BEST PRACTICE OF INTELLIGENT ALGORITHMS TO OPTIMISE AND PRIORITISE CAPITAL INVESTMENTS AND ASSET REHABILITATION

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ABSTRACT

Jefferson County, AL, implemented the application of intelligent algorithms to optimise and prioritise capital investments and asset rehabilitation. The County owns and operates wastewater collection systems across nine treatment plant basins serving approximately 600,000 people. The system-wide optimisation incorporated five treatment plant basins (Cahaba River, Five Mile Creek, Shades Creek, Valley Creek and Village Creek) that are all interconnected either by existing or potential future flow diversion structures. The project delivers simple to understand optimal solutions while delivering significant value added & return on investment through close collaboration with the utility staff.

The study involved the evaluation of conveyance infrastructure, storage facilities, and asset rehabilitation to determine the most cost-effective way to achieve 0.6 m (2 ft) of freeboard system-wide in the 2-year design storms (6-hour and 24-hour), with emphasis on prioritising the elimination of reported SSOs.

Recently completed pilot I/I rehabilitation projects provided updated data to consider different scenarios on the effectiveness of I/I reduction and the performance of other improvement infrastructure. Similarly, asset condition and sediment data were incorporated into analysis to determine whether it is more cost-effective to clean the sediment or replace and upsize based on a holistic consideration of conveyance, storage, and I/I reduction alternatives. The analysis identifies key basins that are cost-effective and ensures conservative conveyance capacity upgrades.

This project successfully demonstrated life-cycle cost savings on the order of $54 M (30%) when compared to Valley Creek's Baseline RMP (where an RMP had been developed). It also demonstrated that a prioritised capital improvement schedule could achieve 40% SSO volume reduction within the first 10% of capital expenditure and 98% reduction within 70% of the total capital expenditure required to eliminate all SSOs and achieve surcharge limit objectives system wide.

The Jefferson County study consistently demonstrated how timely implementation of optimised projects could eliminate the vast majority of SSOs at a fraction of the total program cost.

KEYWORDS

Sanitary sewer overflows, remedial measures plan, alternatives evaluation, optimisation, prioritisation, return on investment, Optimizer

PRESENTER PROFILE

Andrew Faulkner is a water and wastewater infrastructure planning engineer with over 12 years of experience in water distribution and collection systems modelling, strategic planning, and alternatives analysis. He has worked extensively with high-profile water utilities and engineering consultants.

INTRODUCTION

Jefferson County owns and operates wastewater collection systems across nine treatment plant basins serving approximately 600,000 people. A total of approximately 200 reported SSOs are currently recorded by Jefferson County.

In 2019, Jefferson County engaged WCS and Hazen to undertake an optimisation demonstration project to evaluate conveyance, storage and I/I reduction alternatives for the Valley Creek basin which had the highest density of reported SSOs. This project successfully demonstrated life-cycle cost savings on the order of $54 M (30%) when compared to the Baseline RMP (developed using traditional trial-and-error modelling). It also demonstrated that a prioritised capital improvement schedule could achieve 40% SSO volume reduction within the first 10% of capital expenditure and 98% reduction within 70% of the total capital expenditure required to eliminate all SSOs and achieve surcharge objectives.

The Jefferson County, System-Wide RMP Optimization project was undertaken and completed in 2020 based on the success of the Valley Creek demonstration project. The system-wide optimisation incorporated five treatment plant basins that are all interconnected either by existing or potential future flow diversion structures.

The primary objective of this study was to apply intelligent algorithm optimisation technology, "Optimizer", to evaluate and prioritise remedial measure alternatives including conveyance, storage, inter-basin transfer, treatment, and inflow and infiltration (I&I) reduction alternatives to eliminate SSOs in the 2-year design storm (6-hour and 24-hour events). Secondary objectives include performing sensitivity analyses for key assumptions and to identify aspects of the planning strategy that may require further investigation.

METHODOLOGY

The "Optimizer" software integrates improvement alternatives, comprehensive life-cycle costs, design criteria, and the calibrated hydraulic model of the collection system. In a single analysis, the software applies intelligent algorithms and cloud computing to evaluate tens of thousands of possible solution configurations with respect to life-cycle cost and hydraulic performance. Scenarios and sensitivity analyses are easily completed by adjusting relevant assumptions or inputs and rerunning the cloud-based optimization.

Improvement alternatives evaluated in the optimisation include:

- Parallel relief sewers and upsized gravity sewers.
- Sediment removal.
- Pump station upgrades.
- Force mains.
- New storage facilities.
- Inter-basin diversion controls
- High-rate treatment facilities.
- I&I reduction.

Unit cost rates adopted for the optimization analysis are planning level estimates developed by Hazen based on the County's bid tab records. The unit costs include capital, O&M, and replacement estimates of all alternatives.

System-wide optimisation runs were completed for the following scenarios:

- Conveyance-Only – Optimisation without storage or I&I reduction alternatives
- Conveyance + Storage - Optimisation without I&I reduction alternatives
- All Alternatives (Ultra-Conservative I&I)
- All Alternatives (Conservative I&I)
- All Alternatives (Aggressive I&I)

The optimised solution costs for each scenario are compared in Figure 1. The preferred RMP strategy was the All Alternatives (Aggressive I&I) scenario illustrated in Figure 2.

The optimisation model used for the prioritisation task was formulated to select projects from the Optimized RMP (aggressive I&I reduction scenario). The prioritisation analysis used the optimisation model to determine the sequence of implementation that provides the maximum return on investment with respect to reducing total overflow volume in the 2-year design storms. The preliminary prioritization results are shown in Figure 3.

RESULTS

Figure 1: Comparison of Optimisation Scenarios

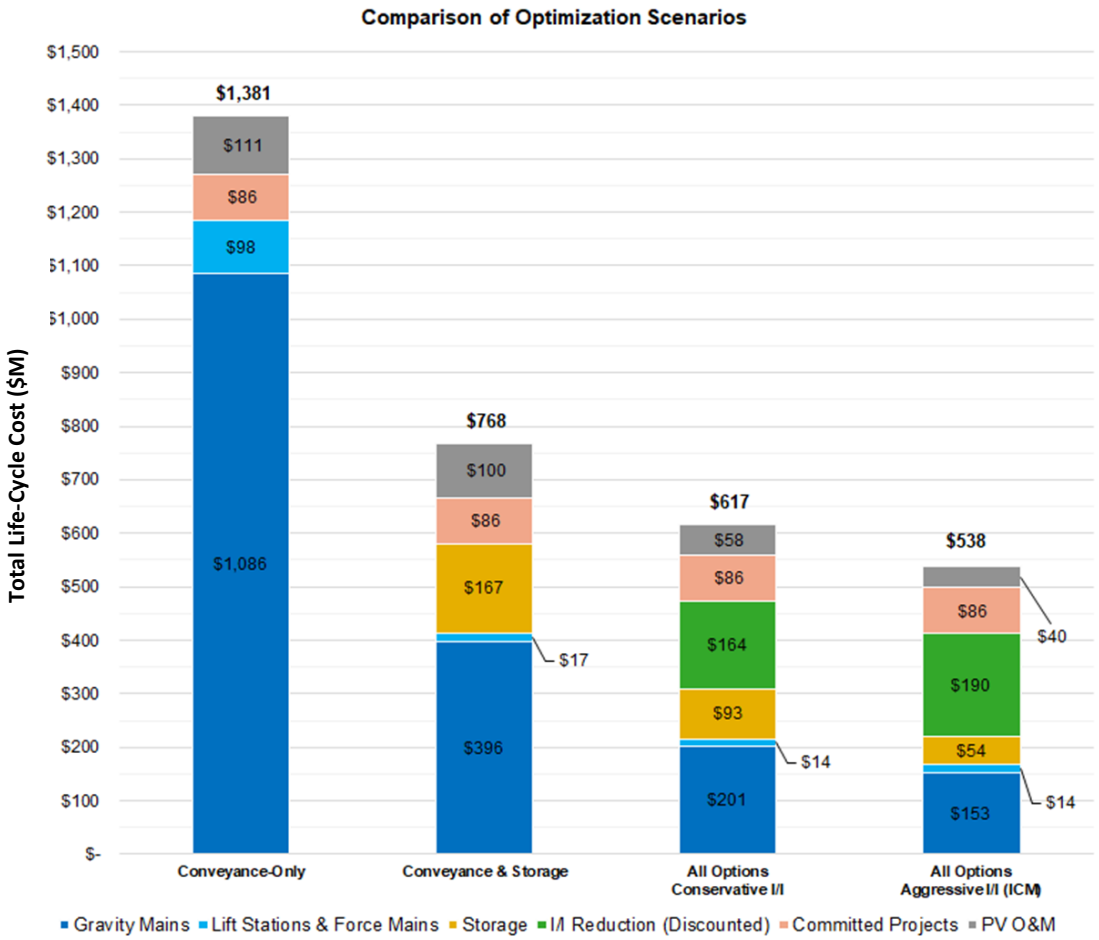
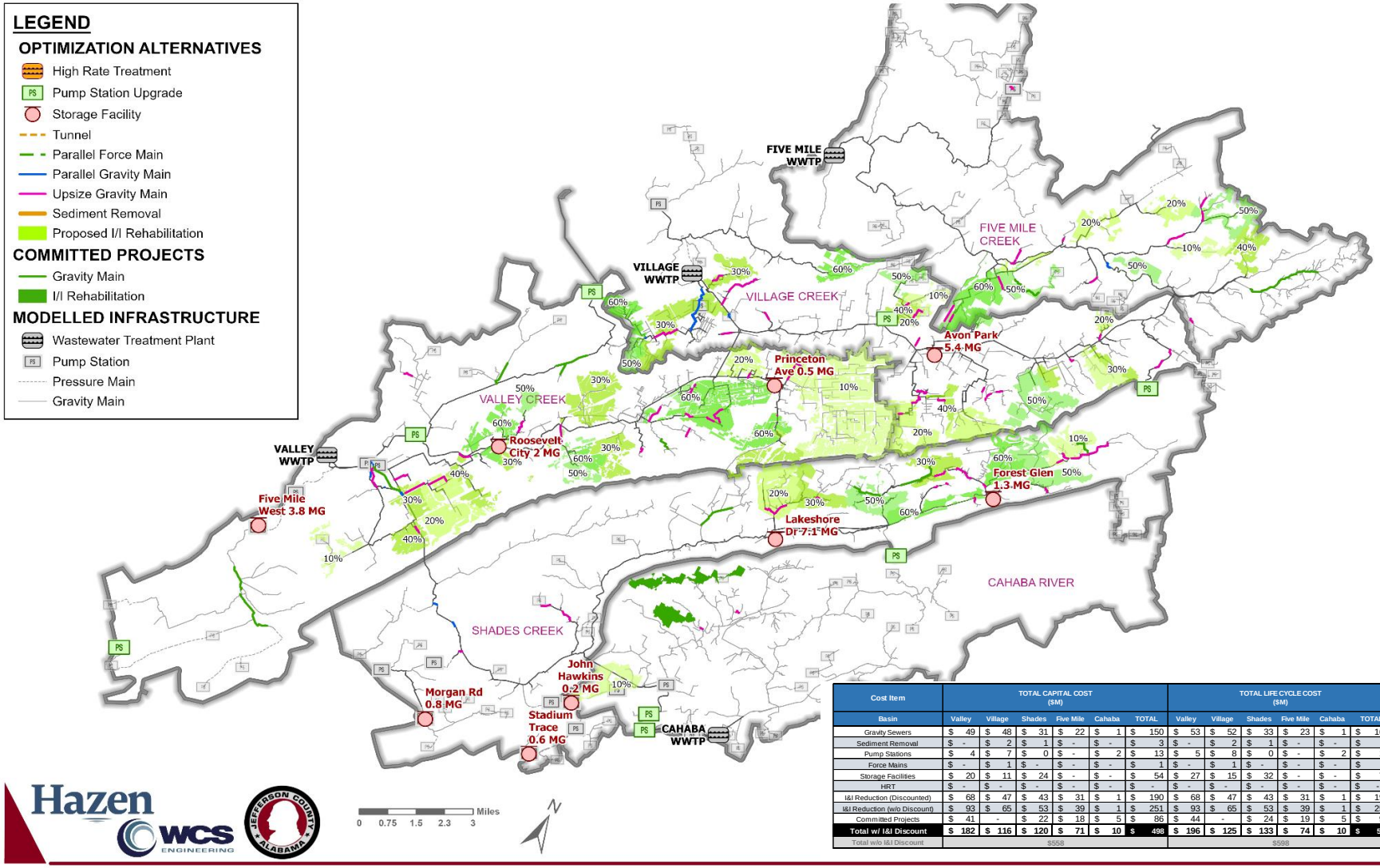
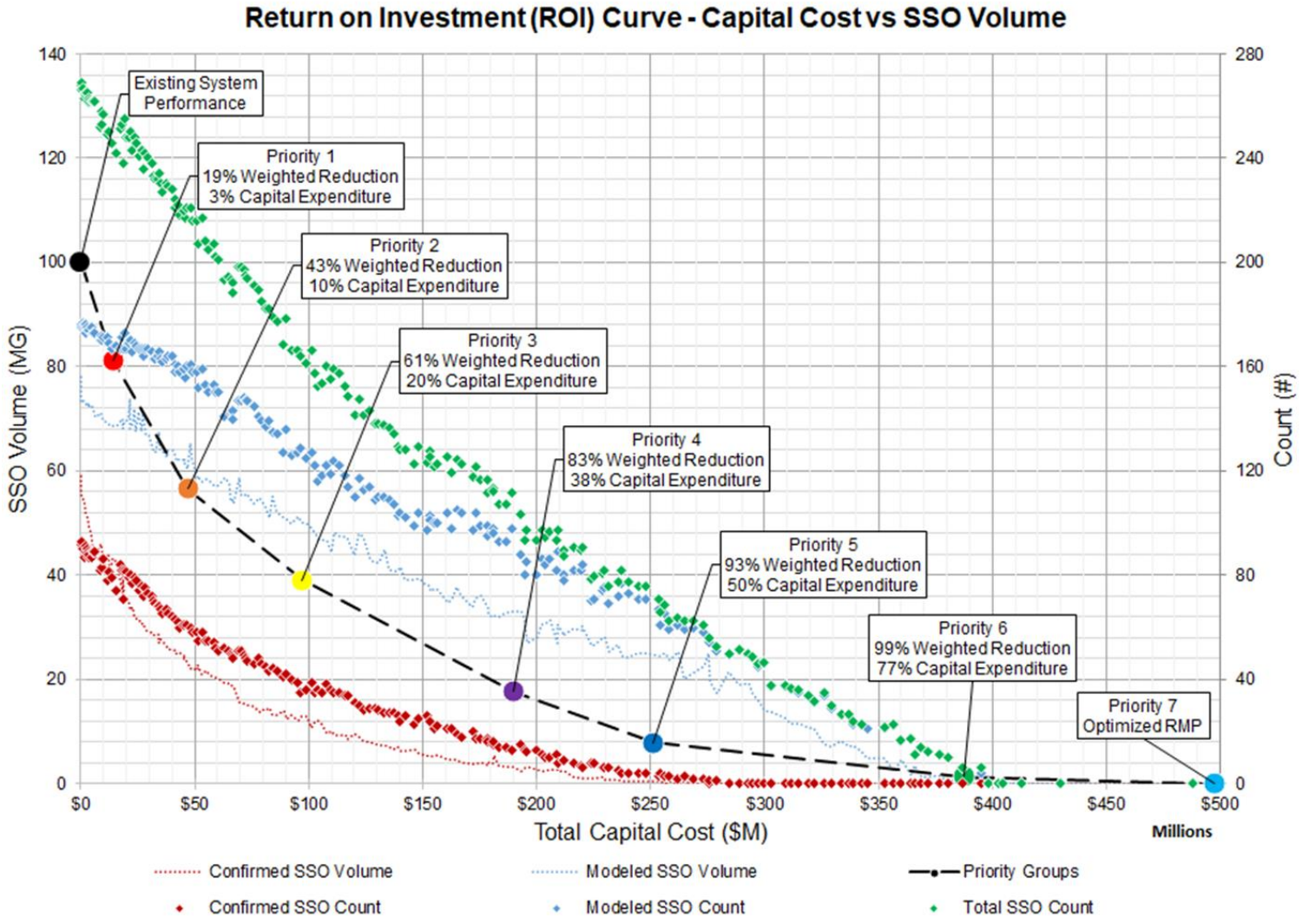


Figure 2: Optimised RMP



Cost Item	TOTAL CAPITAL COST ($M)						TOTAL LIFE CYCLE COST ($M)					
Basin	Valley	Village	Shades	Five Mile	Cahaba	TOTAL	Valley	Village	Shades	Five Mile	Cahaba	TOTAL
Gravity Sewers	$ 49	$ 48	$ 31	$ 22	$ 1	$ 150	$ 53	$ 52	$ 33	$ 23	$ 1	$ 162
Sediment Removal	$ -	$ 2	$ 1	$ -	$ -	$ 3	$ -	$ 2	$ 1	$ -	$ -	$ 3
Pump Stations	$ 4	$ 7	$ 0	$ -	$ 2	$ 13	$ 5	$ 8	$ 0	$ -	$ 2	$ 15
Force Mains	$ -	$ 1	$ -	$ -	$ -	$ 1	$ -	$ 1	$ -	$ -	$ -	$ 1
Storage Facilities	$ 20	$ 11	$ 24	$ -	$ -	$ 54	$ 27	$ 15	$ 32	$ -	$ -	$ 73
HRT	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
I&I Reduction (Discounted)	$ 68	$ 47	$ 43	$ 31	$ 1	$ 190	$ 68	$ 47	$ 43	$ 31	$ 1	$ 190
I&I Reduction (w/o Discount)	$ 93	$ 65	$ 53	$ 39	$ 1	$ 251	$ 93	$ 65	$ 53	$ 39	$ 1	$ 251
Committed Projects	$ 41	-	$ 22	$ 18	$ 5	$ 86	$ 44	-	$ 24	$ 19	$ 5	$ 92
Total w/ I&I Discount	**$ 182**	**$ 116**	**$ 120**	**$ 71**	**$ 10**	**$ 498**	**$ 196**	**$ 125**	**$ 133**	**$ 74**	**$ 10**	**$ 538**
Total w/o I&I Discount	$558						$598					

Figure 3: Prioritisation Results



CONCLUSIONS

The Jefferson County, Valley Creek Optimisation demonstration project and the System-Wide Optimisation project demonstrate both significant savings when compared with an apples-to-apples Baseline RMP developed using traditional trial-and-error modelling and highlighted opportunities for incorporating flexibility to allow the RMP to be adapted over time.

The prioritisation analysis completed for each project consistently demonstrated a high return on investment whereby the vast majority of SSOs could be eliminated at a fraction of the total program cost. This outcome allows Jefferson County to provide customers with immediate and noticeable improvements in system performance during the early stages of the program while also providing an opportunity for the final stages of the program to be adapted and potentially eliminated if a diminishing return on investment can be illustrated as more data is collected.

The County considered the optimisation projects successful in minimizing capital expenditure required to meet consent requirements and informing decision making when selecting where to focus short-term investments to maximize value provided to customers.

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