Optimatics

optimizing water systems

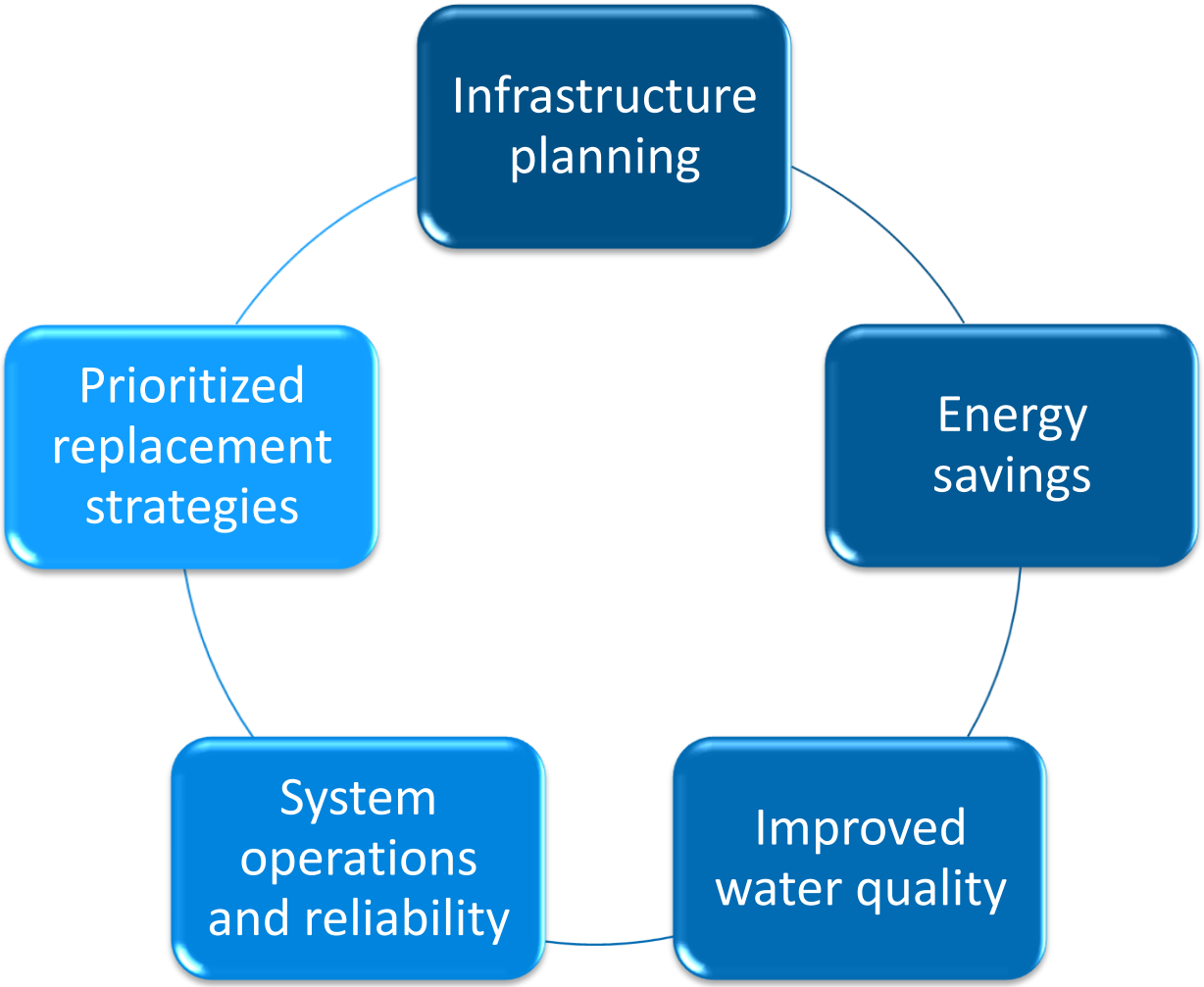
Optimized Decision Support for Water and Wastewater Systems

April 2011

Workshop Agenda

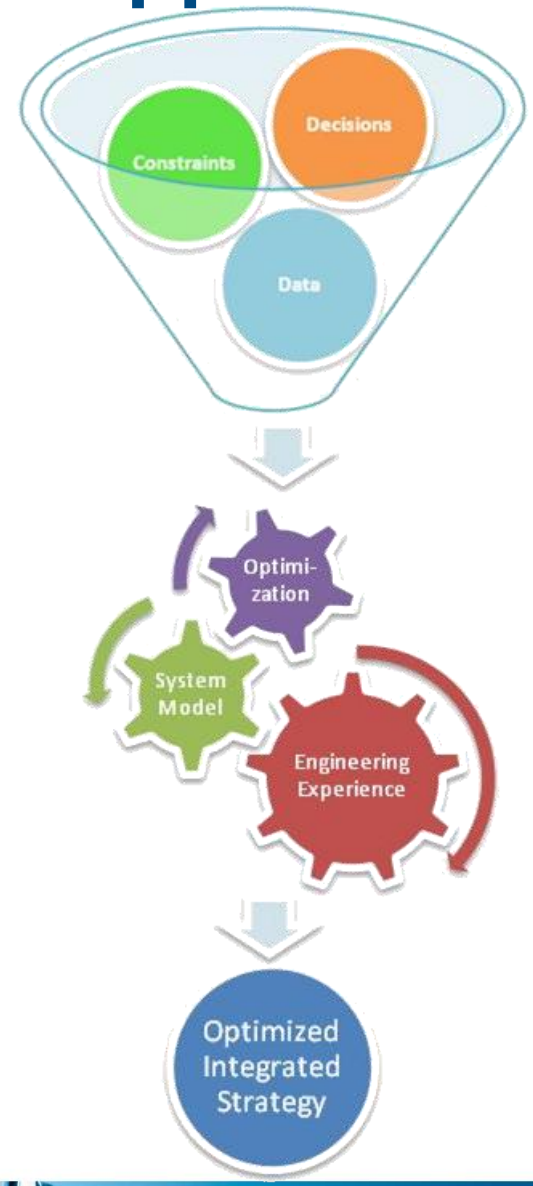
- Overview of advanced modeling applications
- Case Study – Master plan optimization
- Case Study – Optimization for enhanced reliability
- Case Study – Pipe criticality analysis and pipe replacement planning
- Case Study – Seasonal operations optimization

Optimized Decision Support

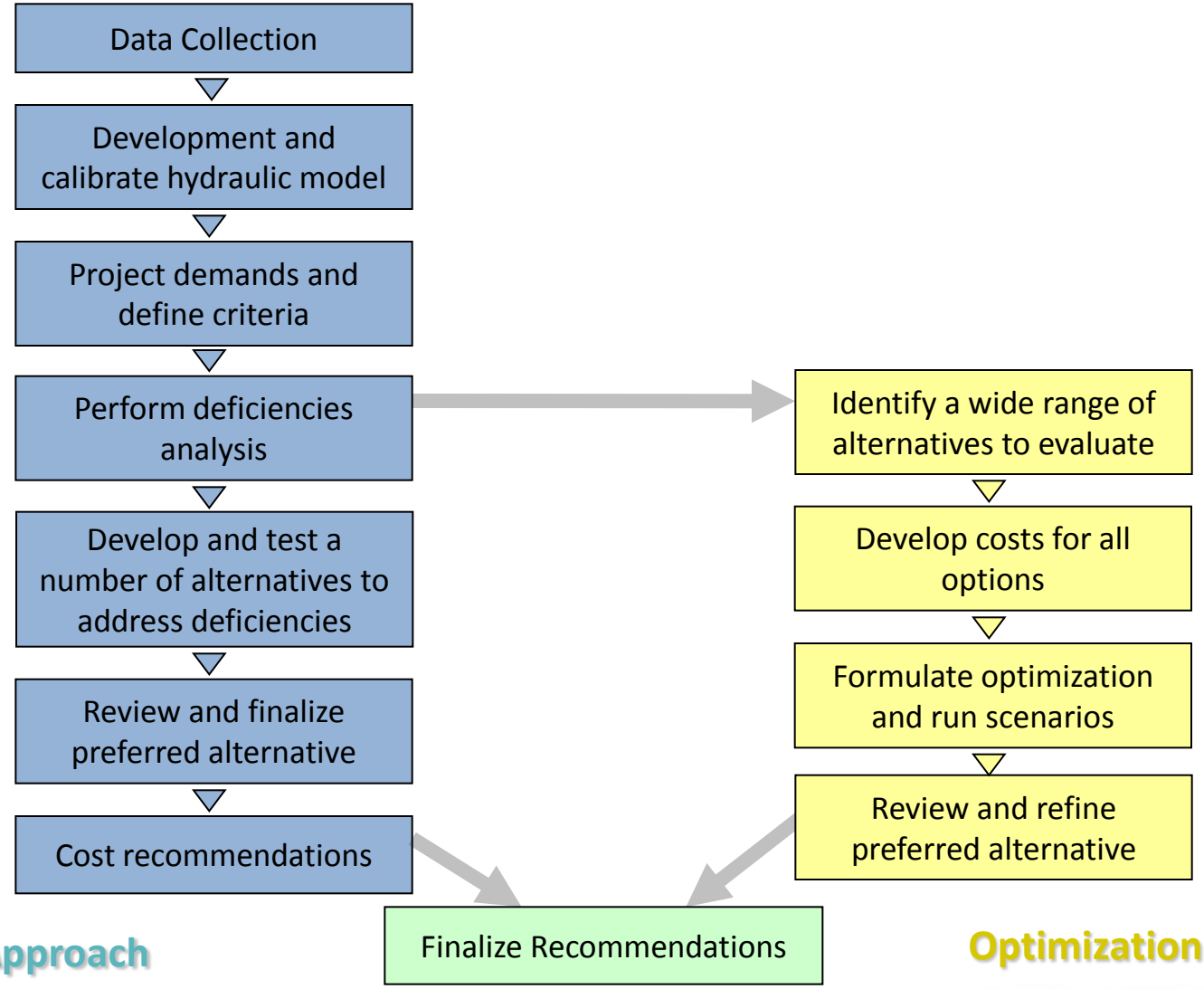


Benefits of Optimized Decision Support

- Optimal, integrated decision making
- Thorough testing of a range of scenarios
- Answers to “what-if” questions
- Improvements to system performance
- Significant and measurable cost savings
- Stakeholder participation
- Defensible, unbiased solutions



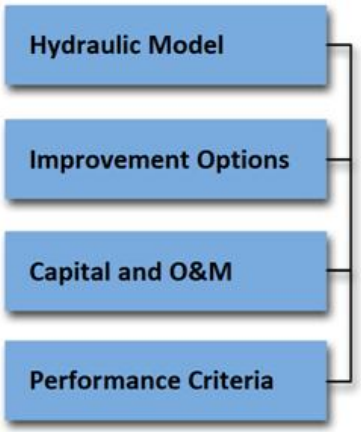
Traditional vs Optimization Approach

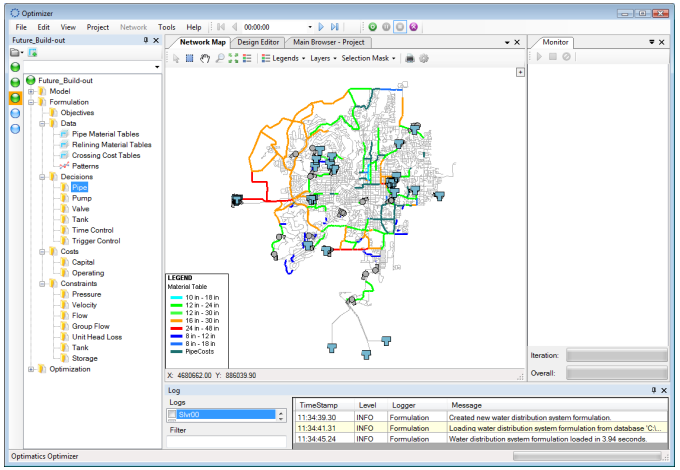


Traditional Approach

Optimization Approach

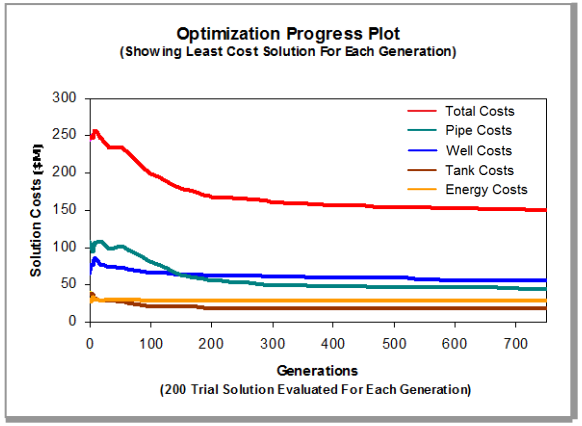
Options Analysis Process





Optimizer WDS User Interface

Sensitivity Evaluations

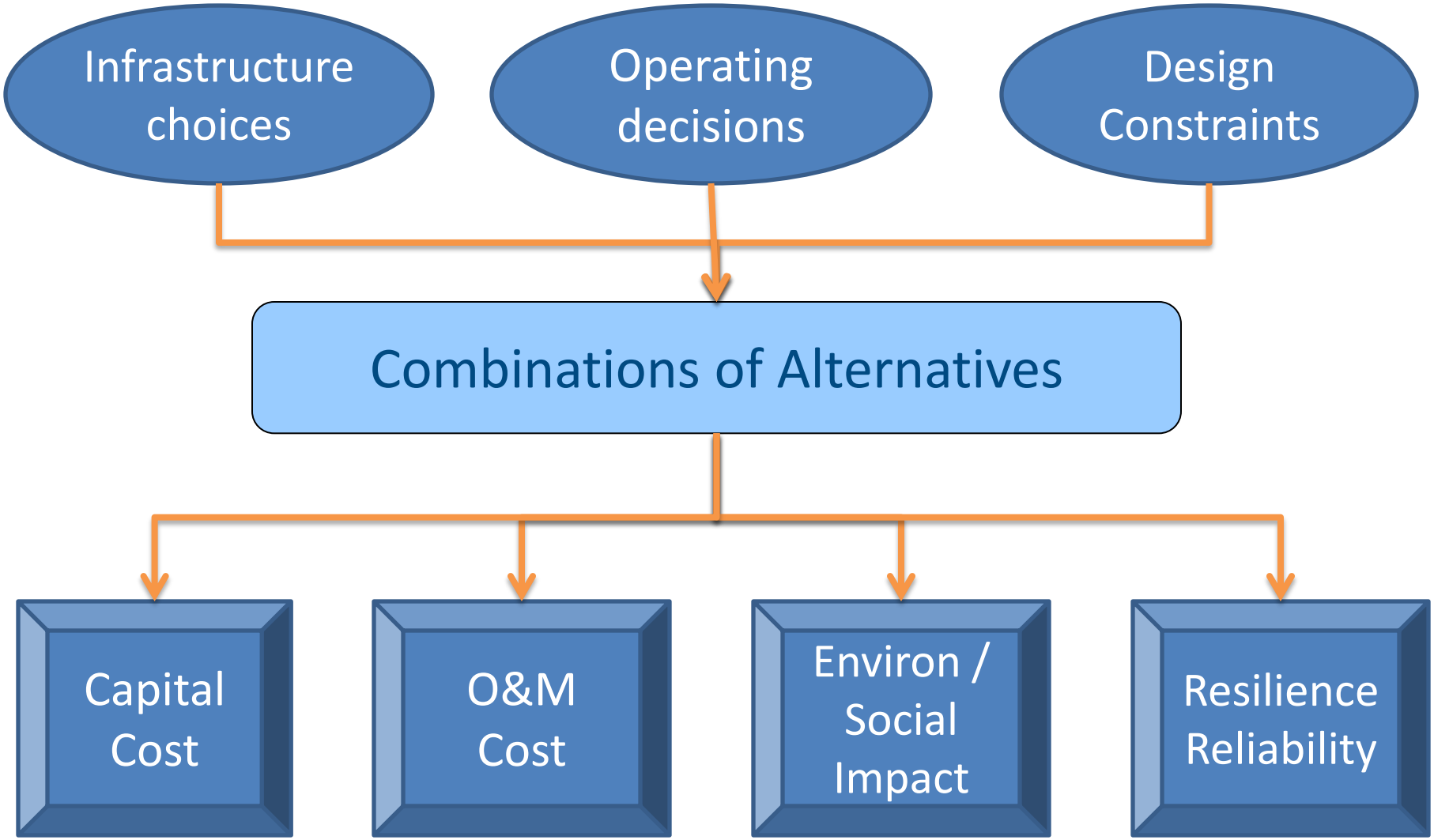


Optimization Progress

Cost Item	Optimized Solution Cost ($M)
Pipes	44.4
Pumps	0.8
Tanks	19.4
Valves	0.6
Wells	55.7
Energy	28.8
TOTAL ($M)	149.7

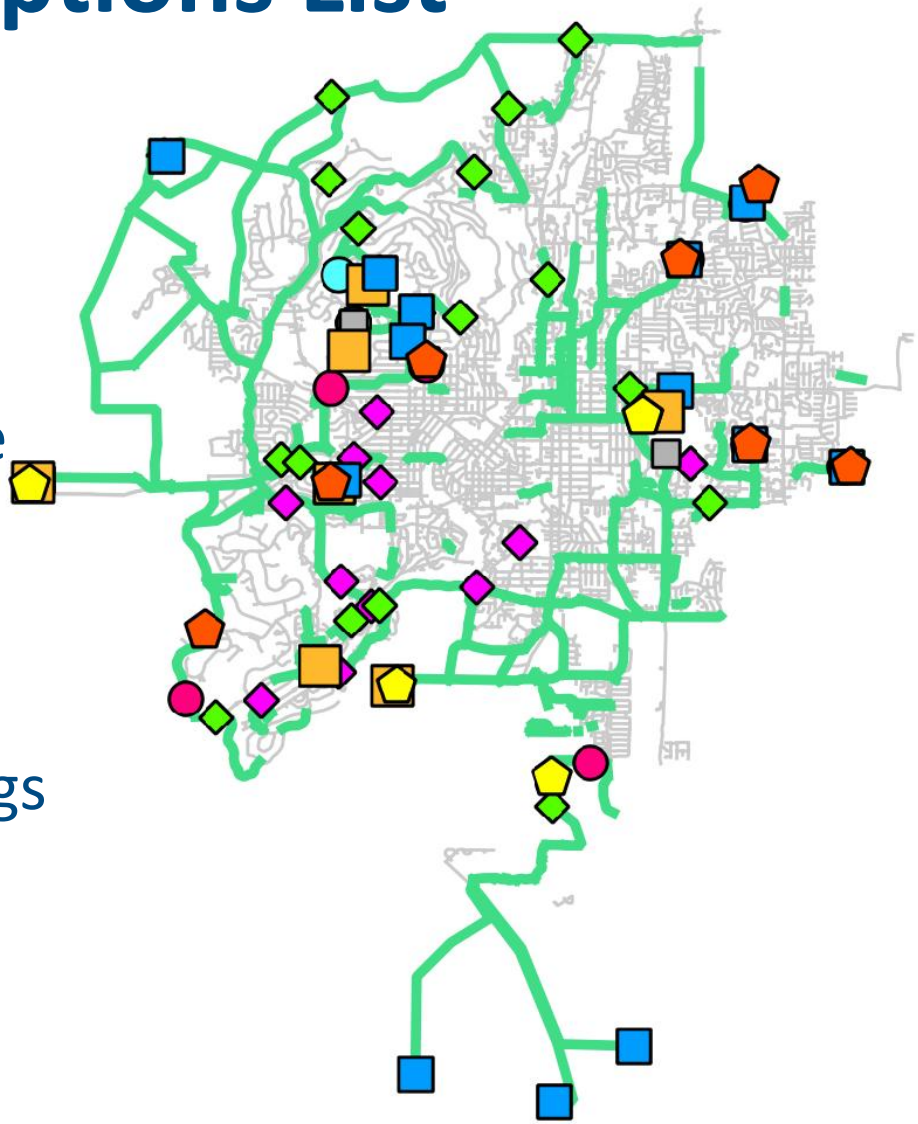
Optimization Solution Cost Summary

Water System Improvement Options & Objectives

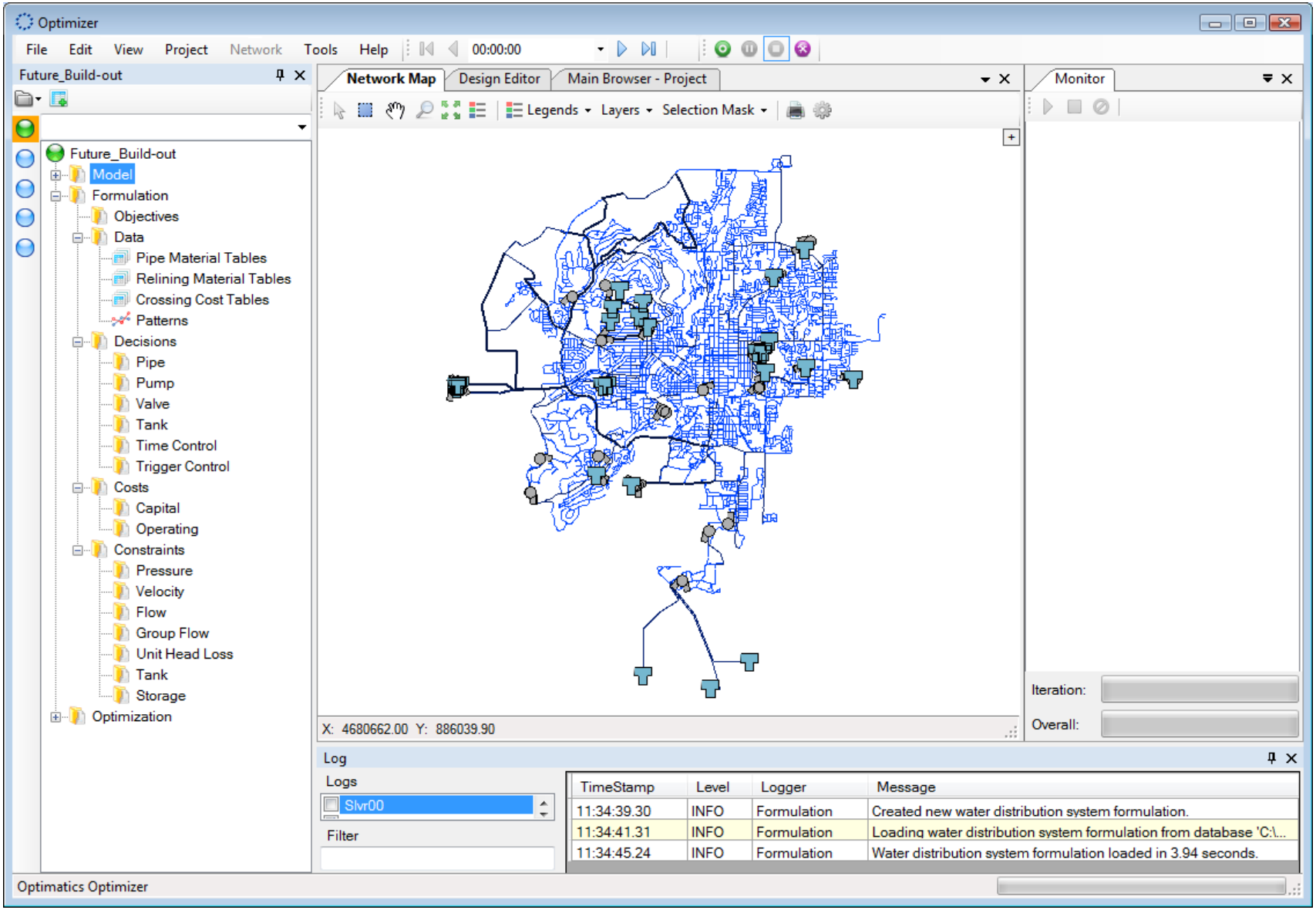


A Comprehensive Options List

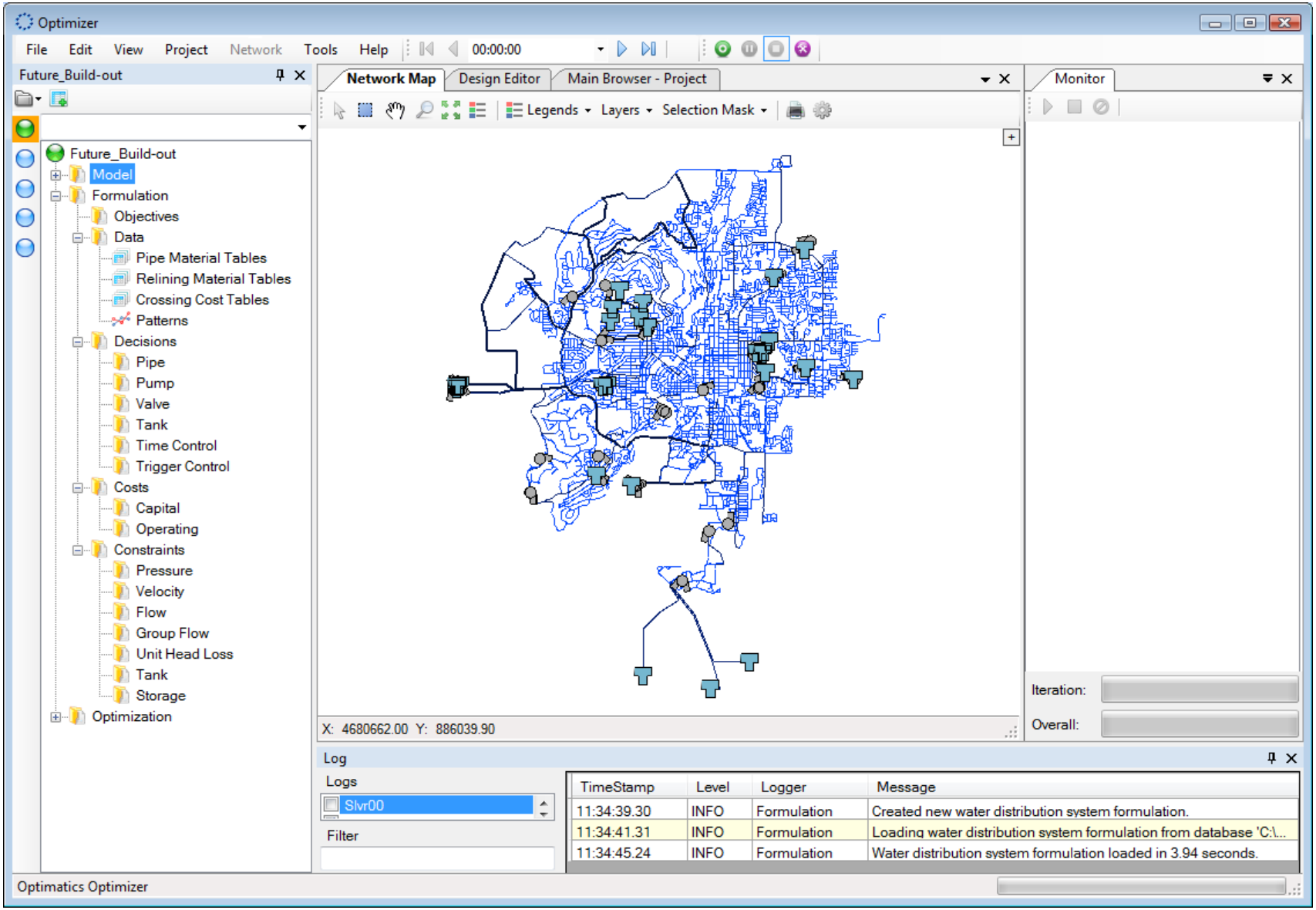
- Location of new wells to supplement surface water
- New and replacement trans-mission and distribution pipe
- New and upgraded PSs
- New and upgraded storages
- Revised pressure zone settings
- Incorporation of new development areas



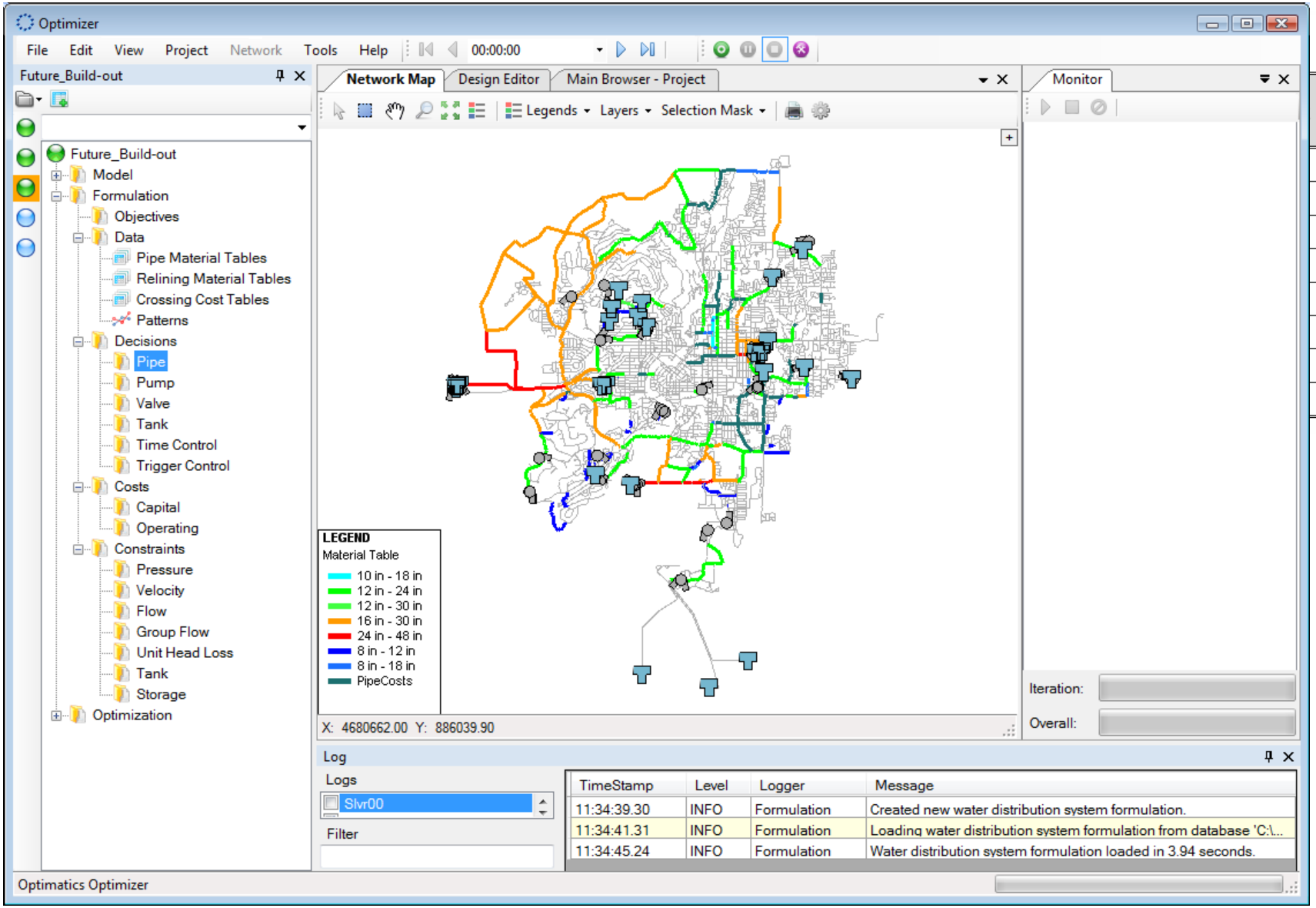
Formulate Optimization Model - ***Optimizer WDS***



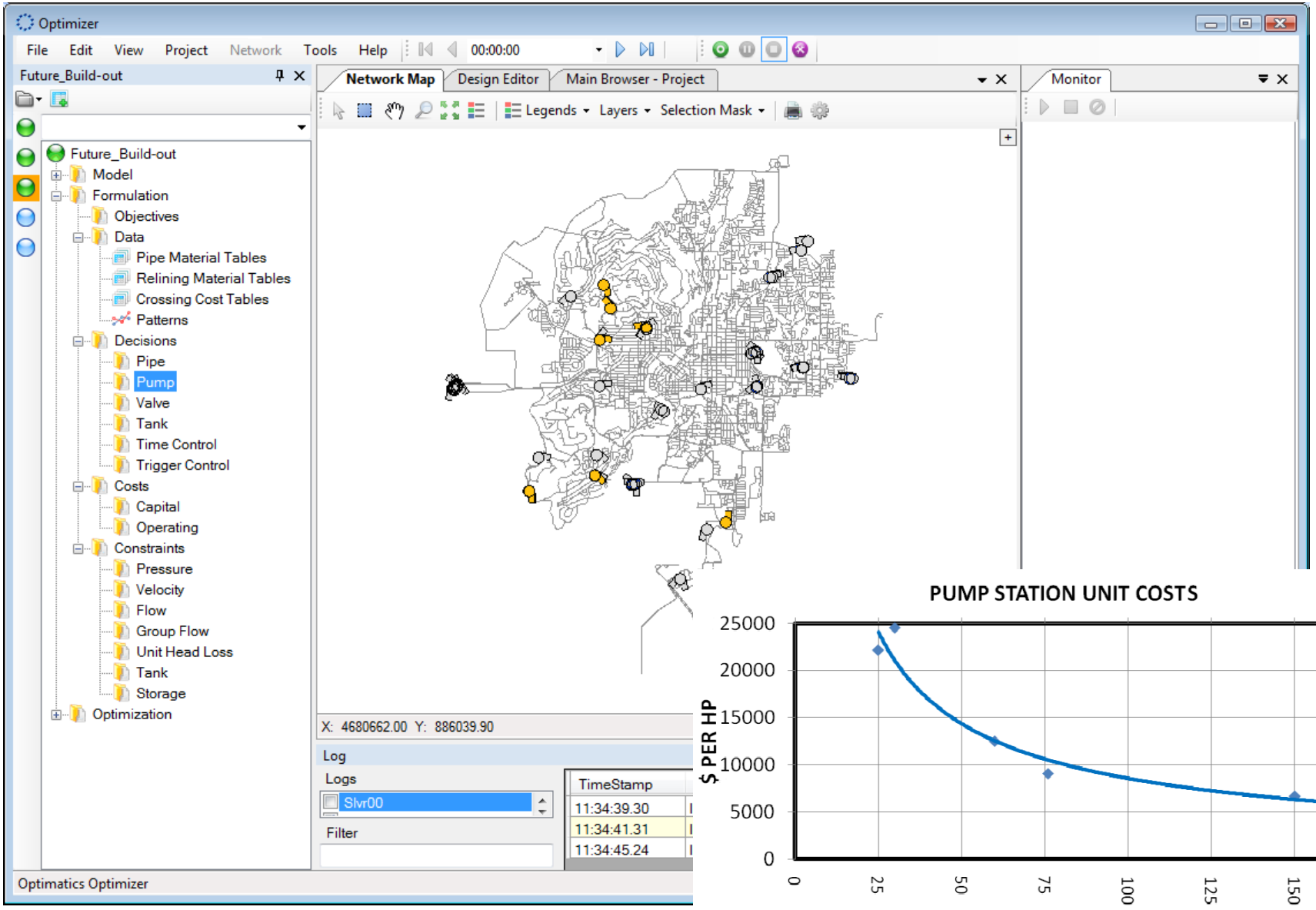
Formulate Optimization Model - *Import Hydraulic Model*



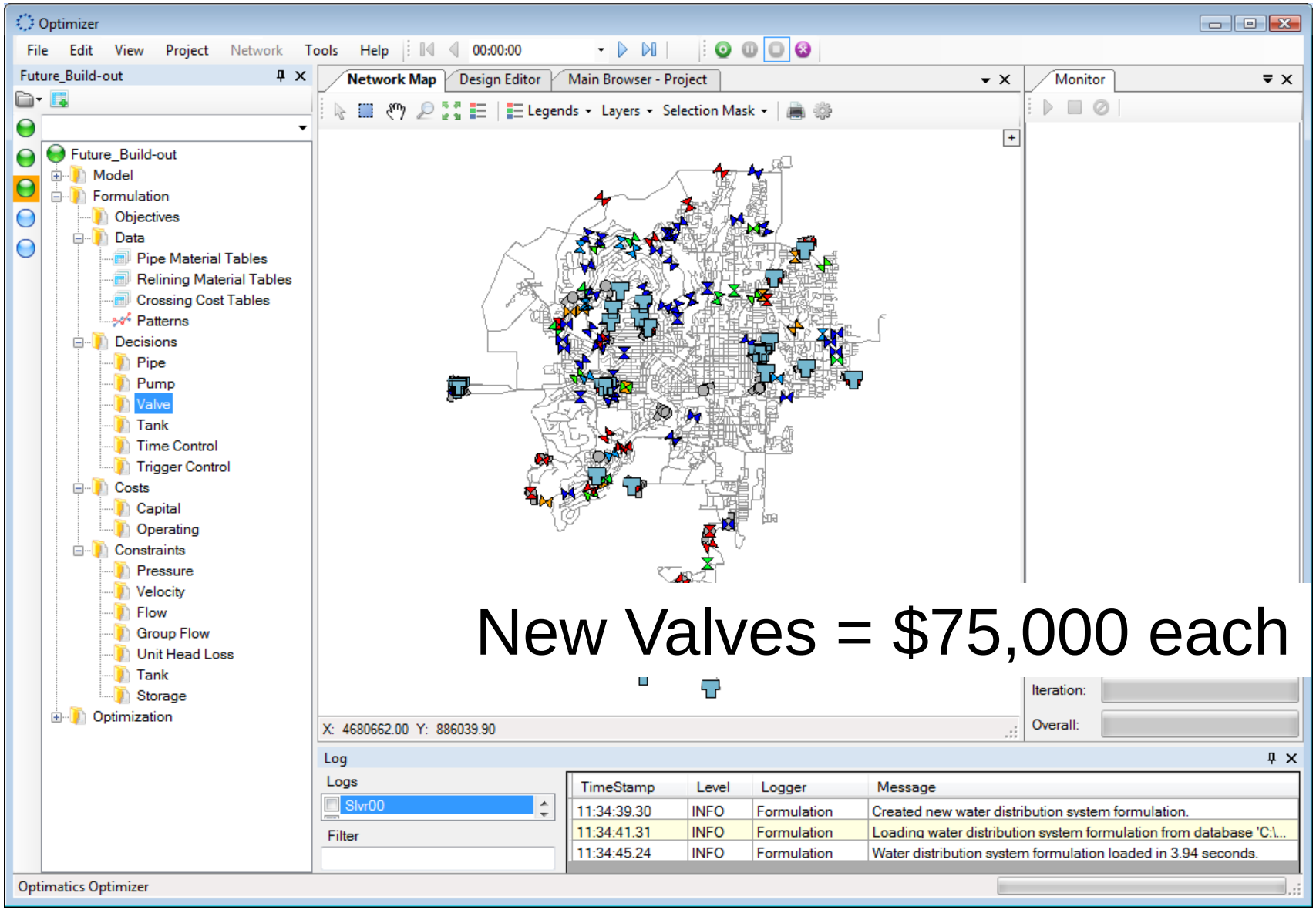
Formulate Optimization Model - *Define Pipe Costs & Decisions*



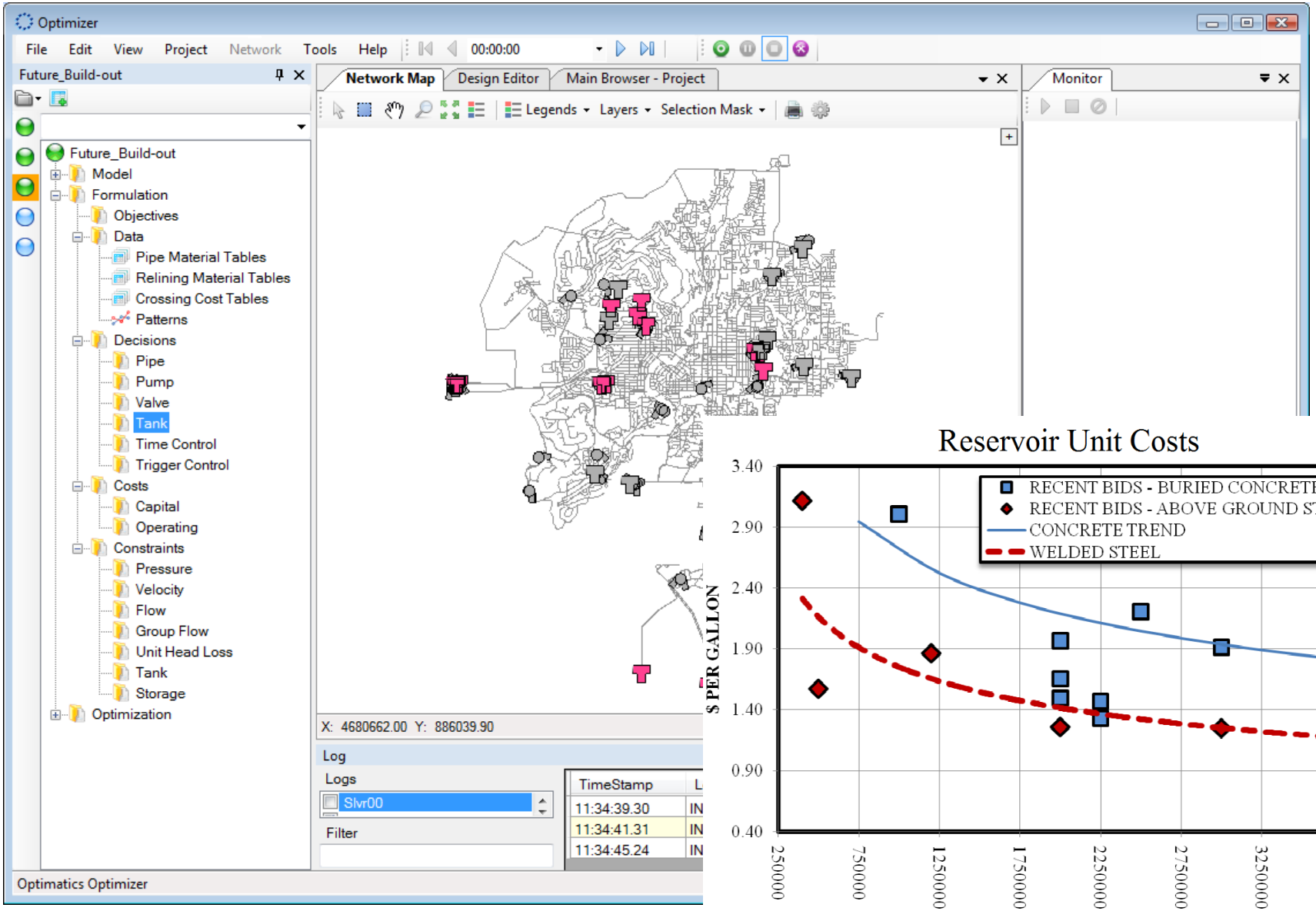
Formulate Optimization Model - *Define Pump Costs & Decisions*



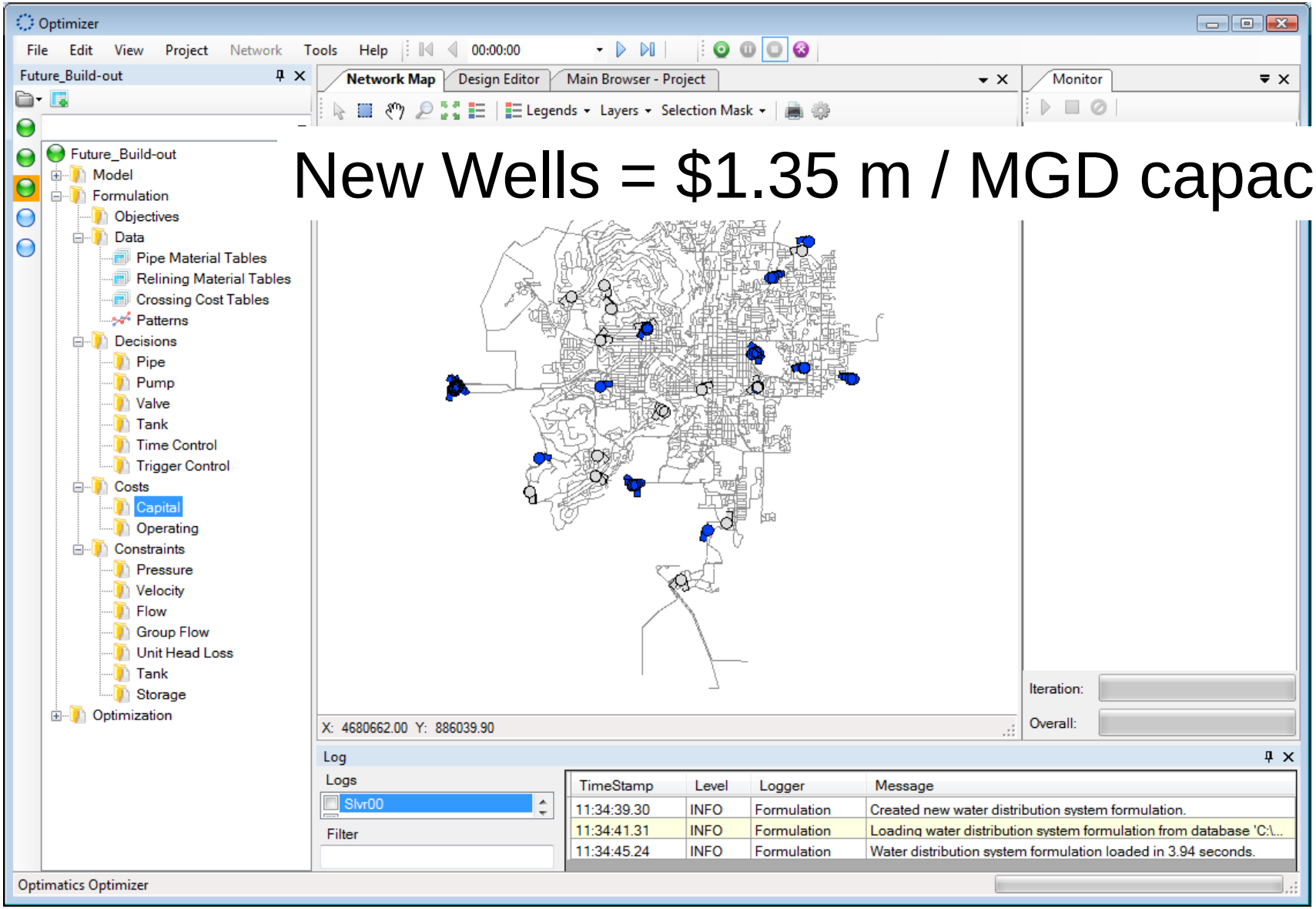
Formulate Optimization Model - *Define Valve Costs & Decisions*



Formulate Optimization Model - *Define Tank Costs & Decisions*

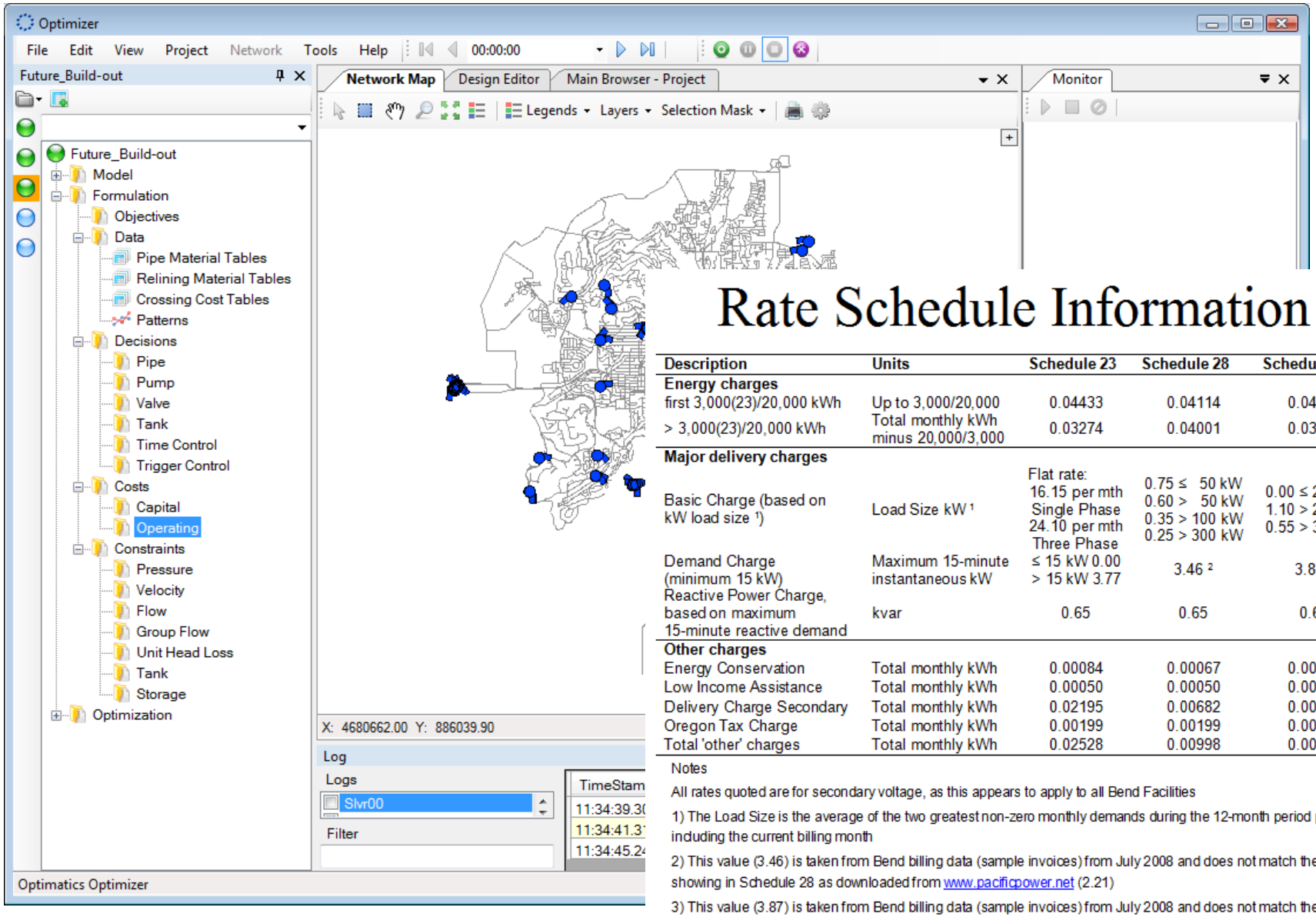


Formulate Optimization Model - *Define Well Costs & Decisions*



New Wells = $1.35 m / MGD capacity

Formulate Optimization Model - *Define Energy Costs*



Rate Schedule Information

Description	Units	Schedule 23	Schedule 28	Schedule 30
Energy charges				
first 3,000(23)/20,000 kWh	Up to 3,000/20,000	0.04433	0.04114	0.04486
> 3,000(23)/20,000 kWh	Total monthly kWh minus 20,000/3,000	0.03274	0.04001	0.03881
Major delivery charges				
Basic Charge (based on kW load size [1])	Load Size kW [1]	Flat rate: 16.15 per mth Single Phase 24.10 per mth Three Phase	0.75 ≤ 50 kW 0.60 > 50 kW 0.35 > 100 kW 0.25 > 300 kW	0.00 ≤ 200 kW 1.10 > 200 kW 0.55 > 300 kW
Demand Charge (minimum 15 kW)	Maximum 15-minute instantaneous kW	≤ 15 kW 0.00 > 15 kW 3.77	3.46 [2]	3.87 [3]
Reactive Power Charge, based on maximum 15-minute reactive demand	kvar	0.65	0.65	0.65
Other charges				
Energy Conservation	Total monthly kWh	0.00084	0.00067	0.00061
Low Income Assistance	Total monthly kWh	0.00050	0.00050	0.00050
Delivery Charge Secondary	Total monthly kWh	0.02195	0.00682	0.00190
Oregon Tax Charge	Total monthly kWh	0.00199	0.00199	0.00199
Total 'other' charges	Total monthly kWh	0.02528	0.00998	0.00500

Notes

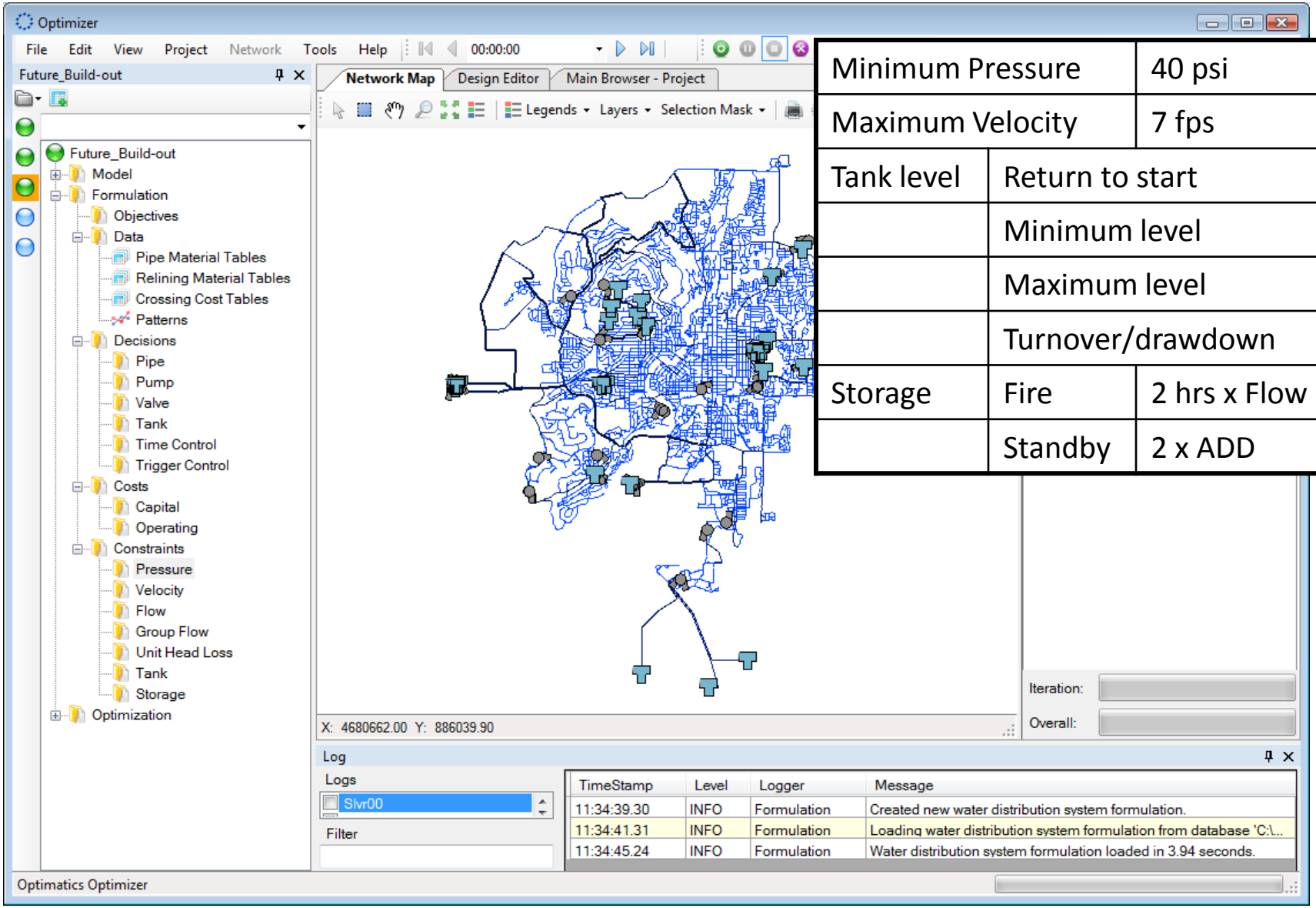
All rates quoted are for secondary voltage, as this appears to apply to all Bend Facilities

1) The Load Size is the average of the two greatest non-zero monthly demands during the 12-month period prior to and including the current billing month

2) This value (3.46) is taken from Bend billing data (sample invoices) from July 2008 and does not match the value showing in Schedule 28 as downloaded from www.pacificpower.net (2.21)

3) This value (3.87) is taken from Bend billing data (sample invoices) from July 2008 and does not match the value showing in Schedule 30 as downloaded from www.pacificpower.net (2.49)

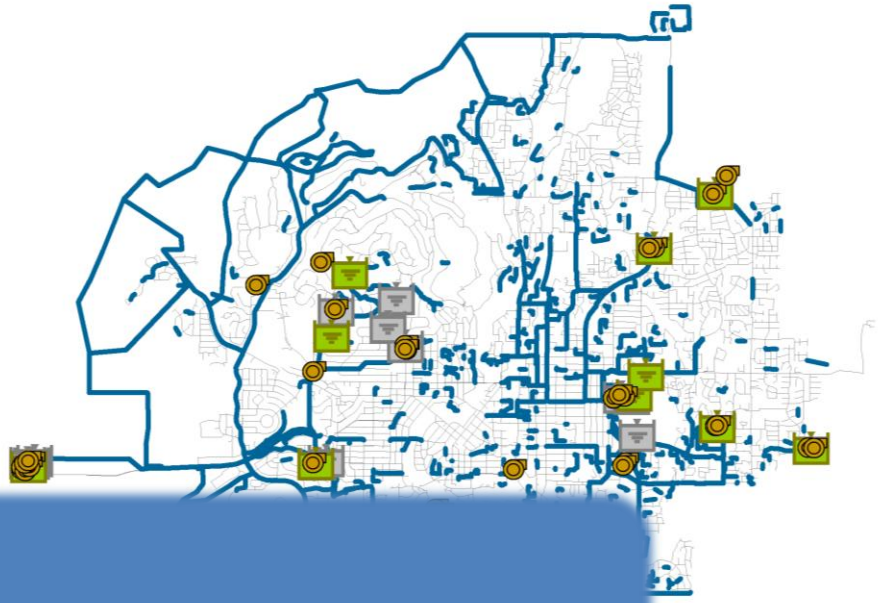
Formulate Optimization Model - *Specify Planning Criteria*



Minimum Pressure		40 psi
Maximum Velocity		7 fps
Tank level	Return to start	
	Minimum level	
	Maximum level	
	Turnover/drawdown	
Storage	Fire	2 hrs x Flow
	Standby	2 x ADD

Current Solution – Being Processed

Cost Item	Total Cost ($M)
Pipes	
Pumps	
Tanks	
Valves	
Wells	
Energy	
TOTAL ($M)	



- Processing
- Performing simulations

Run Optimization Model

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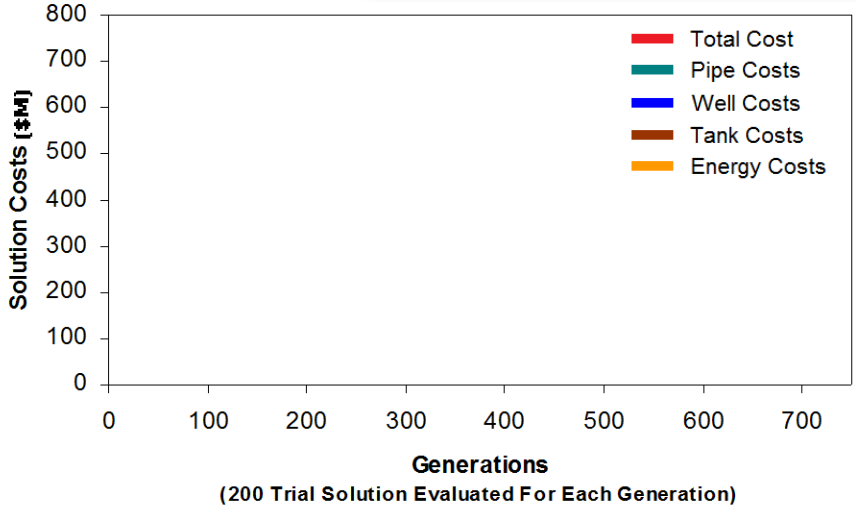
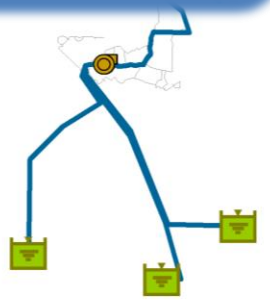




Water Main (in)

Existing

Decision Option

Tanks (MG)

Existing

Decision Option

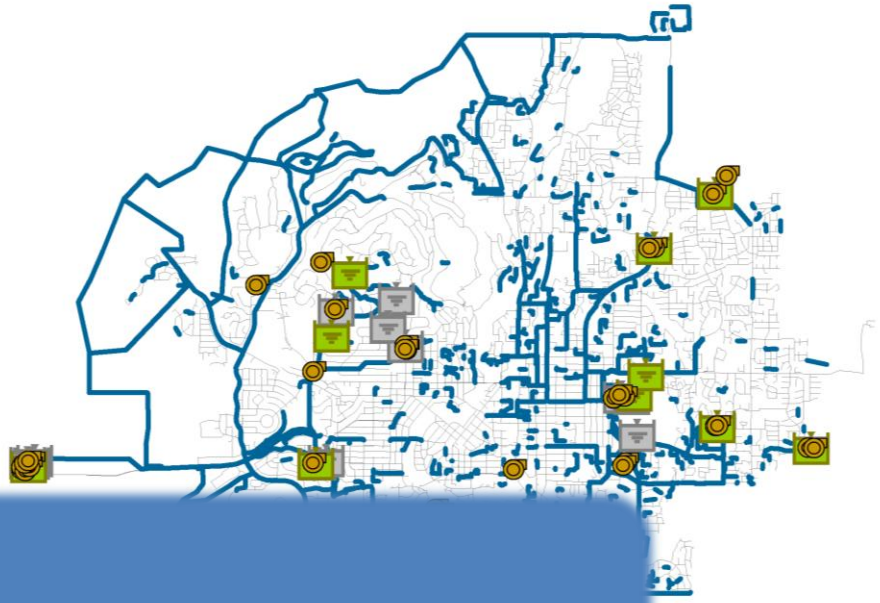
Pump (gpm)

Existing

Decision Option

Current Solution – Being Processed

Cost Item	Total Cost ($M)
Pipes	
Pumps	
Tanks	
Valves	
Wells	
Energy	
TOTAL ($M)	



- Processing
- Performing
  simulations

Run Optimization Model

Optimi
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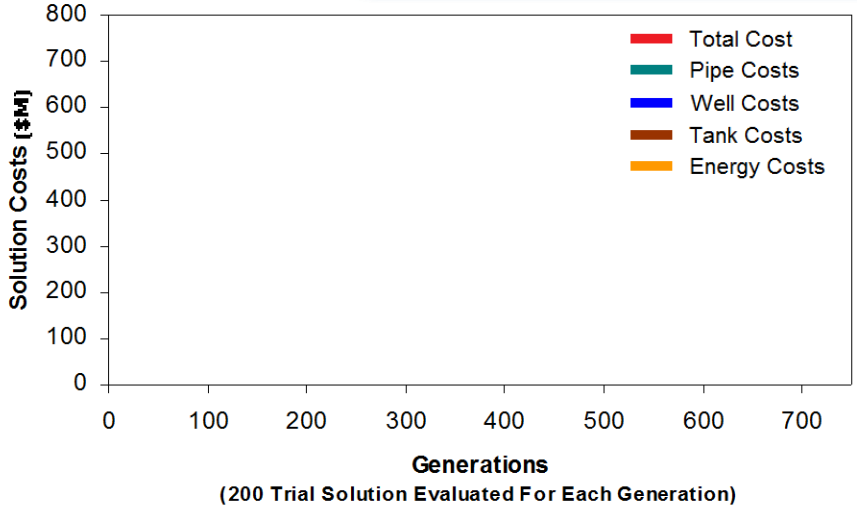
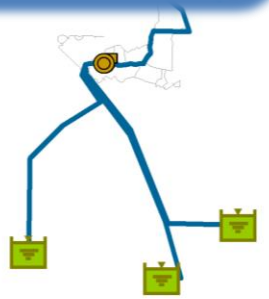




Water Main (in)

Existing

Decision Option

Tanks (MG)

Existing

Decision Option

Pump (gpm)

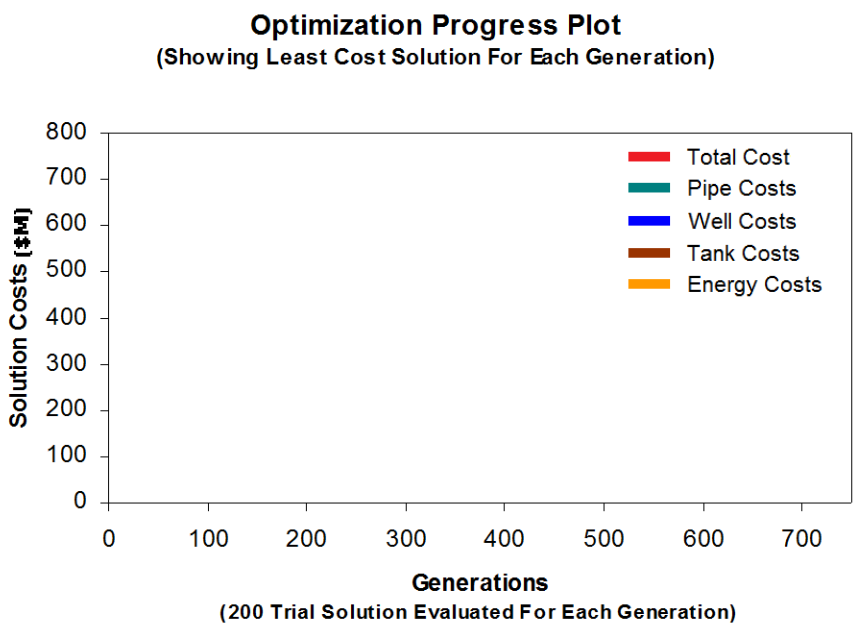
Existing

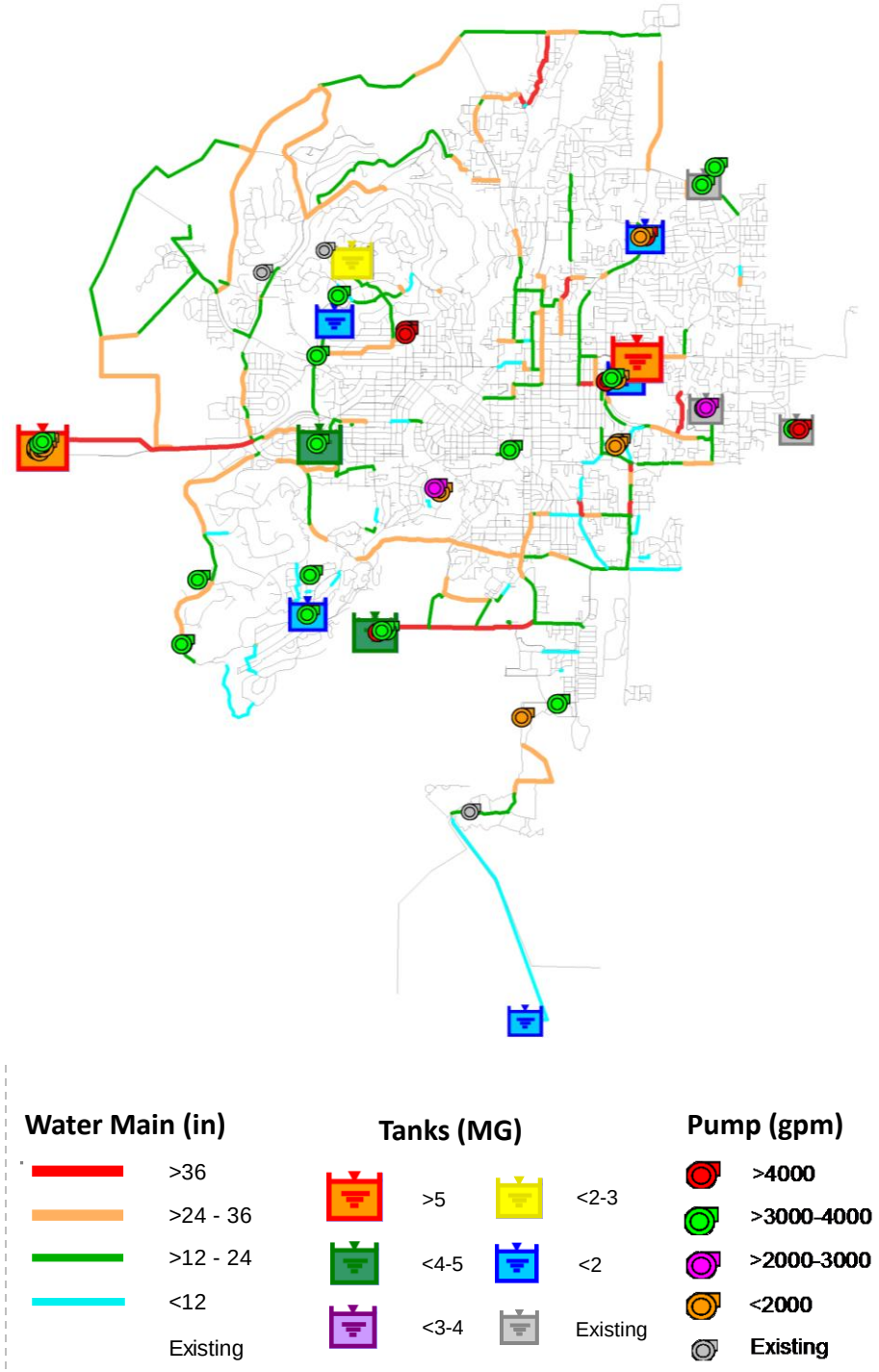
Decision Option

Current Solution - $242.8 M

Cost Item	Total Cost ($M)
Pipes	107.3
Pumps	2.9
Tanks	38.9
Valves	0.6
Wells	65.1
Energy	28.1
TOTAL ($M)	242.8

- Best solution in 1st generation
- Total of 200 trial solutions evaluated
- Actual processing time: 0.03 hours (72 cores)

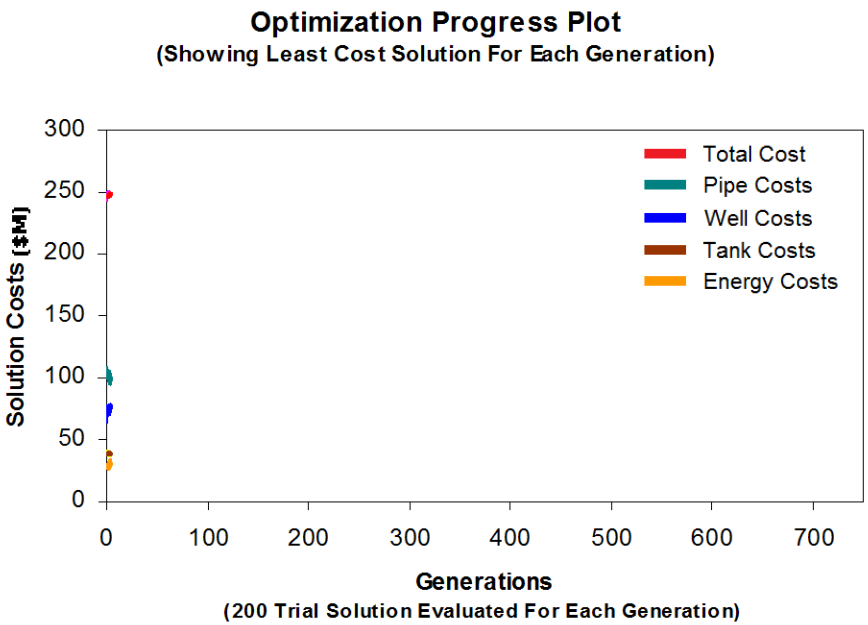


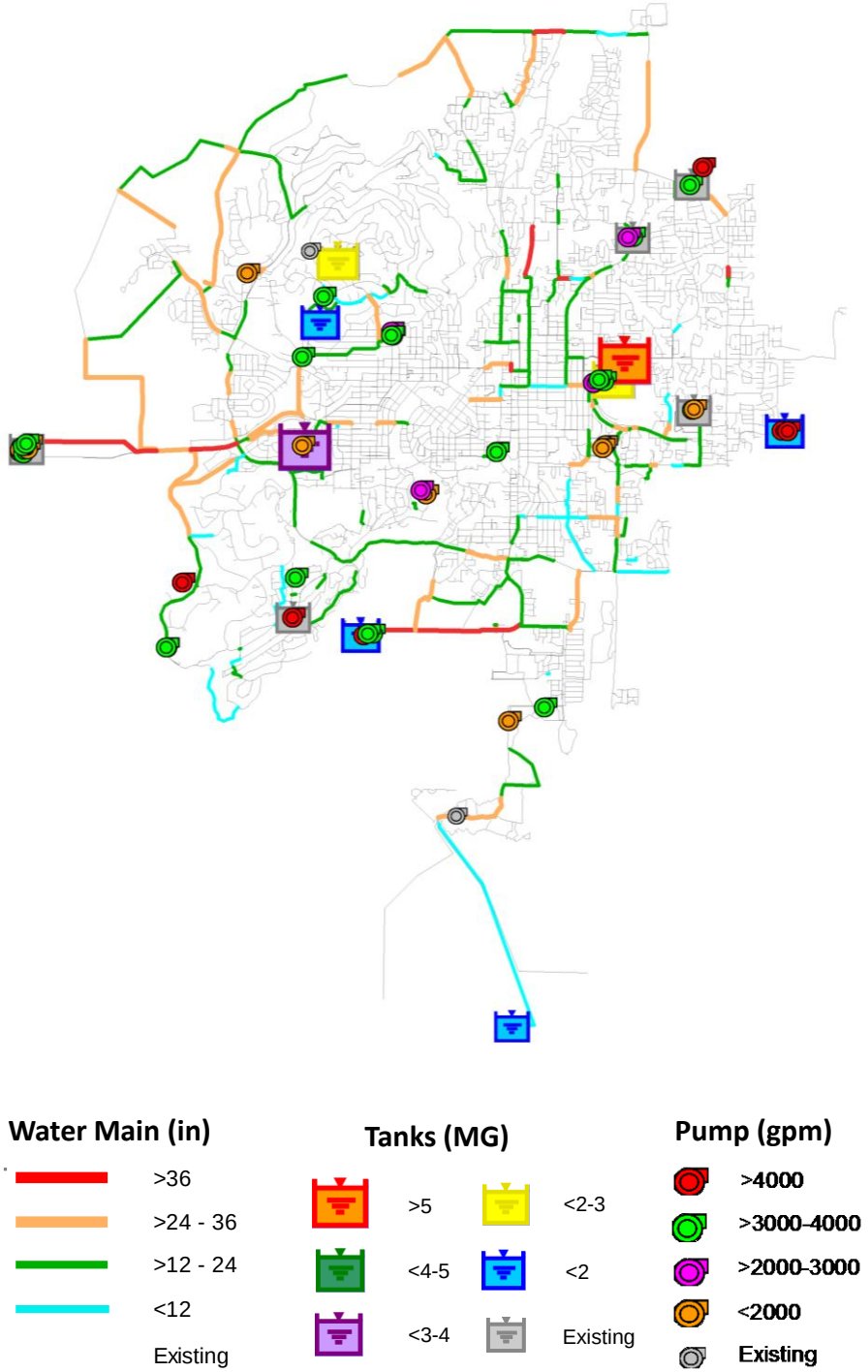


Current Solution - $246.6 M

Cost Item	Total Cost ($M)
Pipes	94.5
Pumps	2.8
Tanks	37.4
Valves	0.6
Wells	77.7
Energy	33.5
TOTAL ($M)	246.6

- Best solution in 4th generation
- Total of 800 trial solutions evaluated
- Actual processing time: 0.14 hours (72 cores)

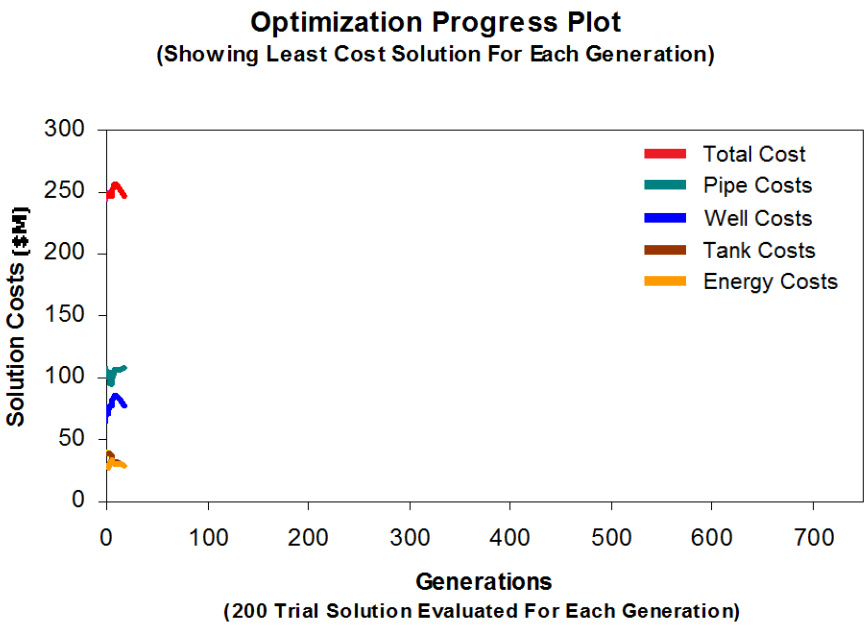


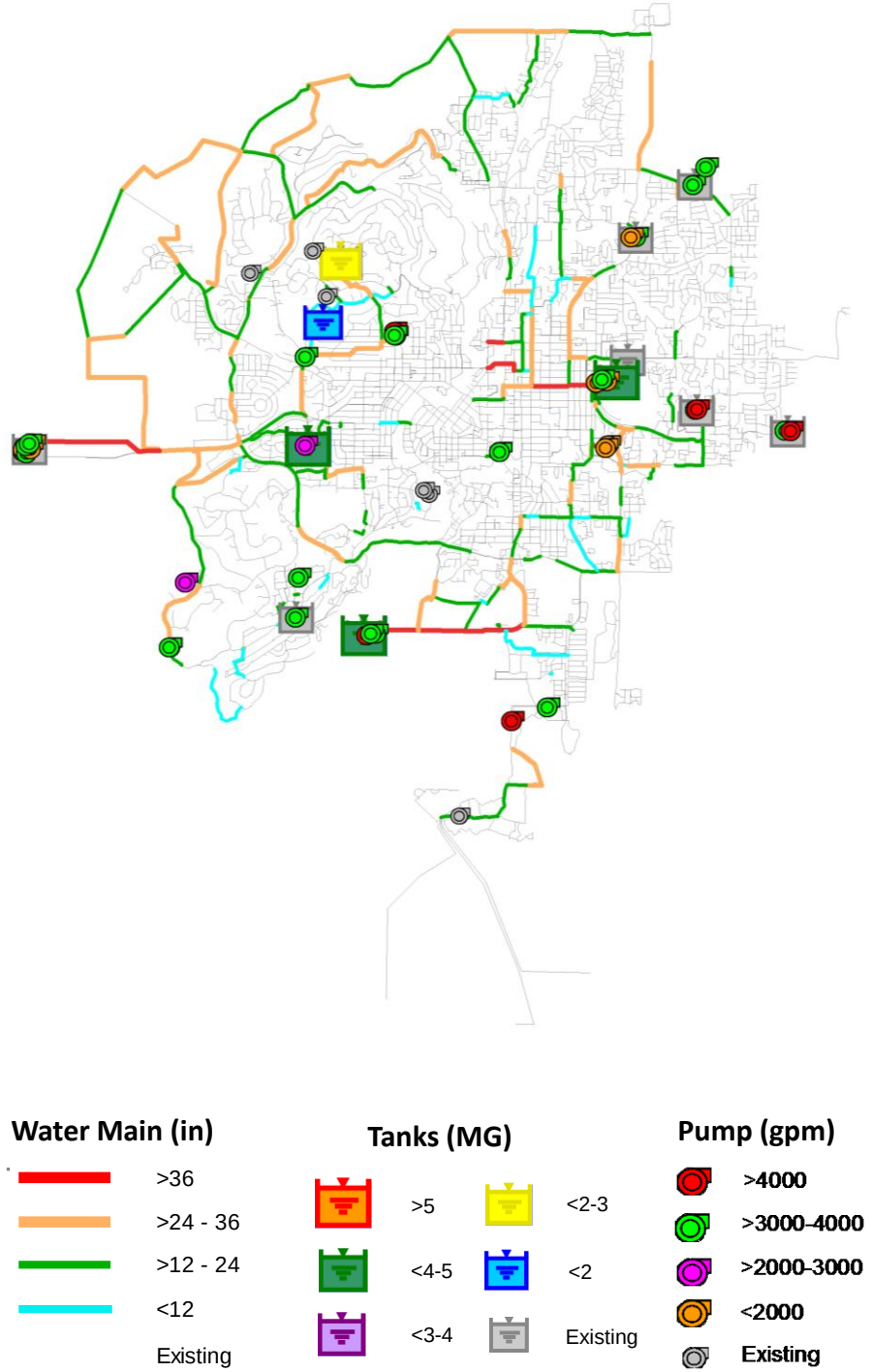


Current Solution - $246.2 M

Cost Item	Total Cost ($M)
Pipes	108.1
Pumps	0.9
Tanks	29.8
Valves	0.6
Wells	77.5
Energy	29.2
TOTAL ($M)	246.2

- Best solution in 16th generation
- Total of 3,200 trial solutions evaluated
- Actual processing time: 0.47 hours (72 cores)

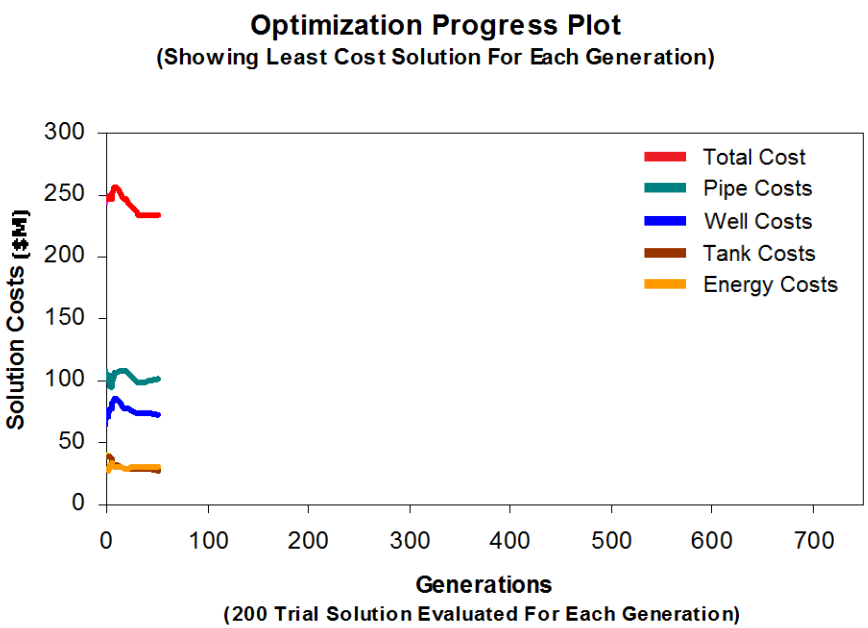


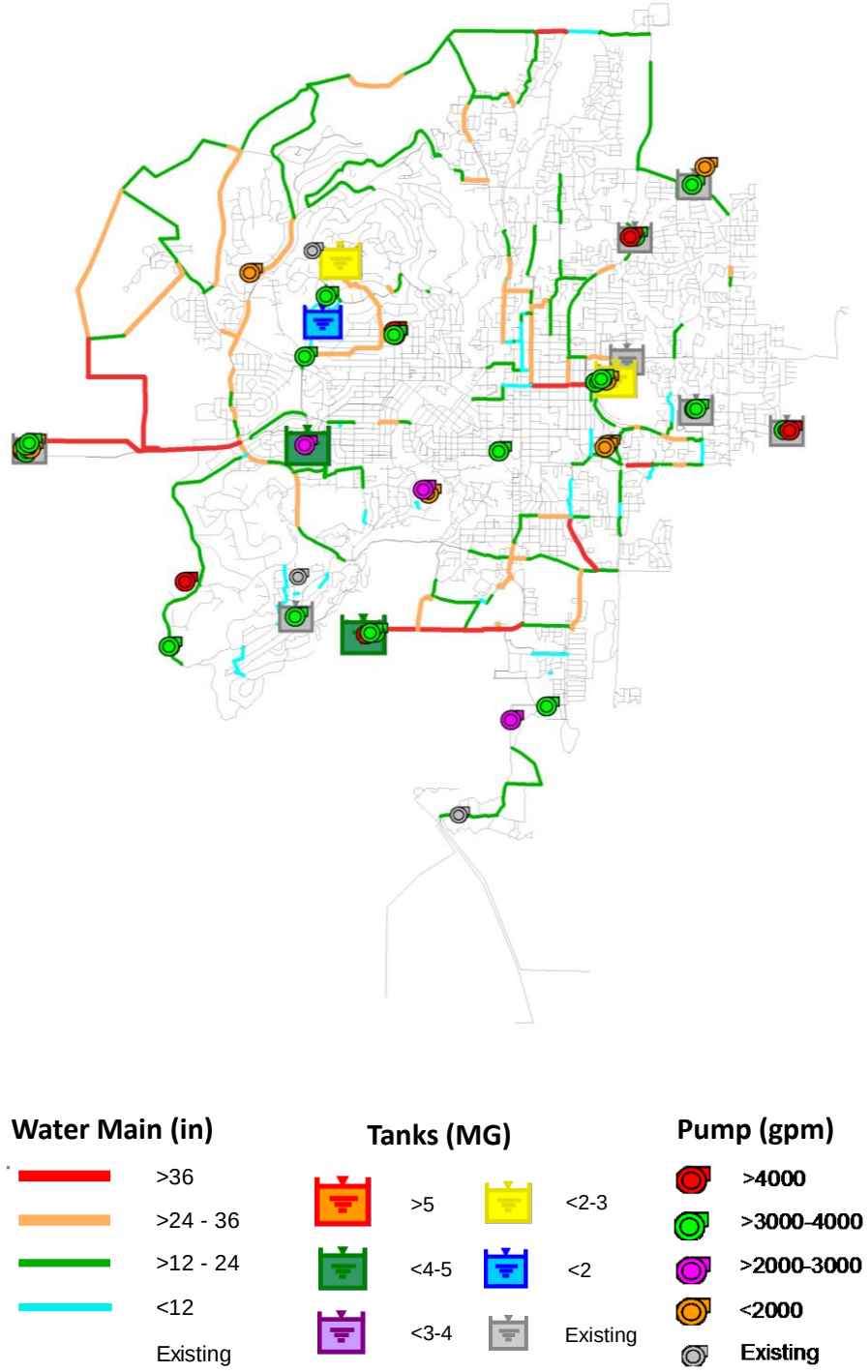


Current Solution - $233.2 M

Cost Item	Total Cost ($M)
Pipes	101.8
Pumps	0.8
Tanks	27.5
Valves	0.6
Wells	72.3
Energy	30.1
TOTAL ($M)	233.2

- Best solution in 50th generation
- Total of 10,000 trial solutions evaluated
- Actual processing time: 1.42 hours (72 cores)

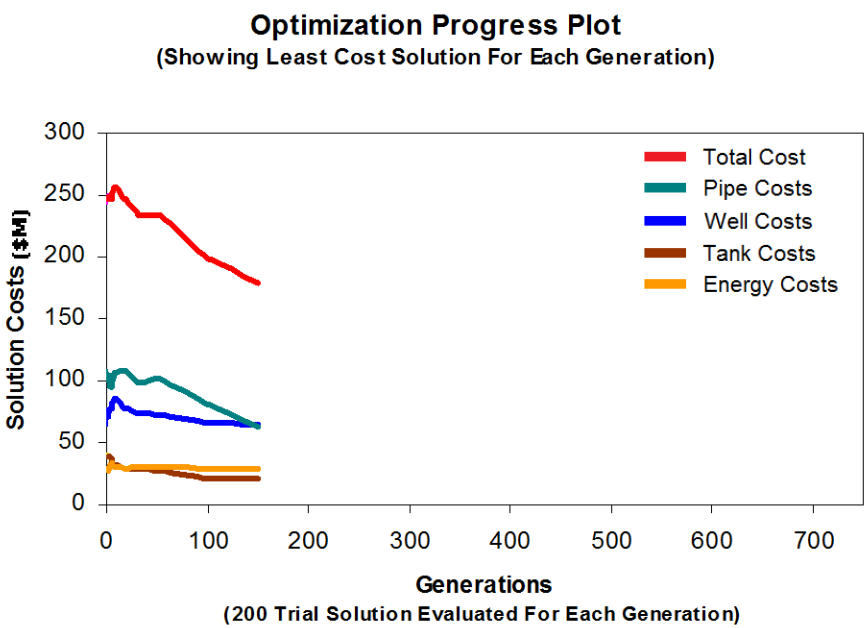


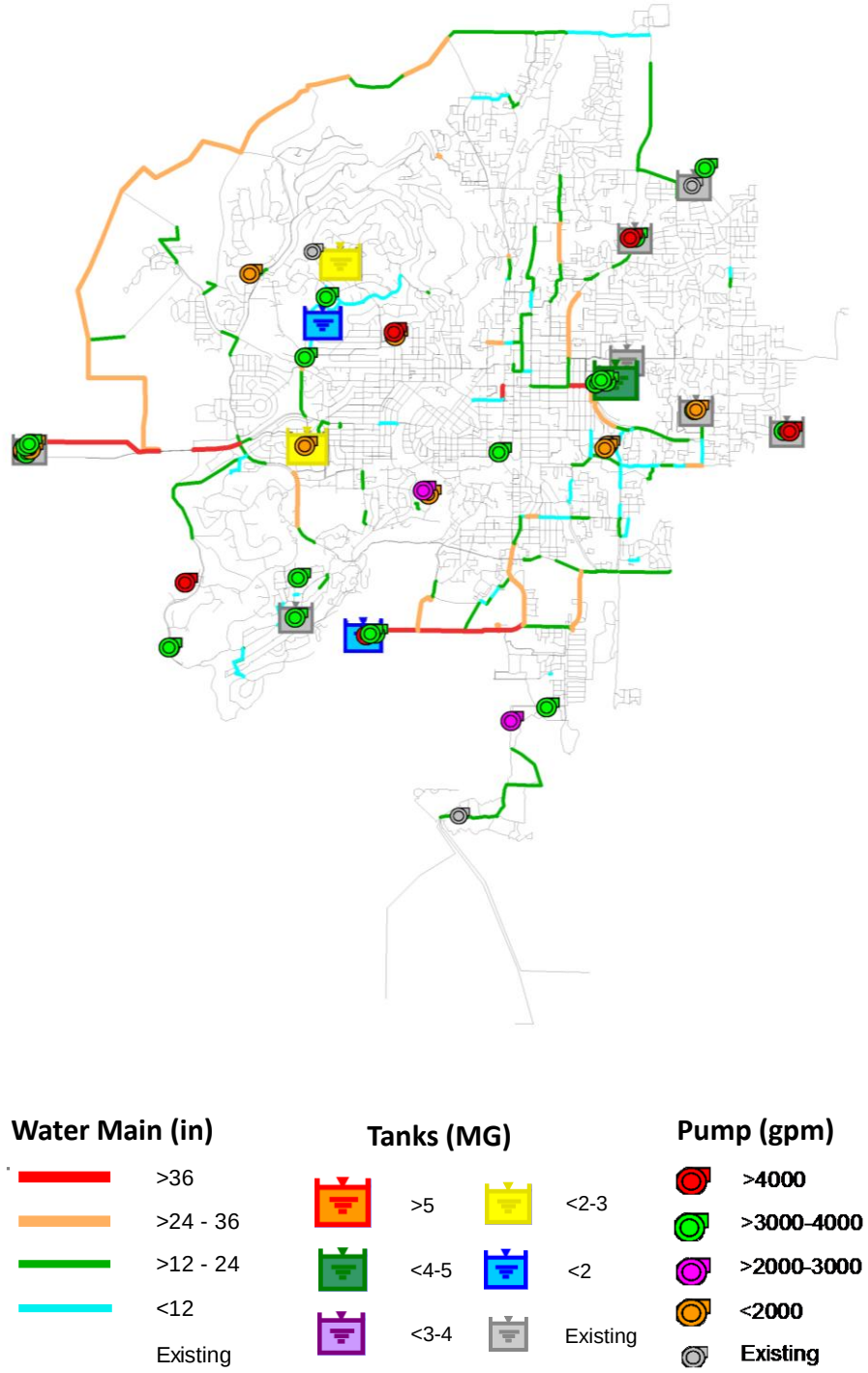


Current Solution - $178.9 M

Cost Item	Total Cost ($M)
Pipes	63.1
Pumps	0.9
Tanks	20.5
Valves	0.6
Wells	63.9
Energy	29.8
TOTAL ($M)	178.9

- Best solution in 150th generation
- Total of 30,000 trial solutions evaluated
- Actual processing time: 4.19 hours (72 cores)

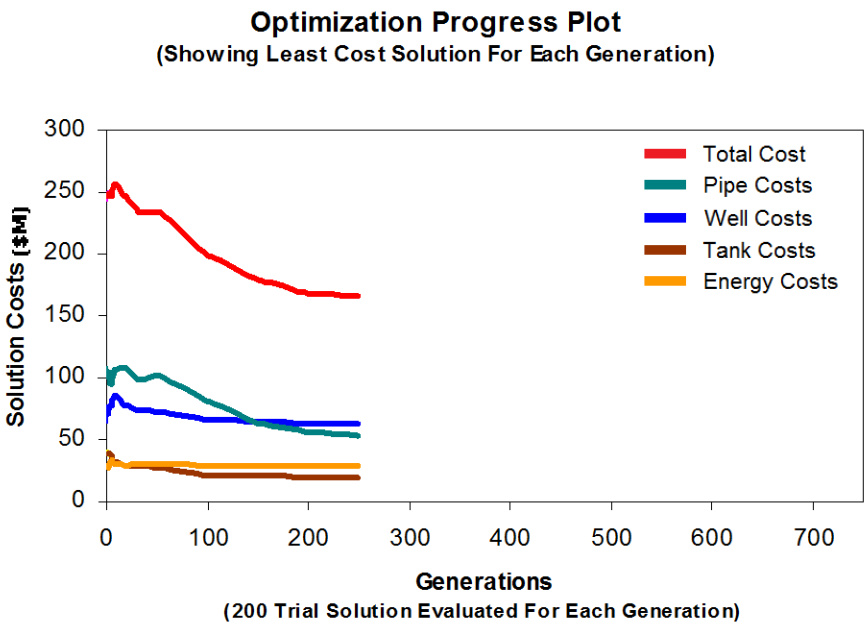


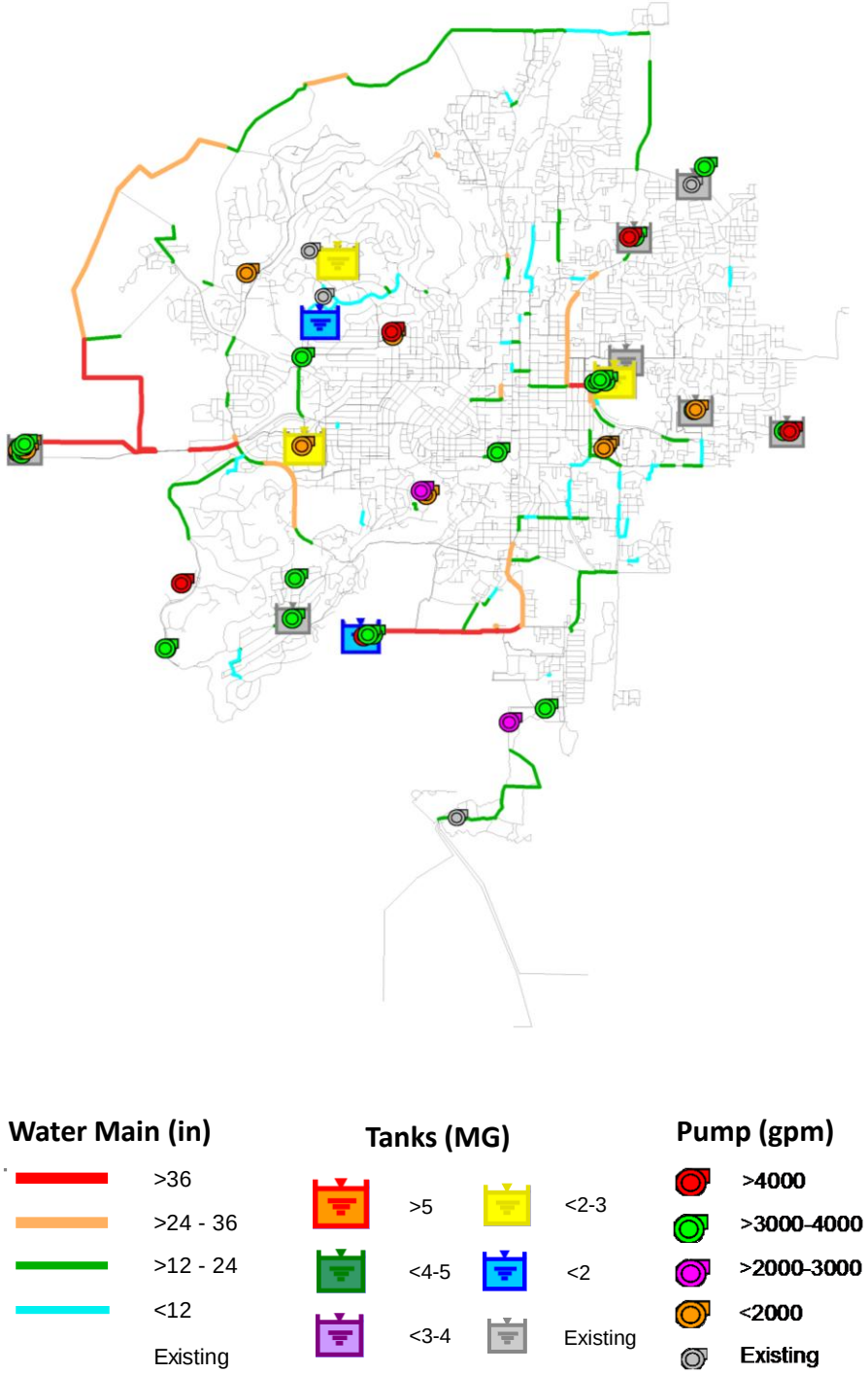


Current Solution - $165.3 M

Cost Item	Total Cost ($M)
Pipes	53.3
Pumps	1.0
Tanks	19.4
Valves	0.6
Wells	62.3
Energy	28.8
TOTAL ($M)	165.3

- Best solution in 250th generation
- Total of 50,000 trial solutions evaluated
- Actual processing time: 6.97 hours (72 cores)

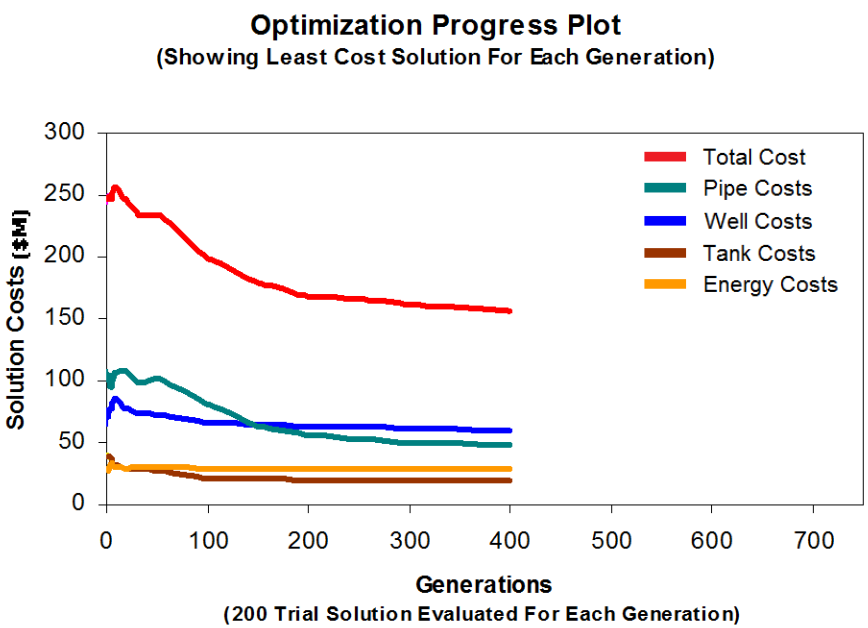


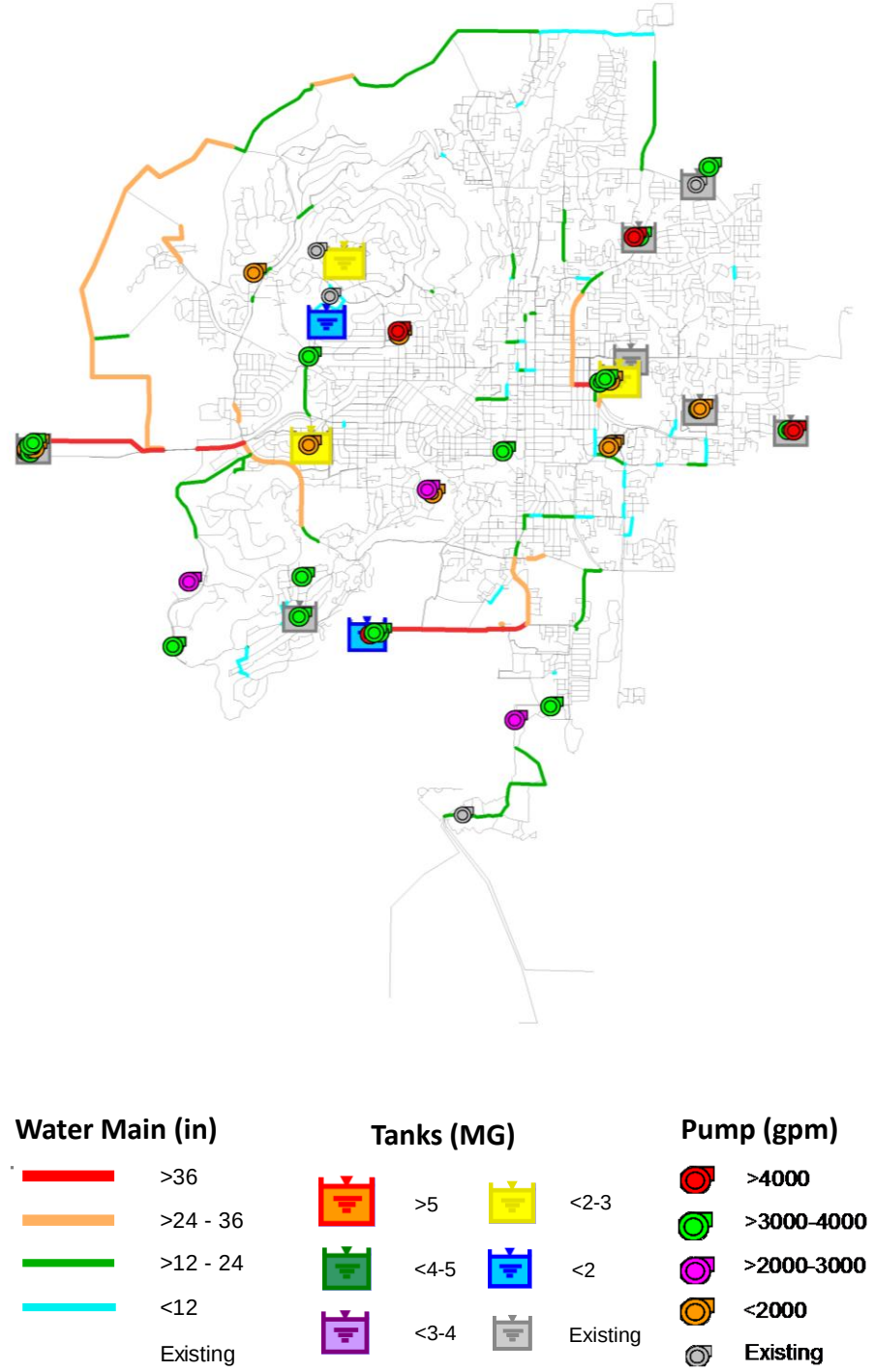


Current Solution - $157.2 M

Cost Item	Total Cost ($M)
Pipes	48.1
Pumps	0.8
Tanks	19.4
Valves	0.6
Wells	59.6
Energy	28.7
TOTAL ($M)	157.2

- Best solution in 400th generation
- Total of 80,000 trial solutions evaluated
- Actual processing time: 11.14 hours (72 cores)

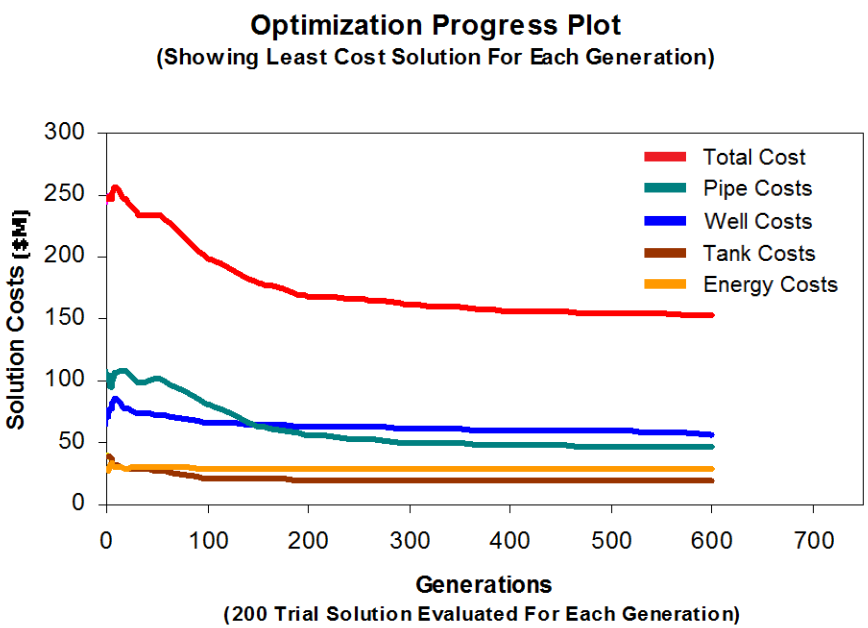


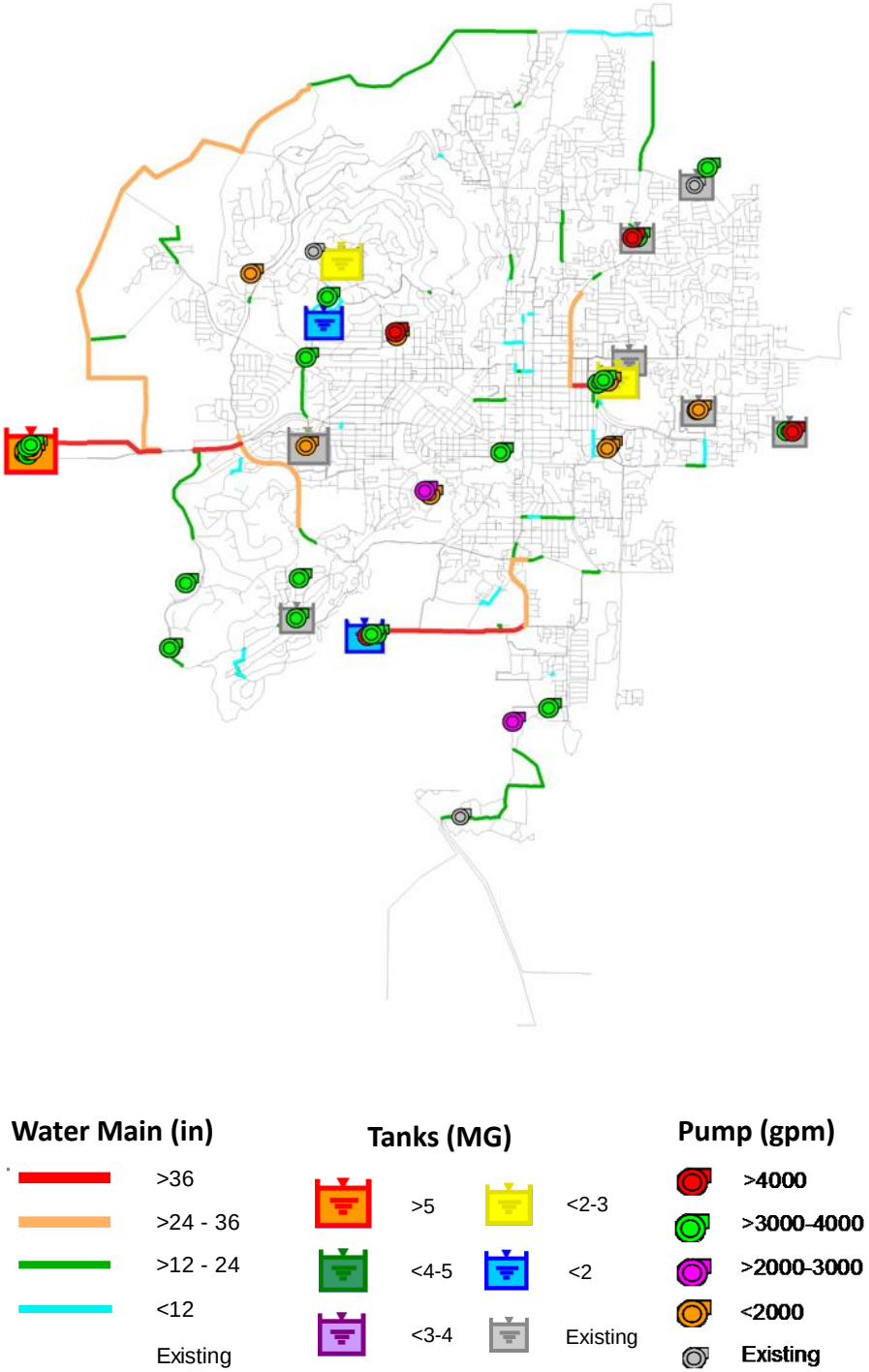


Current Solution - $152.6 M

Cost Item	Total Cost ($M)
Pipes	47.4
Pumps	0.9
Tanks	19.4
Valves	0.6
Wells	55.7
Energy	28.6
TOTAL ($M)	152.6

- Best solution in 600th generation
- Total of 120,000 trial solutions evaluated
- Actual processing time: 16.69 hours (72 cores)

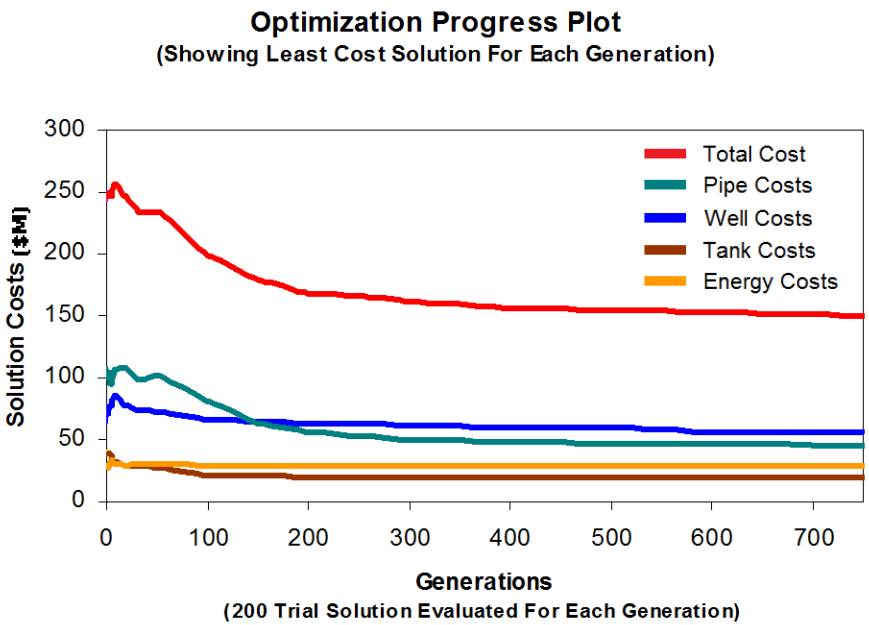


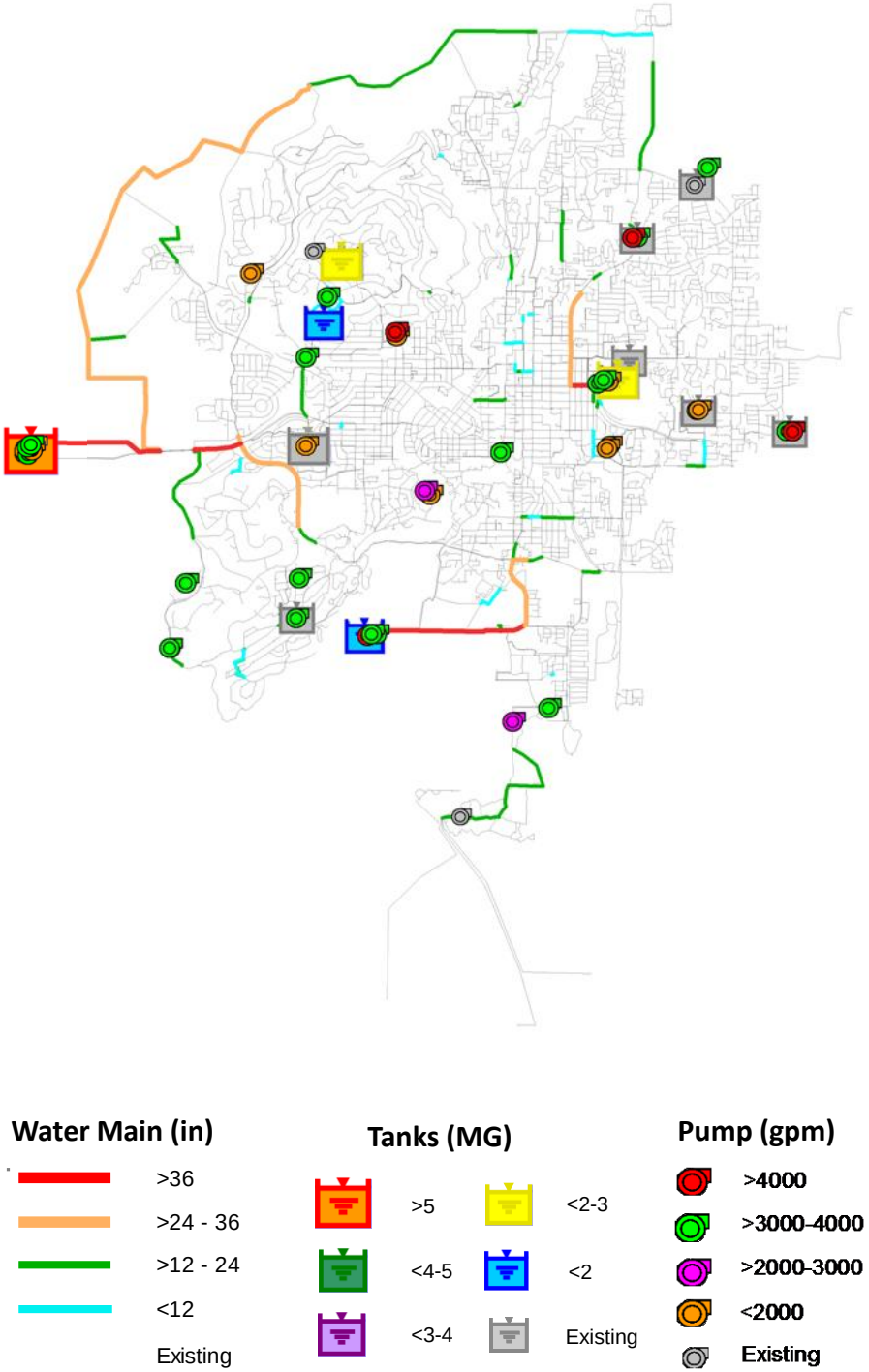


Current Solution - $144.3 M

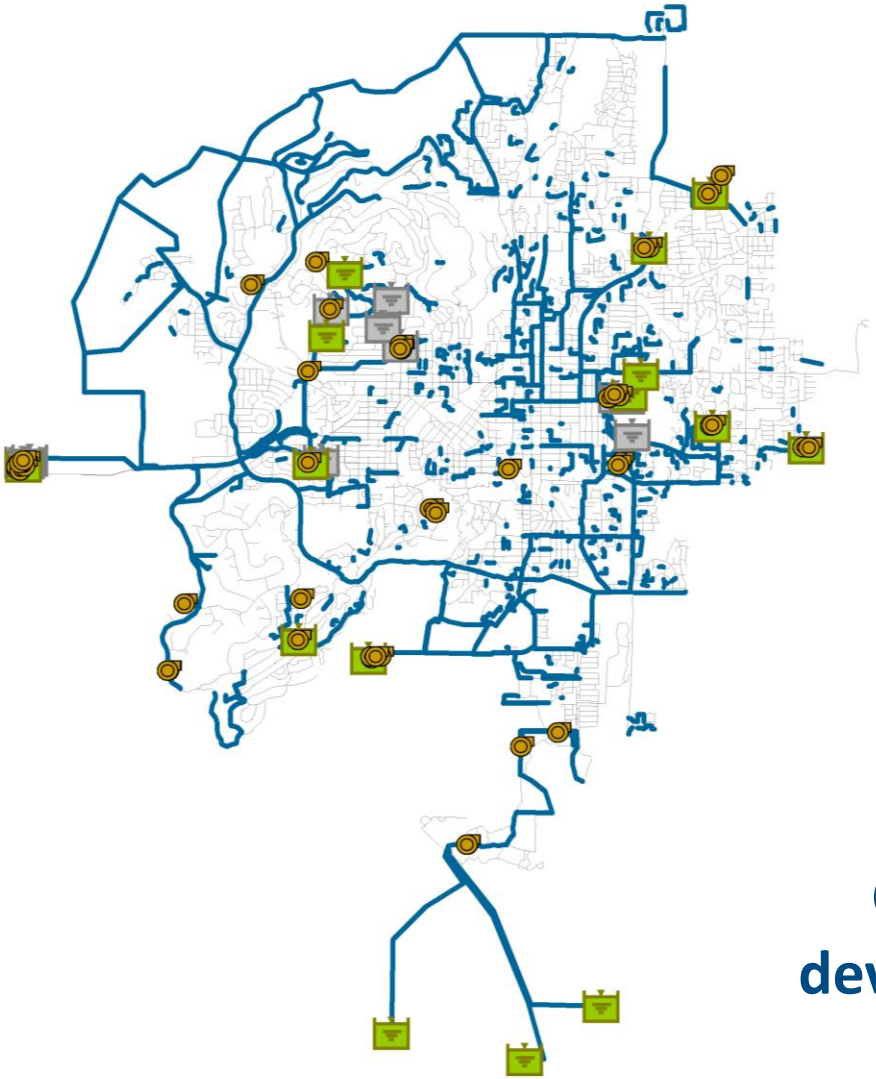
Cost Item	Total Cost ($M)
Pipes	43.6
Pumps	1.7
Tanks	24.1
Valves	0.6
Wells	45.5
Energy	28.8
TOTAL ($M)	144.3

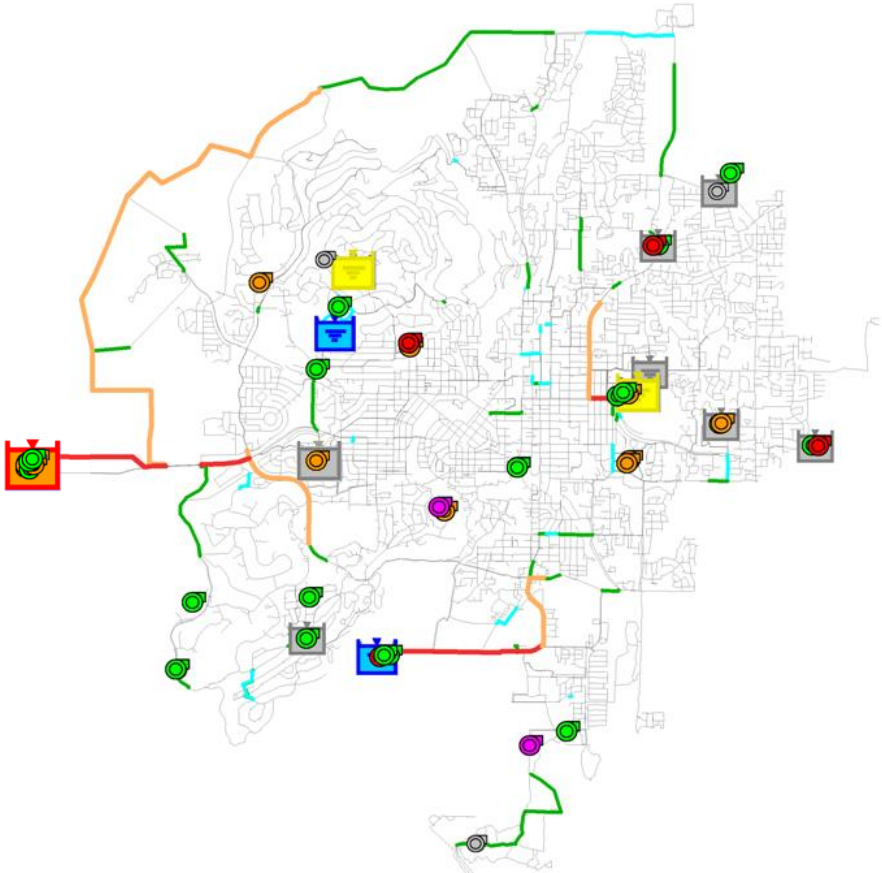
- Best solution in 750th generation
- Total of 150,000 trial solutions evaluated
- Actual processing time: 20.86 hours (72 cores)





From many options… few are selected





Change the setup and re-run to develop more optimized solutions to review with decision-makers

Pipe Criticality Analysis

Consequences of Pipe Failure

- Potential impacts include
  - Reduction in system pressure
  - Reduced fire fighting capacity
  - Loss of supply to critical customers, medical facilities, dialysis machines
  - Property damage
  - Traffic disruption
  - Safety of public and City personnel
  - Harm to reputation

OptiCritical™ – Pipe Failure Risk

PIPE FAILURE RISK

Probability

Factors input to predictive model:

- Break history
- Pipe age
- Pipe material
- Soil type
- Pressure
- Year of construction
- Location
- Ground movement

Consequence

Hydraulic Factors

- Loss of supply
- Water quality issues
- Flooding

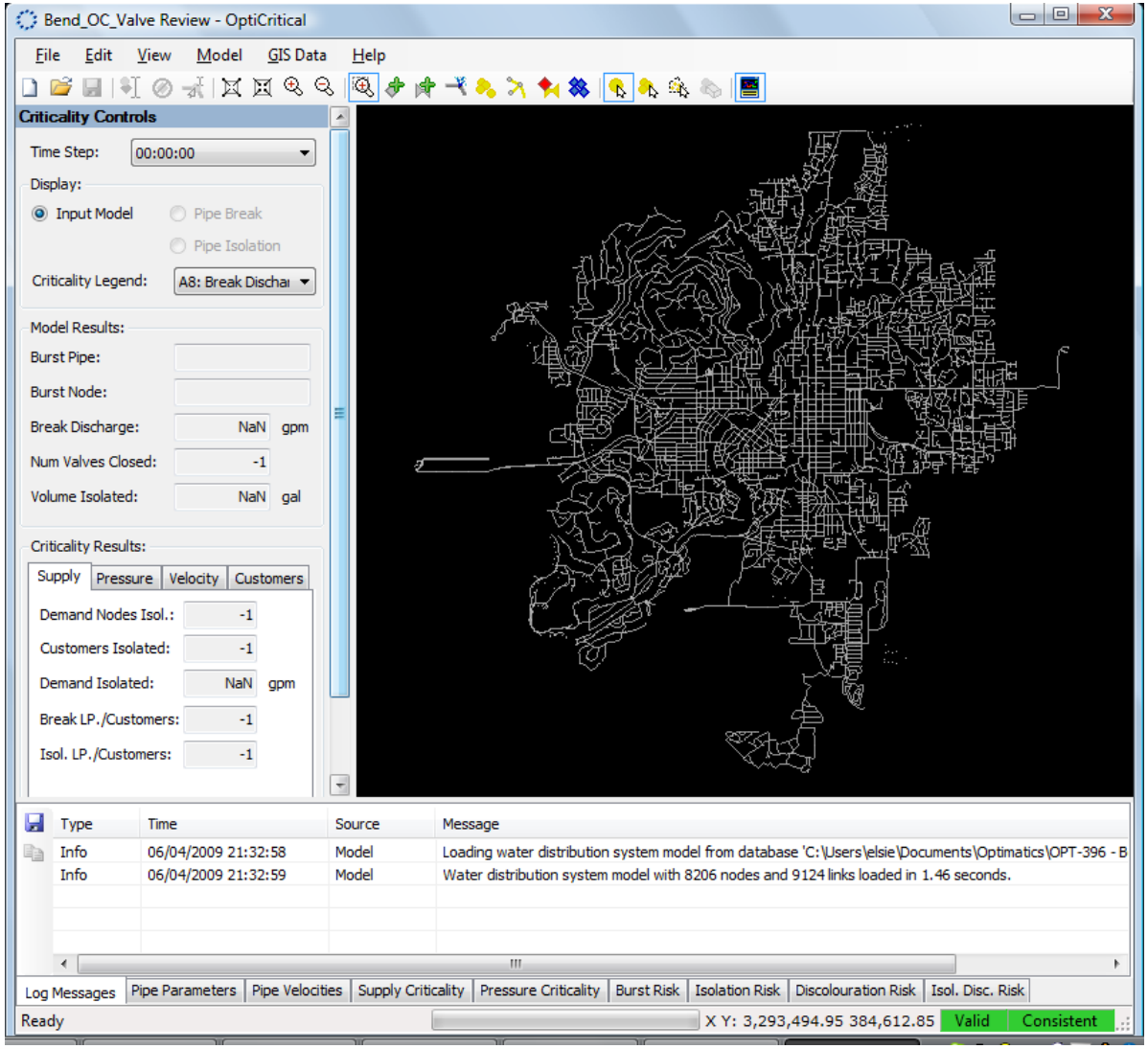
Economic Costs

- Repair costs
- Compensation
- Fines
- Loss of reputation

Pipe Criticality Analysis – Benefits

- Better understanding of where the system is most vulnerable and why it is vulnerable
- Improve system redundancy and lower risk by strengthening key areas of the system
- More effective spending of pipe R&R dollars
- Improved pipe break incident response

Pipe Criticality Analysis – Setup



- Updated, calibrated hydraulic model
- System shutoff valves imported (8,889 valves)
- Analysis breaks and isolates every pipe (9,980 pipes),
  - System pressures
  - Flow velocities
  - Supply to customers

Bend Sept 25 added 3 vlvs SEV_a* - OptiCritical - Optimatics\Chicago 'Flyer'

File Edit View Model GIS Data Help

Criticality Controls

Time Step: 00:00:00

Display:

- Input Model
- Pipe Break
- Pipe Isolation

Criticality Legend: B1: Valves Closed

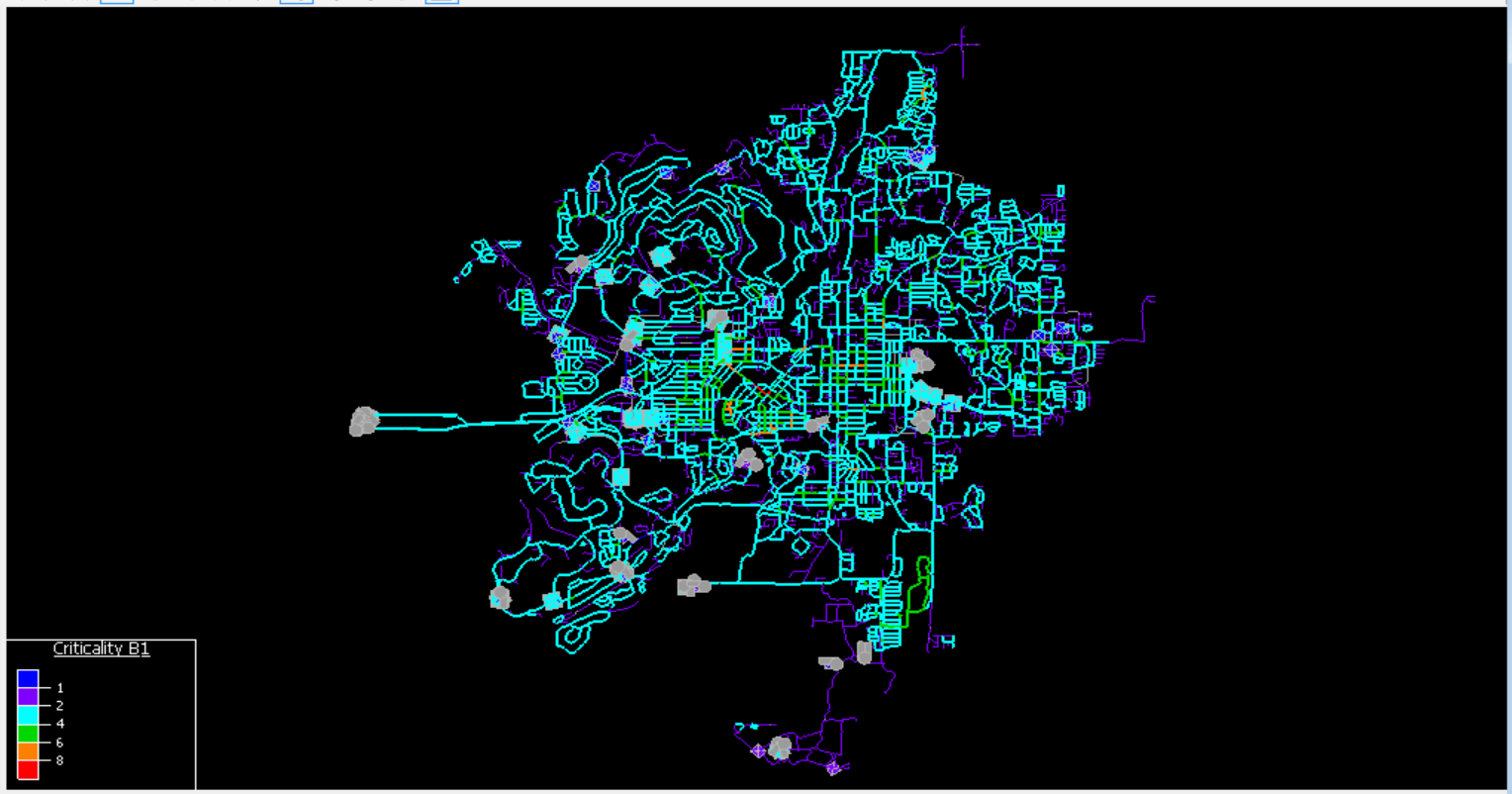
Model Results:

Burst Pipe:	WWM002819	
Burst Node:	J00005QQ	
Break Discharge:	2,360.03	gpm
Num Valves Closed:	2	
Volume Isolated:	653.60	gal

Criticality Results:

Supply | Pressure | Velocity | Customers

Demand Nodes Isol.:	0	
Customers Isolated:	0	
Demand Isolated:	0.00	gpm
Break LP./Customers:	0	
Isol. LP./Customers:	0	



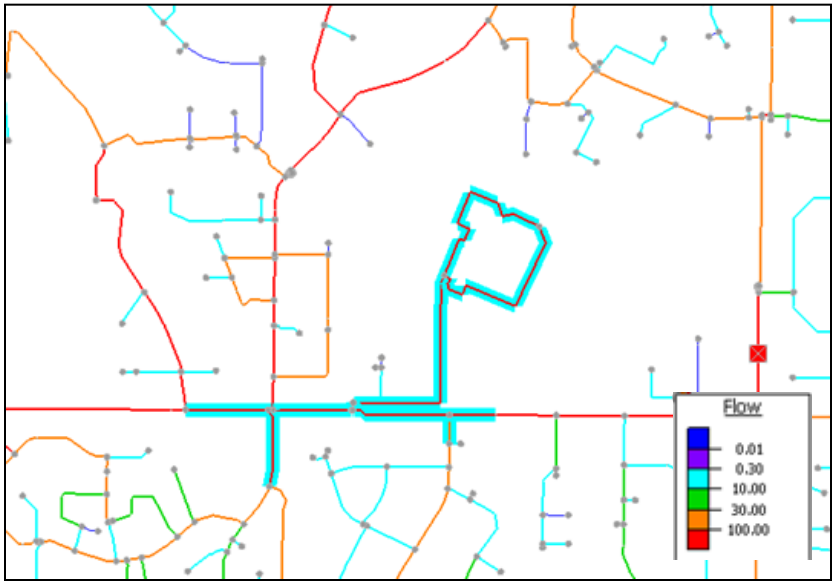
A1: Pipe ID	B1: Valves Closed	B2: Demand Nodes Isolated	B2.1: Customers Isolated	B3: Volume Isolated (gal)	B3.1: Length Isolated (ft)	B4: Demand Isolated (gpm)	B5: Low Pressure Customers During Break	B6: Low Pressure Customers During Isolation	Surrounding Valves
P00001TZ	2	2	17	1,549.34	593.31	4.37	0	0	WV0014476,WV0014484
WWM002937	4	2	9	1,180.78	389.27	2.40	0	0	WV0012486,WV00124...
WWM002940	4	2	24	2,929.11	498.52	8.60	0	0	WV0010607,WV00106...
WWM005452	3	2	15	2,858.19	1,094.52	9.24	0	0	WV0005724,WV00062...
WWM002944	2	2	12	211.80	81.11	3.83	0	0	WV0008206,WV0008207
WWM002963	1	2	7	1,527.50	692.99	3.69	0	0	WV0004977
WWM005311	2	2	10	5,904.65	711.24	3.66	0	0	WV0007490,WV0007491
WWM005840	2	2	22	1,605.59	614.85	6.89	0	0	WV0006101,WV0006105
WWM007039	3	2	21	3,816.28	1,137.58	3.59	0	0	WAPRV076A,WAPRV0...
WWM002979	1	2	17	2,894.22	1,146.74	8.07	388	0	WV0011566
WWM002982	4	2	3	3,611.09	732.74	6.78	0	0	WV0003494,WV00034...

Log Messages | Pipe Parameters | Pipe Velocities | Supply Criticality | Pressure Criticality | Burst Risk | Isolation Risk | Discolouration Risk | Isol. Disc. Risk

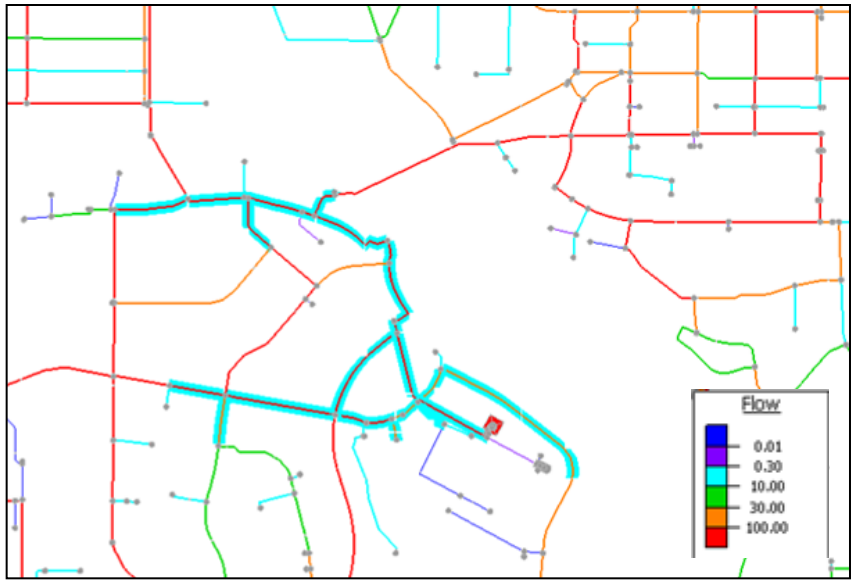
Ready X Y: 4,741,466.59 856,866.23 Valid Consistent

Critical Customers

- Two high risk customers identified
  - Hospital and adjacent medical area
  - Brewery (equipment relies on sustained pressure)

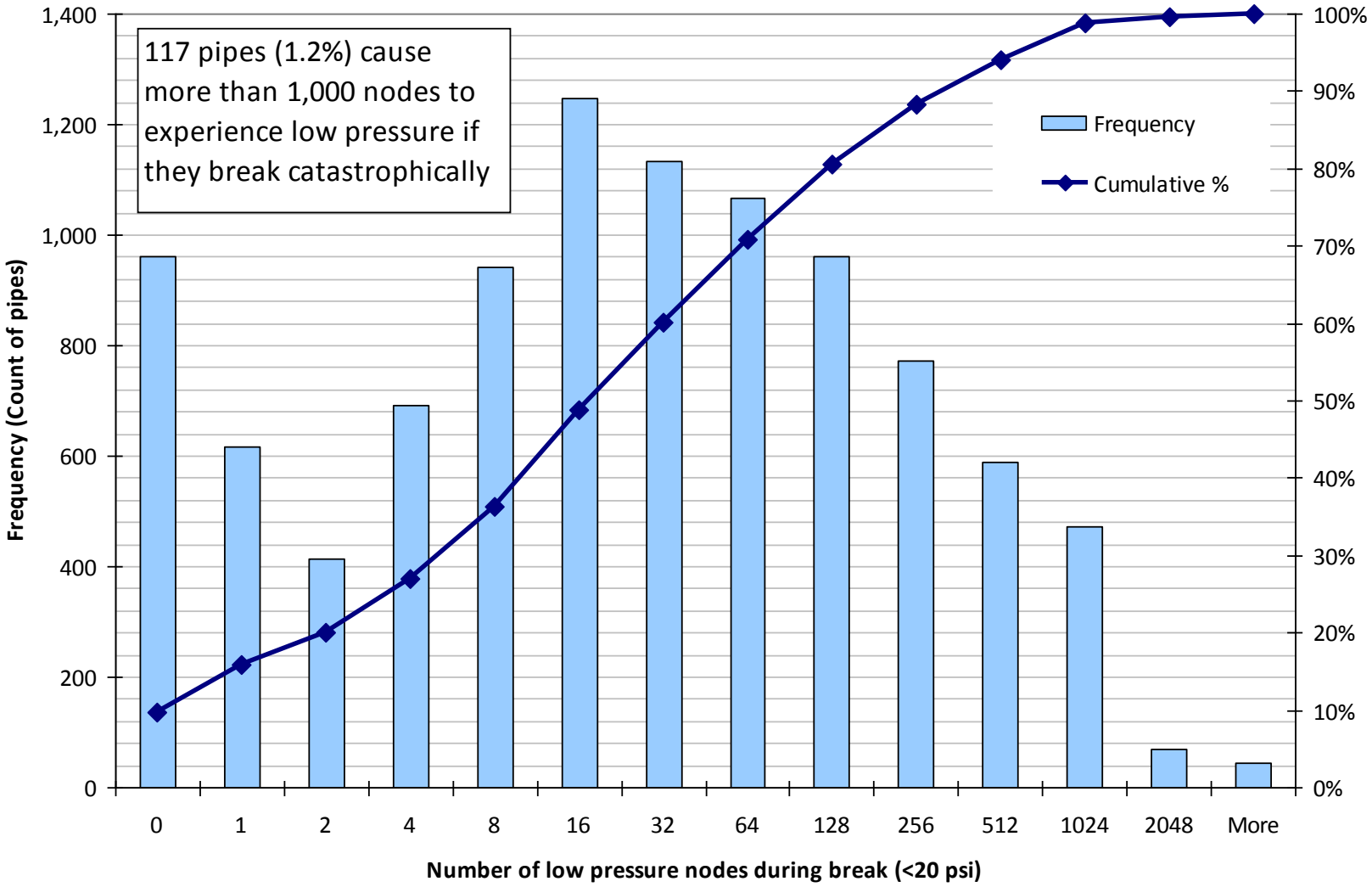


St Charles Medical Center

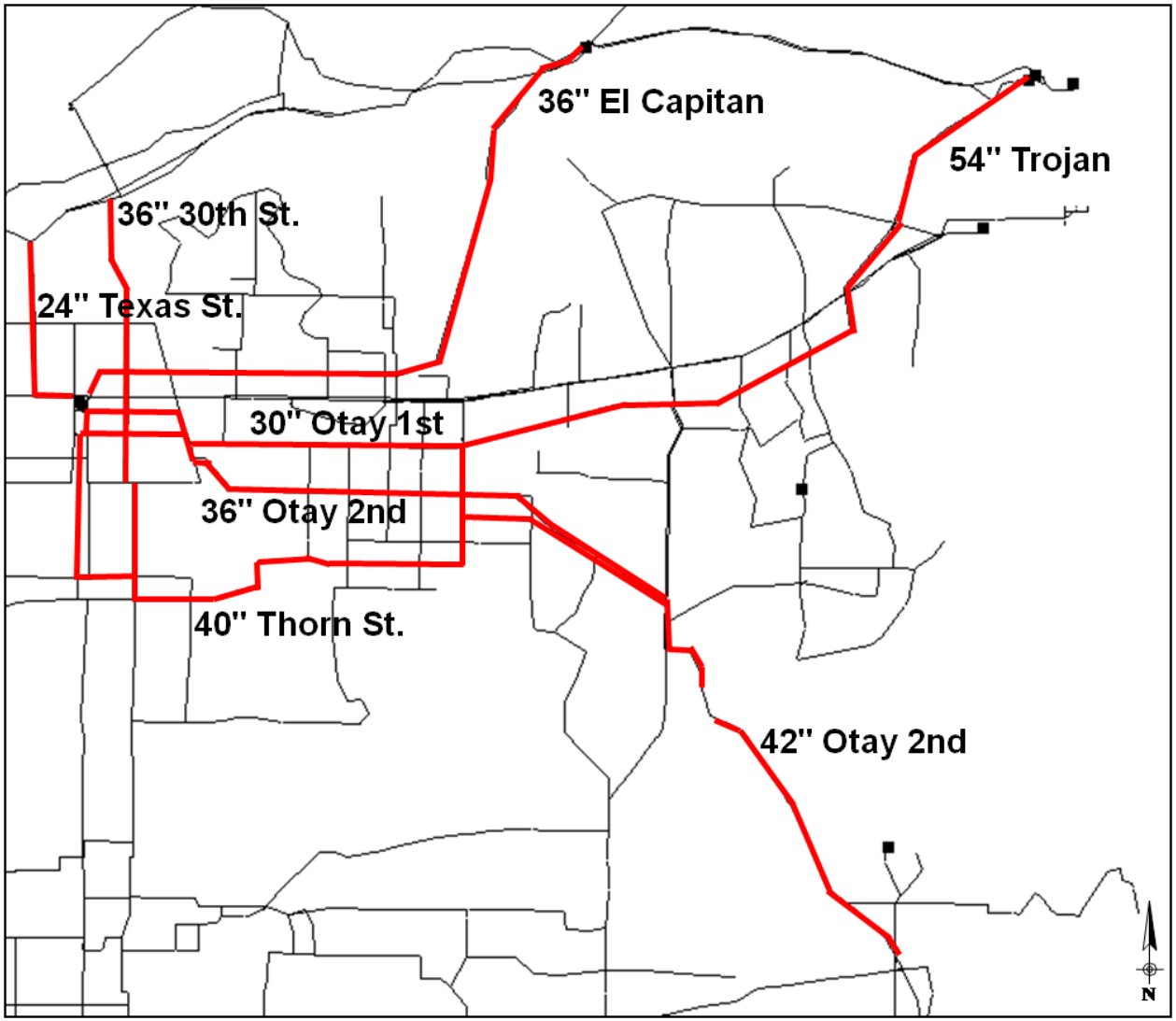


Deschutes Brewery

Low System Pressure during a break



San Diego Water Mains Replacement

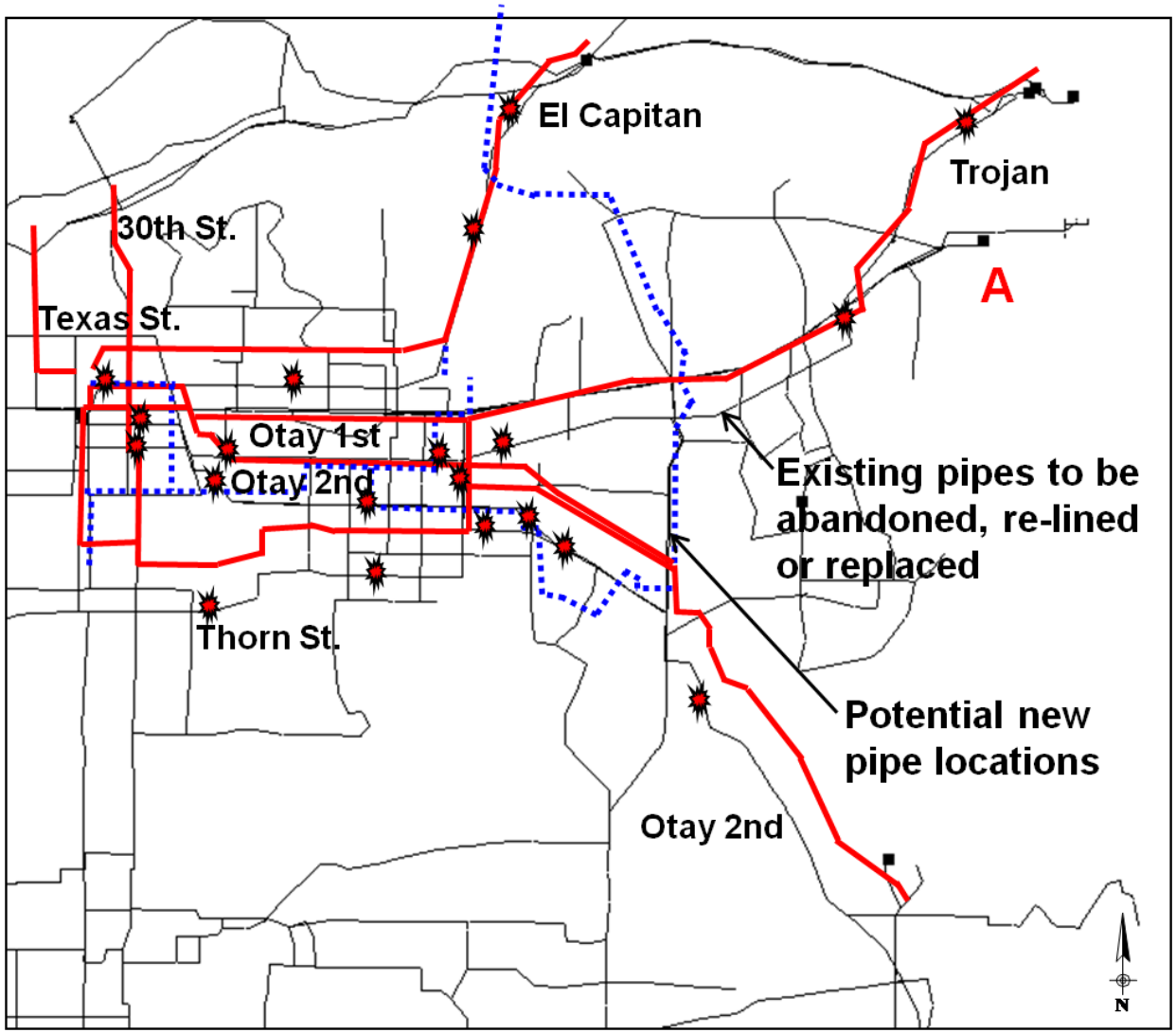


Major Mains Example

By 2030, seven major mains require rehab or replacement

Minimize capital improvement costs while meeting strict redundancy criteria.

Optimizer WDS™ to Size Replacements



Aging transmission mains

26 miles of 24” – 54”

New pipe choices

10.5 mi
(inc. interconnects)

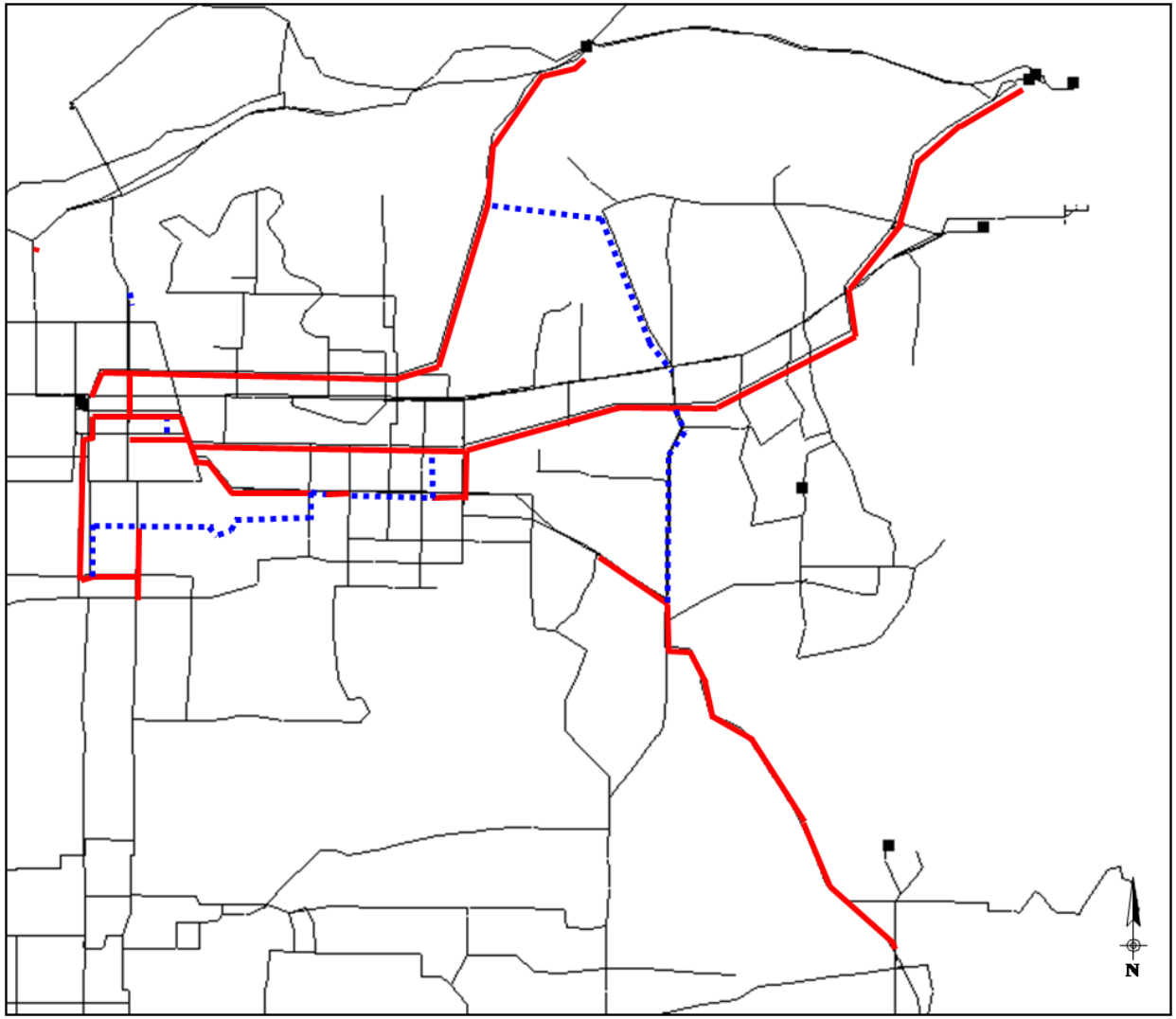
2030 peak hour

Redundancy cases

20 main break locations

Aqueduct supply outage at **A**

$35.3M vs. $55M: 36% Cost Savings



Optimized Solution

16.1 mi pipe replaced
1.8 mi. pipe relined
7.8 mi abandoned
5.3 mi new pipe

Capital cost savings of $19.7M (or 36%)

Optimized solution meets redundancy criteria; replacement solution does not

Seasonal Operations Optimization

Optimization Goals

- Minimize energy costs
- Summer: Maximize surface water use
- Winter: Improve reservoir turnover
- Make best use of existing infrastructure

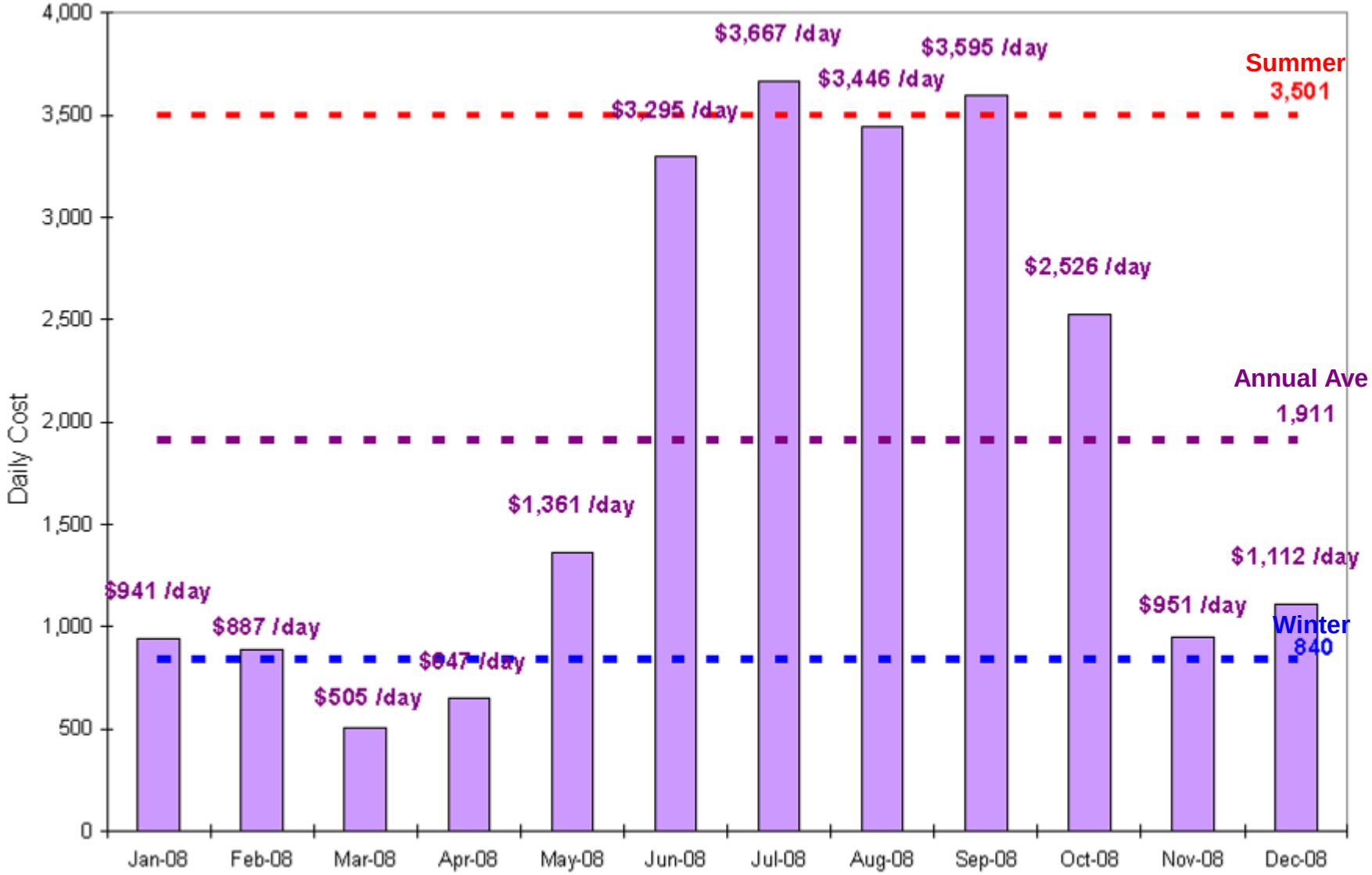
- Operations and Planning staff involved in review of proposed recommendations

Review of Past Annual Power Costs

Year	Average Annual Daily Production (MGD)	Pacific Power Costs[1]
2006	11.55	$660,000
2007	13.84	$740,000
2008	12.84	$700,000

1) Represents the sum of charges under four accounts: water delivery pumping systems, watershed surface water, water wells and water production disinfection. Includes all charges (energy and demand/load size).

System-wide daily costs by month – 2008

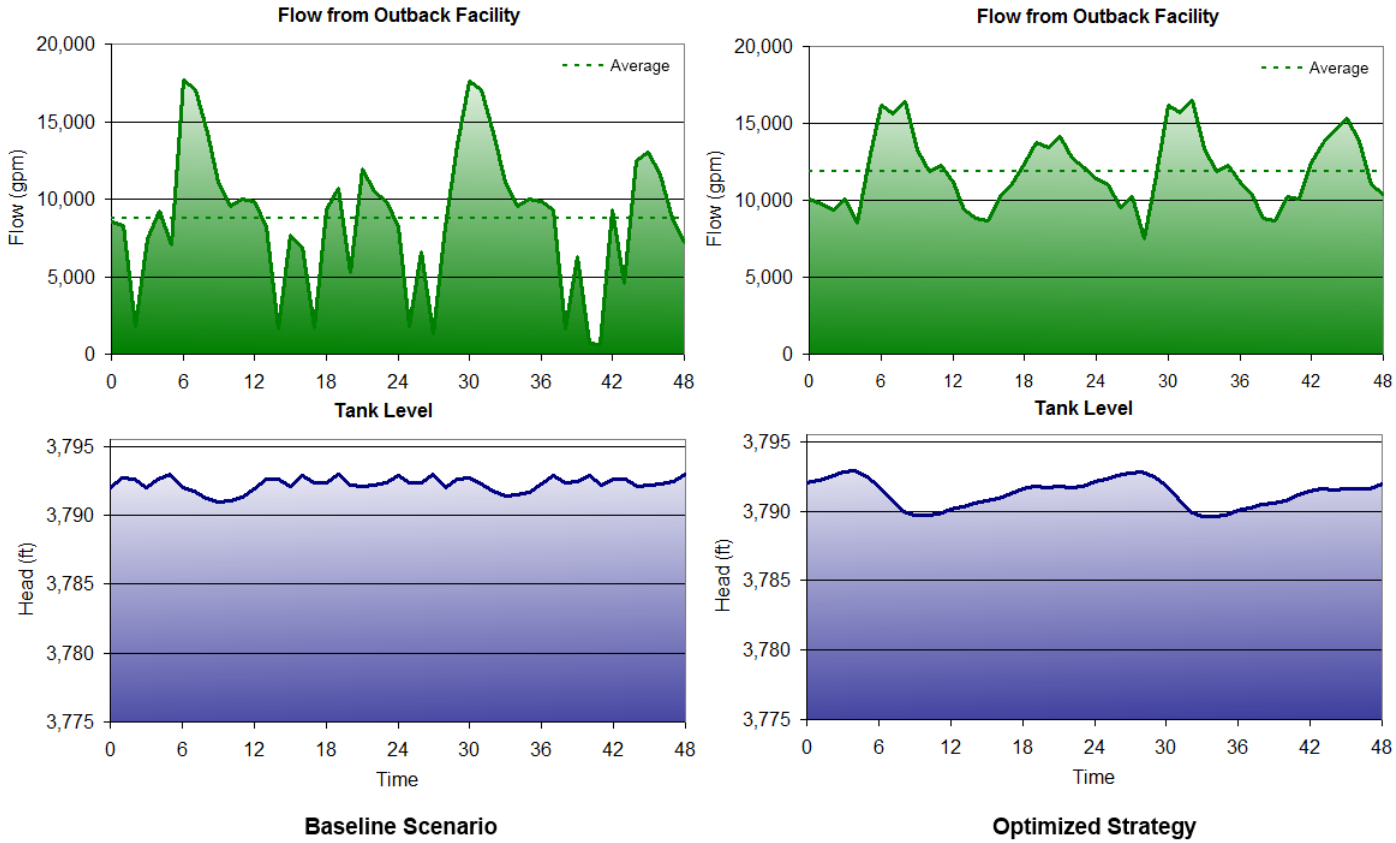


Formulation – Options

- Selection of which facilities to operate
- Adjustment of pumping controls
- Adjustment of control valve settings
- Modifications to zone boundaries
- Elimination of small sub-zones
- Minor capital improvements
  - Pipe connections
  - New booster pumps

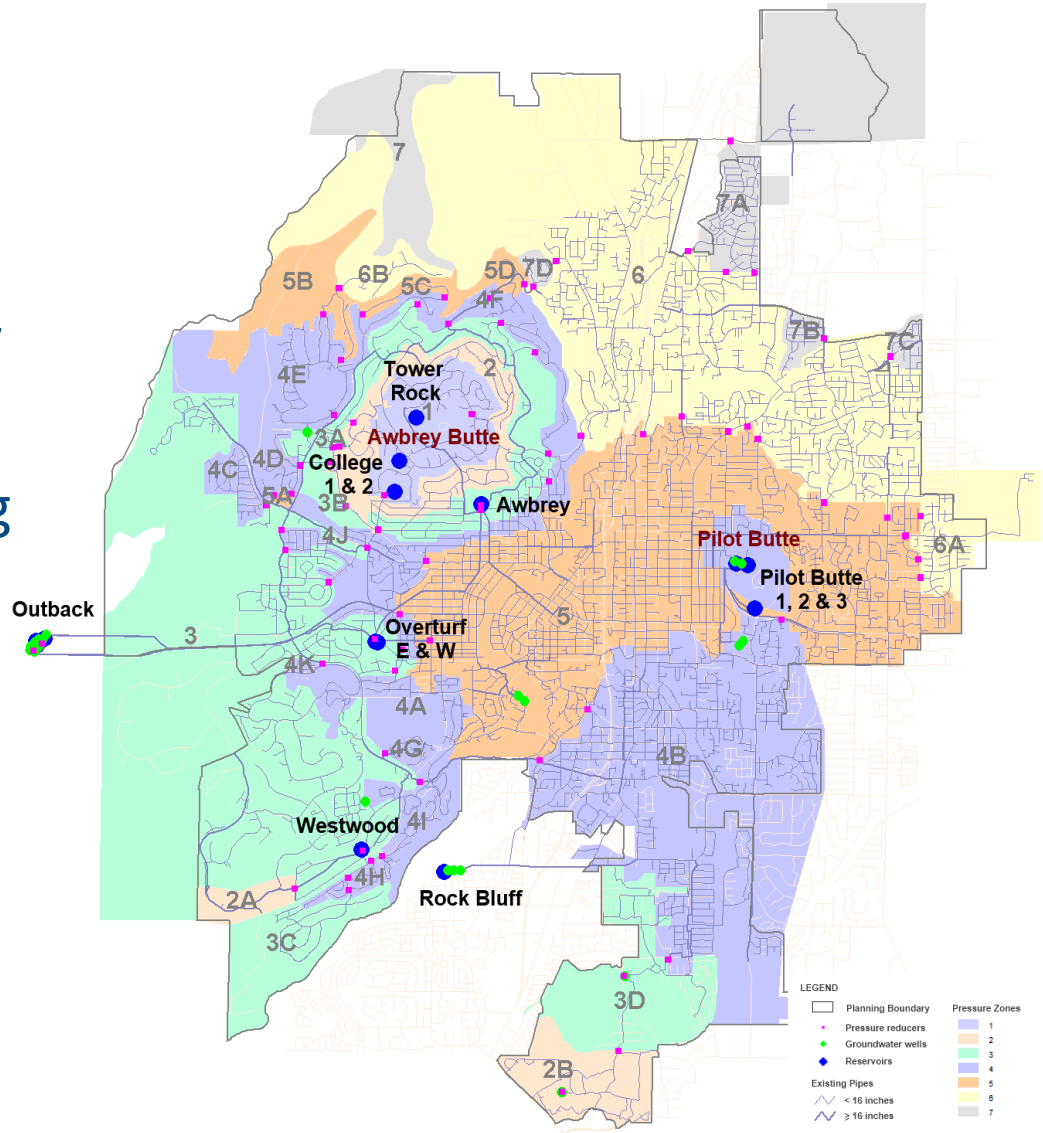
Summer – Recommendations

- Increased transmission, adjusted flow into Awbrey Reservoir



Summer – Recommendations

- Transmission and Supply
  - Increased surface flow from west to east
  - Reduced well pumping
  - Utilization of booster pumps to transfer supply



Summer – Cost Savings

Estimated Costs	Baseline	Strategy #1 (Long-term)	Strategy #2 (Short-term)
		River Wells	No River Wells
Annual	$378,000	$290,750	$289,340
Daily	$1,895	$1,458	$1,451
Savings		**23 %**	**23 %**

Costs represent estimated annual energy costs for key water facilities only, using $0.05/kWh. Do not include other power costs such as demand charges/load size charges or costs associated with reservoirs, valve stations, buildings, disinfection, etc.

Optimatics

optimizing water systems

Thank You