelines, the OGA was given the opportunity to locate and size new pipes in the Alvarado area. Allowable new pipe choices were identified as shown in Figure 1 (as dashed lines).

SDW’s Hydraulic Model

In 1999, Stoner Associates completed a detailed hydraulic model of the SDW system. The system-wide SynerGEE model contains about 90,000 pipes covering 106 pressure

zones. For the Alvarado area OGA study, Stoner extracted the relevant area and skeletonized it from about 30,000 pipes to 4,400 pipes within five major pressure zones.

The next step was to convert the skeletonized SynerGEE model to EPANET, the model format required by the OGA. Following the conversion to EPANET, Stoner verified the model to ensure that nearly identical hydraulic results were obtained under year 2030 conditions.

Optimizing Alvarado R&R Options

In terms of a specific objective, the OGA study of R&R options aimed to identify the optimal mix of abandoning, re-lining or replacing pipe sections for 25.7 miles of existing pipelines. The OGA also optimized locations and sizes for up to 10.5 miles of new pipes, and for potential pipe interties between the major pipelines.

The OGA first considered a normal operating condition based on the 7:00 a.m. peak for the year 2030 maximum day. In each run, the OGA evaluated hundreds of thousands of trial solutions as it narrowed in on the best mix of R&R actions and new pipe choices. The 171 existing pipe sections and 27 new pipe

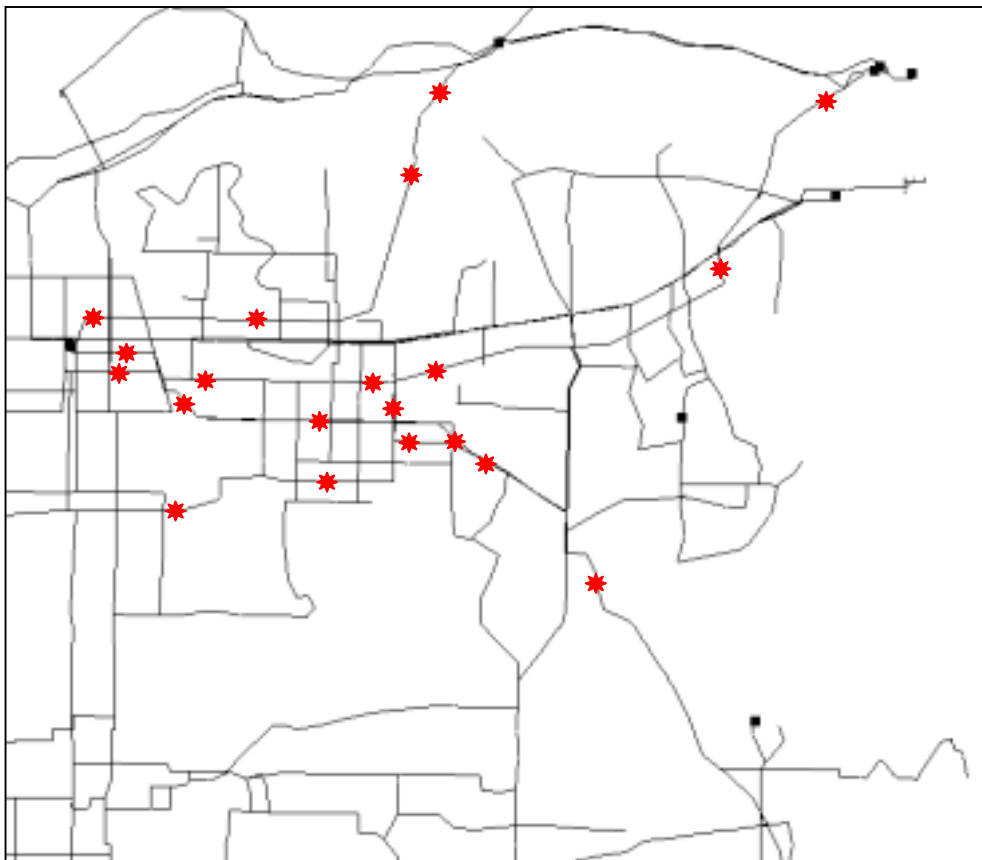


Figure 2. Pipe Outage Locations Considered in OGA Analysis—to ensure system reliability under a wide range of emergency conditions.

OGA solutions were verified for two scenarios: with all supply sources in service and with one supply source out of service.

locations represented a total of 198 decision variables in the OGA search.

Emergency Conditions to be Satisfied

The most challenging aspect of the OGA study of Alvarado pipeline R&R options was SDW’s strict emergency criteria. SDW required that the system must continue to operate at full service under the condition of a supply source or a major pipeline being out of service. As a result, the OGA needed to develop a highly redundant solution.

To accomplish this, two different supply scenarios were investigated, one with all supply sources in service and one with a supply source out of service. Also, separate cases for each of 20 different pipe outage conditions were analyzed. (Figure 2 shows the outage locations.) OGA runs were formulated to simultaneously analyze the base case demand plus the individual pipe outage conditions as distinct steady-state cases, and then checked against the second scenario with a supply out of service. The final OGA-optimized solutions thus supplied system demands while meeting required pressures for

the different supply scenarios and for each of the 20 individual pipe outage cases.

The Preferred Alvarado R&R Solution

Throughout the course of the study, SDW was involved in reviewing the assumptions used in formulating the OGA model and reviewing interim OGA solutions. Based on a familiarity with the optimized plan details, SDW was quick to adopt its preferred solution SD-26b as shown in Figure 3 below.

Solution SD-26b consists of the following:

- 47 abandoned pipe sections (7.8 mi)
- 15 re-lined pipe sections (1.8 mi)
- 109 replacement pipe sections (16.1 mi)
- 11 new pipe sections (5.3 mi)

The estimated cost of the SD-26b solution is \$35.3 million. For a point of comparison, the cost of simply replacing the existing seven major pipelines with new pipe of the same diameter would be \$55.0 million.

At this point, SDW is moving ahead to implement the first improvement projects (about \$8 million) defined in the OGA study.

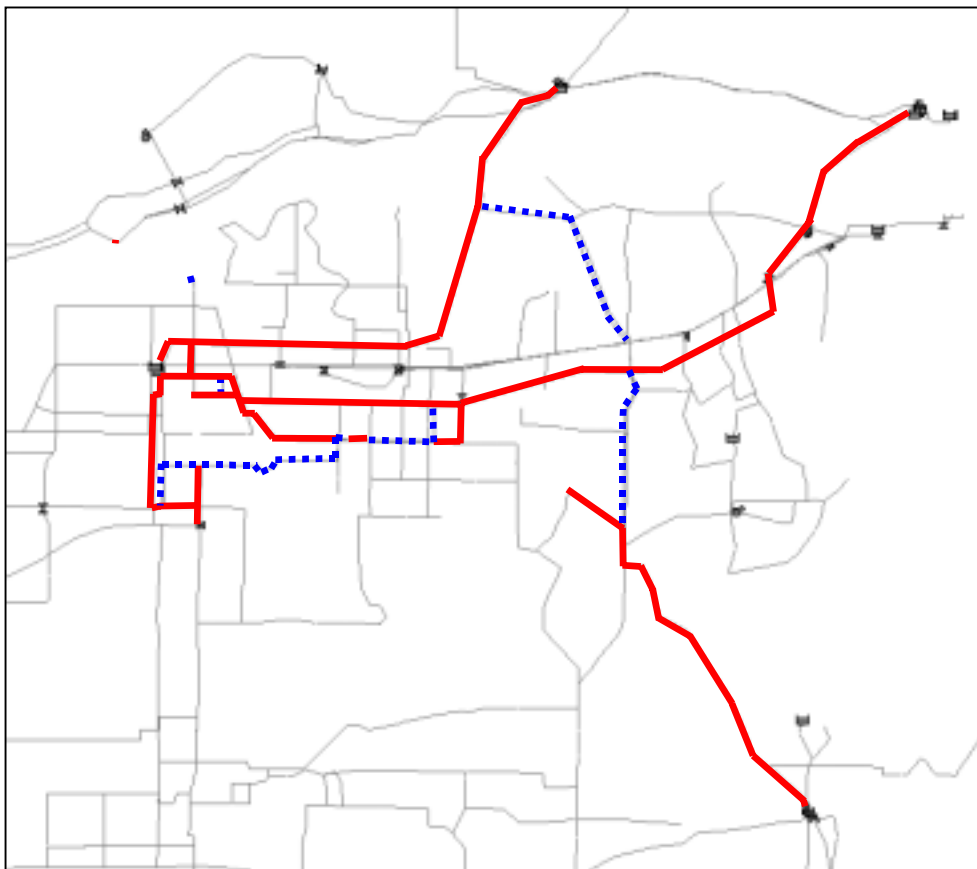


Figure 3. OGA-Optimized Solution SD-26b—SDW’s preferred mix of existing pipes for R&R (solid lines) and new pipes (dashed lines).

116 of 171 existing pipes are re-lined or replaced, and 11 of 27 new pipes considered are selected and sized.

The Optimatics Letter

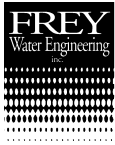
Advances in optimization for water utilities and consultants

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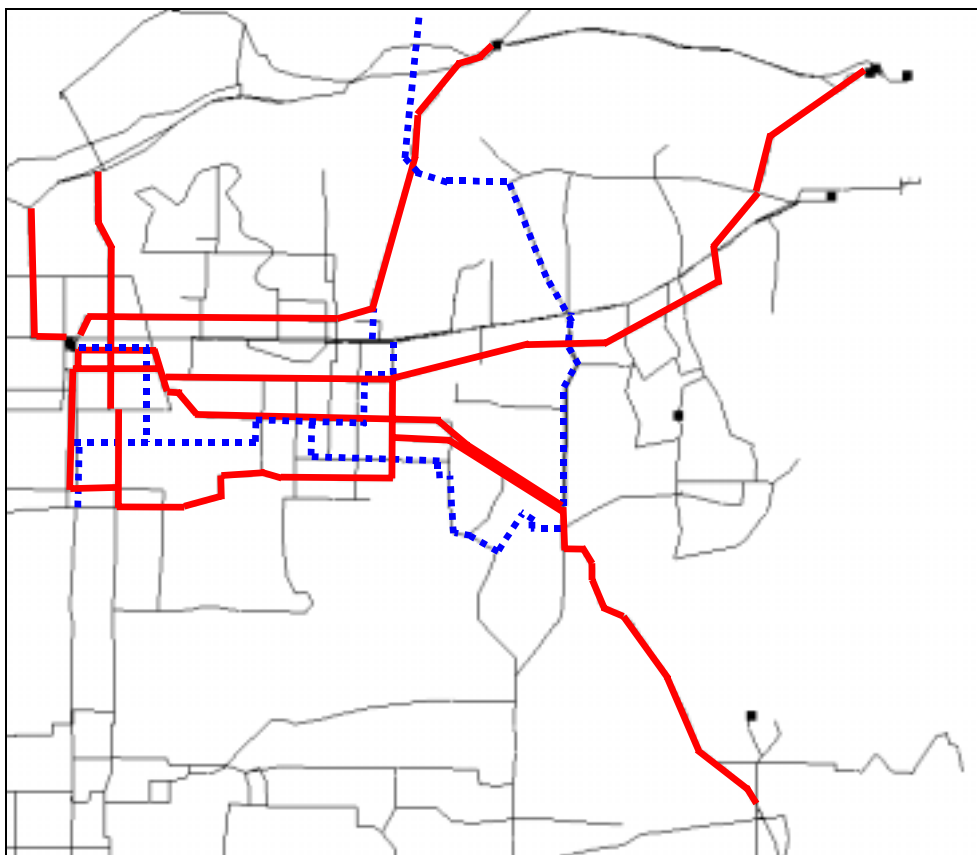


Figure 1. SDW Pipe Choices Considered in Alvarado Service Area Optimization—existing pipes to be abandoned, re-lined or replaced (solid lines), and potential new pipe locations (dashed lines).

A total of 198 pipe sections were optimized to find the best mix of rehabilitation and replacement actions and new pipe locations and sizes.