Optimatics

optimizing water systems

Optimized Decision Support Approach Ensures Best Use of Funds for City of Bend Water Improvements

PNWS-AWWA 2011, Boise, ID
Friday May 6

Introductions

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The City of Bend

- Central Oregon, east of Cascade Mountains
- Population of 81,000
- Explosive Growth from 1990 to 2005
- City serves approximately 62,000 residents
- Water and wastewater services

The City of Bend – Water Supply

- Surface water
  - Collected 13 miles from the City limits
  - Delivered to system via the Outback facility

- Groundwater
  - Extracted from 25 wells at nine locations spread across the City

The City of Bend - Water System Facts

- 15 finished water storage reservoirs
- 6 booster pump stations
- 420 miles of mains
- 7 primary pressure zones, many sub-zones

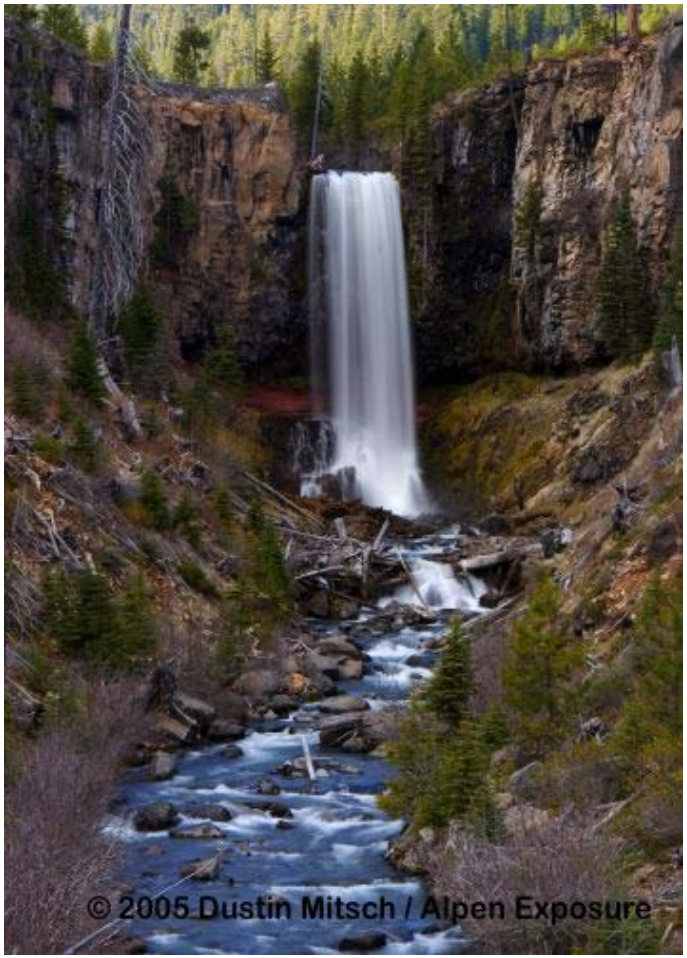
Outback Reservoir

Outback Well

Scott Street Pump Station

Bend & Optimization

- Coordinated Water Management and Conservation Plan and Water Master Plan in 2004
  - Good WMCP, weak WMP
- New WMP Update in 2006-07
  - good WMP, more work needed
  - poor data available to consultants
  - many inputs from City not coordinated with operations



Why Optimatics vs Traditional Modeling?

- Economic crisis in 2007 = tighter budgets to perform work (SDC funds especially hard hit)
- Need a defensible, comprehensive decision making tool to defend expenditures (to stand up to public scrutiny and all what if scenarios)
- Goals
  - Prioritize needed CIP work
  - Reduce expenditures for future system improvements
  - Understand how the system performance changed under dynamic conditions

Study Scope

- Bend Water System Master Plan Update Optimization Study
  - Pipe Criticality Analysis
  - Typical Summer & Winter Operations
  - Build-out Master Plan Optimization

Pipe Criticality Analysis

Consequences of Pipe Failure

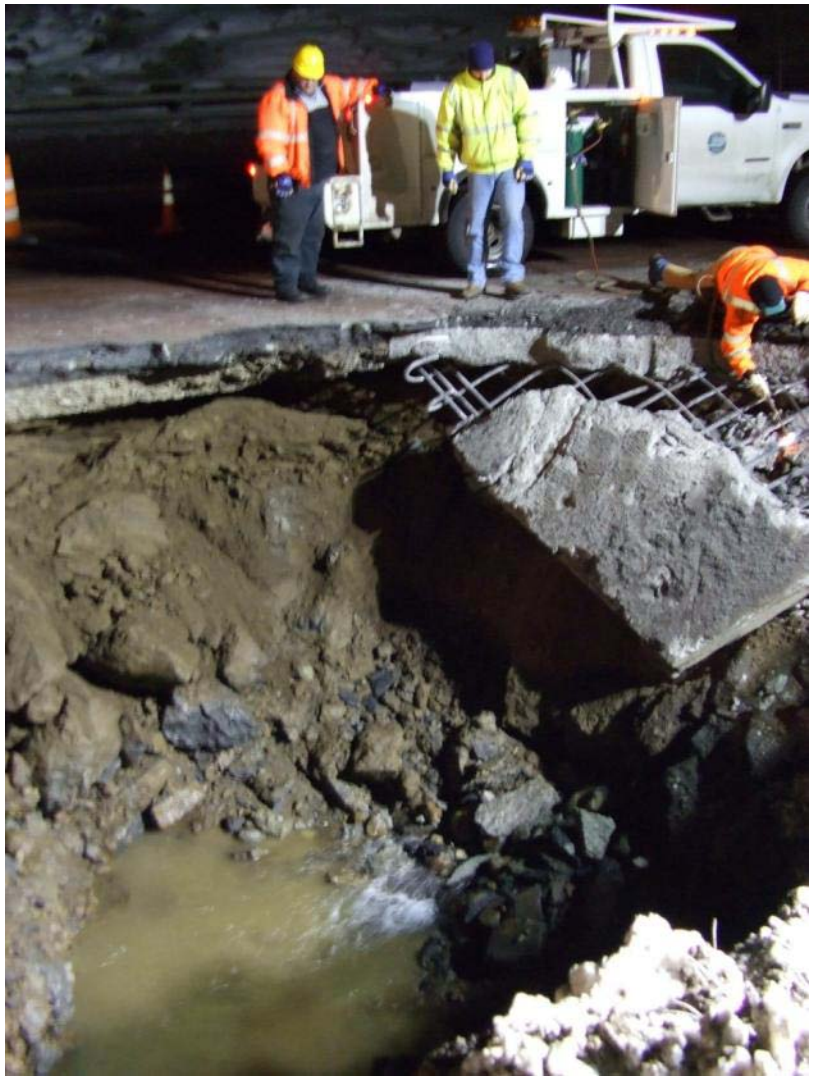
- Potential impacts include
  - Reduction in system pressure
  - Reduced fire fighting capacity
  - Loss of supply to critical customers, medical facilities, dialysis machines
  - Property damage
  - Traffic disruption
  - Safety of public and City personnel
  - Harm to reputation

Pipe Criticality Analysis – Objectives

Determine where system is vulnerable to

a) Pipe break events

b) Isolation of a pipe for repair



Pipe Criticality Analysis – Objectives

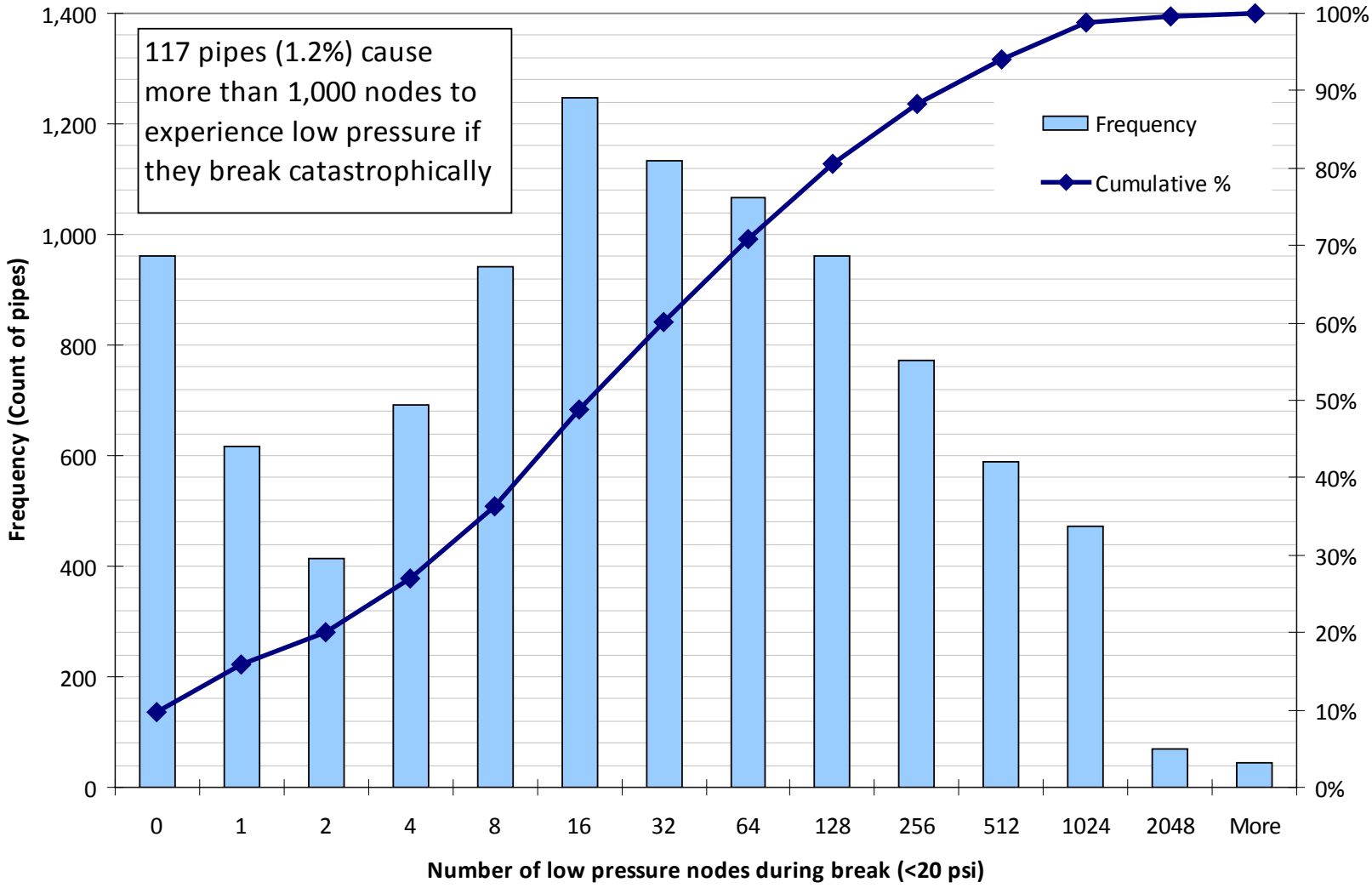
- Prioritize areas based on the relative impact of break or isolation events
  - Provide operators with an understanding of higher risk areas
  - Identify improvements to reduce impact

Pipe Criticality Analysis

- Most important metrics for Bend:
  - loss of supply (number of customers affected)
  - hydraulic performance (low pressures)
  - maintenance (valves required to isolate a break)

- Bend system has not experienced problems related to water discoloration due to excessive velocities or reverse flows

Low System Pressure during a break



Prioritization

Rank areas based on consequence of failure

Priority Number	Location	Affects St. Charles Medical Center	Affects Brewery	Low system pressure during break	# Customers isolated during break or isolation
1	Zone 5 - Medical Center	✓		✓	✓
2	Zone 5 - Key Customer		✓	✓	
3	Zone 4B - North			✓	
4	Zone 3 - South			✓	✓
5	Zone 3C			✓	✓
6	Zone 4B - South			✓	
7	Zone 3 - North				✓

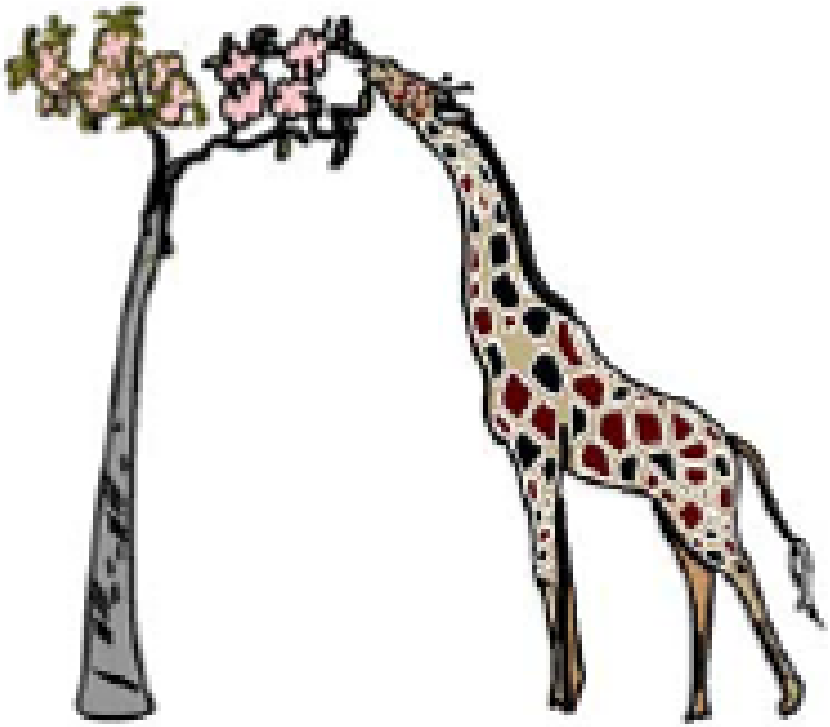
Optimization applied to Water Systems for Planning and Operations

Managing a Water Utility is Complex

Genetic algorithm optimization

Evolutionary search

Only the fittest solutions survive



Genetic algorithm optimization

Objective ?

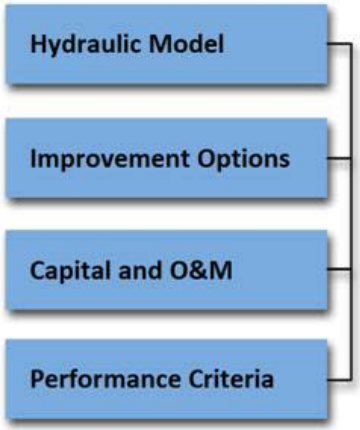
Decisions ?

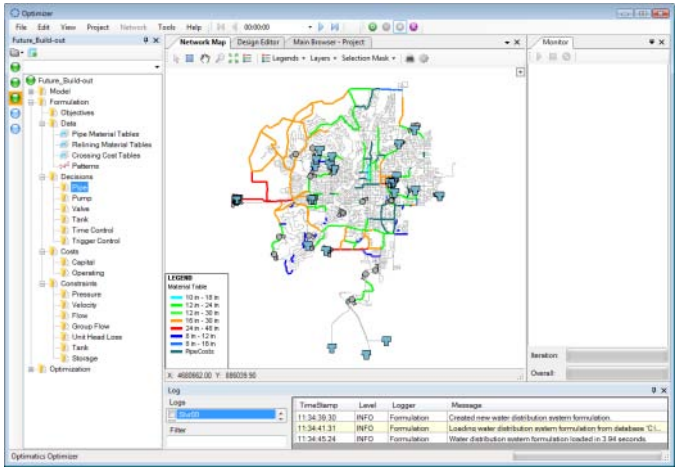
Options ?

Constraints ?

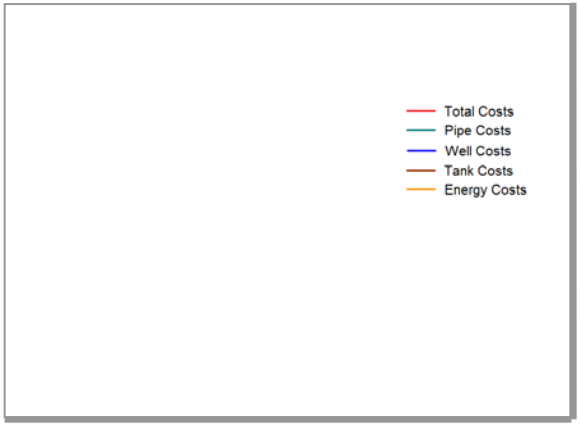
Near optimal solutions…

Options Analysis Process





Optimizer WDS User Interface



Optimization Progress

Sensitivity Evaluations

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

Seasonal Operations Optimization

Seasonal Operations Optimization

- Bend system operation varies significantly throughout the year:
  - Summer
    - Mixture of surface and groundwater supply
    - Base scenario: Calibrated July 2009 model
  - Winter
    - Primarily surface water supply
    - Base scenario: January 2009 model

Optimization Goals

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

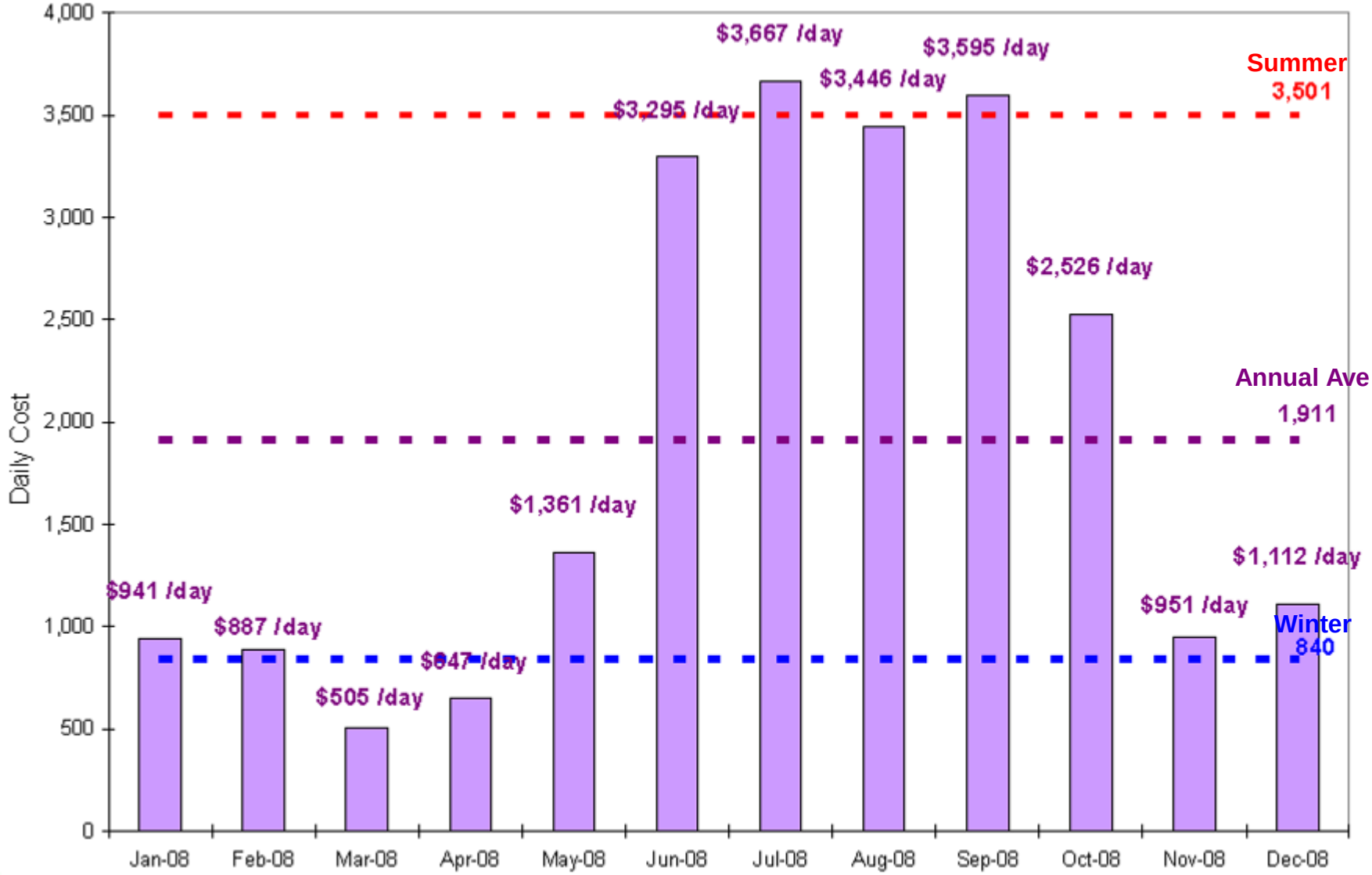
- Operations and Planning staff involved in review of proposed recommendations

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

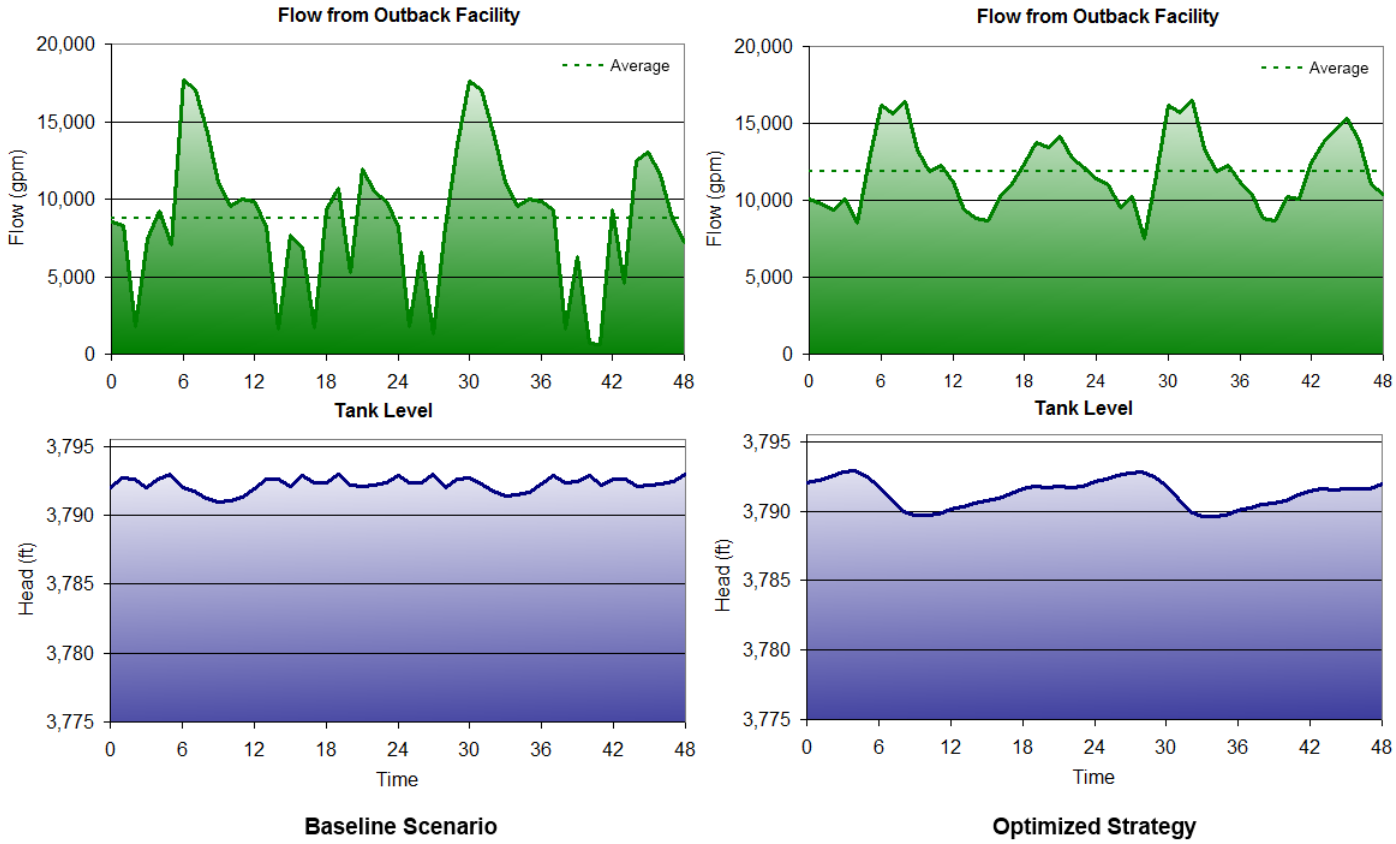


Formulation – Options

- 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

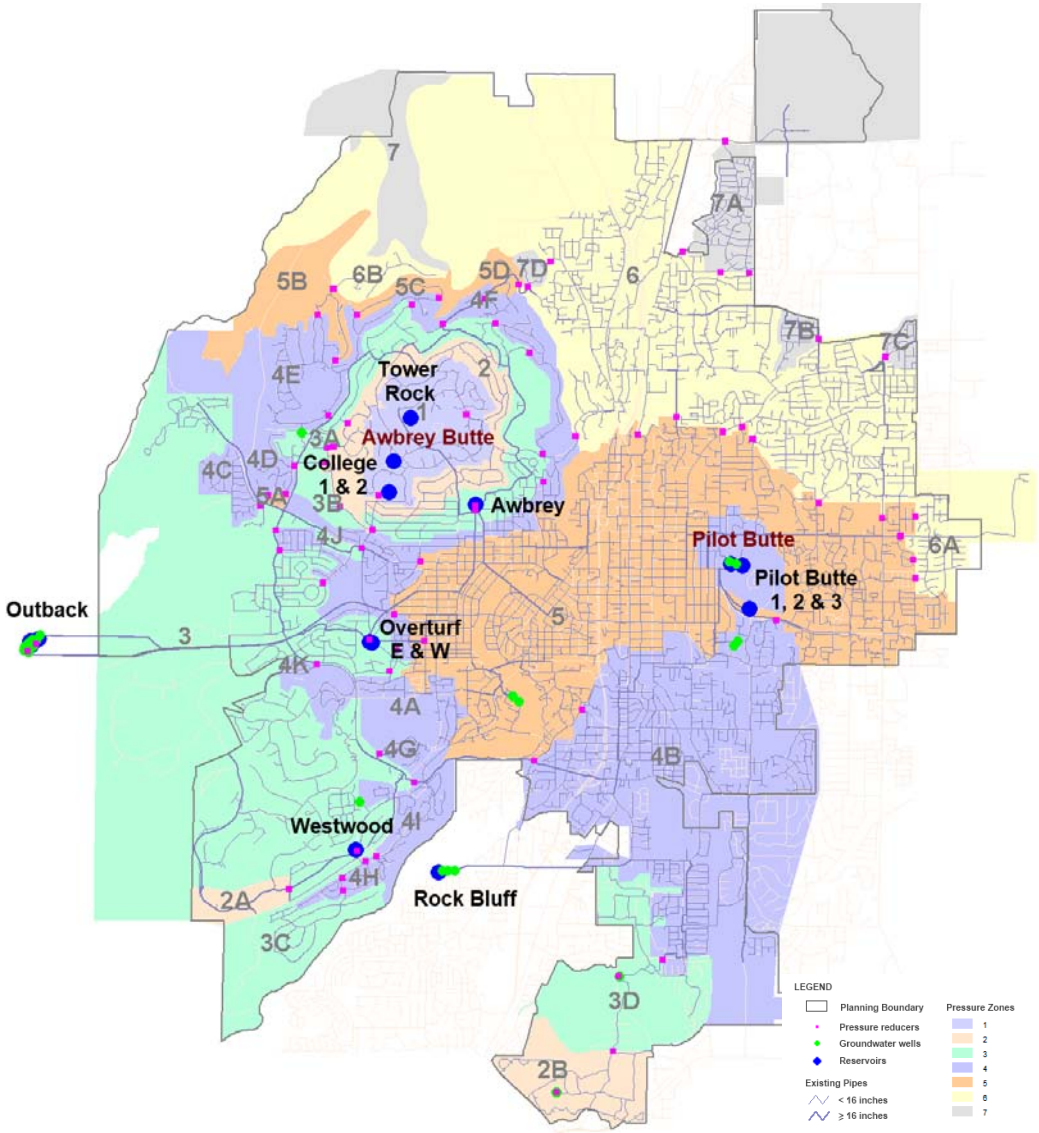
Summer – Recommendations

- Increased transmission volume, 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.

The Columbian

Study: Bend may save up to 67 percent on energy

Monday, November 29, 2010

More like this

Insurer won't cover damage from city pipe bursting

Vancouver to consolidate, cut departments

Energy Adviser: Snowbirds can save electricity while away

Vancouver to merge Transportation Department; eliminate Media Services

Turkey of a Thanksgiving forecast: freezing rain

BEND, Ore. (AP) -- By turning off a few valves and adding some new pipes to Bend's water system, the city may be able to shave a couple of hundred thousand dollars off its $700,000 -a-year energy costs.

The Bulletin newspaper reports a study could reduce its wintertime energy costs by about 67 percent and its summertime costs by about 23 percent.

The study was performed by Optimatics, an international firm specializing in finding the most efficient ways to operate water systems.

The study used complex engineering formulas, and took into account things like daily energy costs for wells and pump stations, water levels in reservoirs and the amount of pressure coming through city pipes.

Build-out System Master Plan Optimization

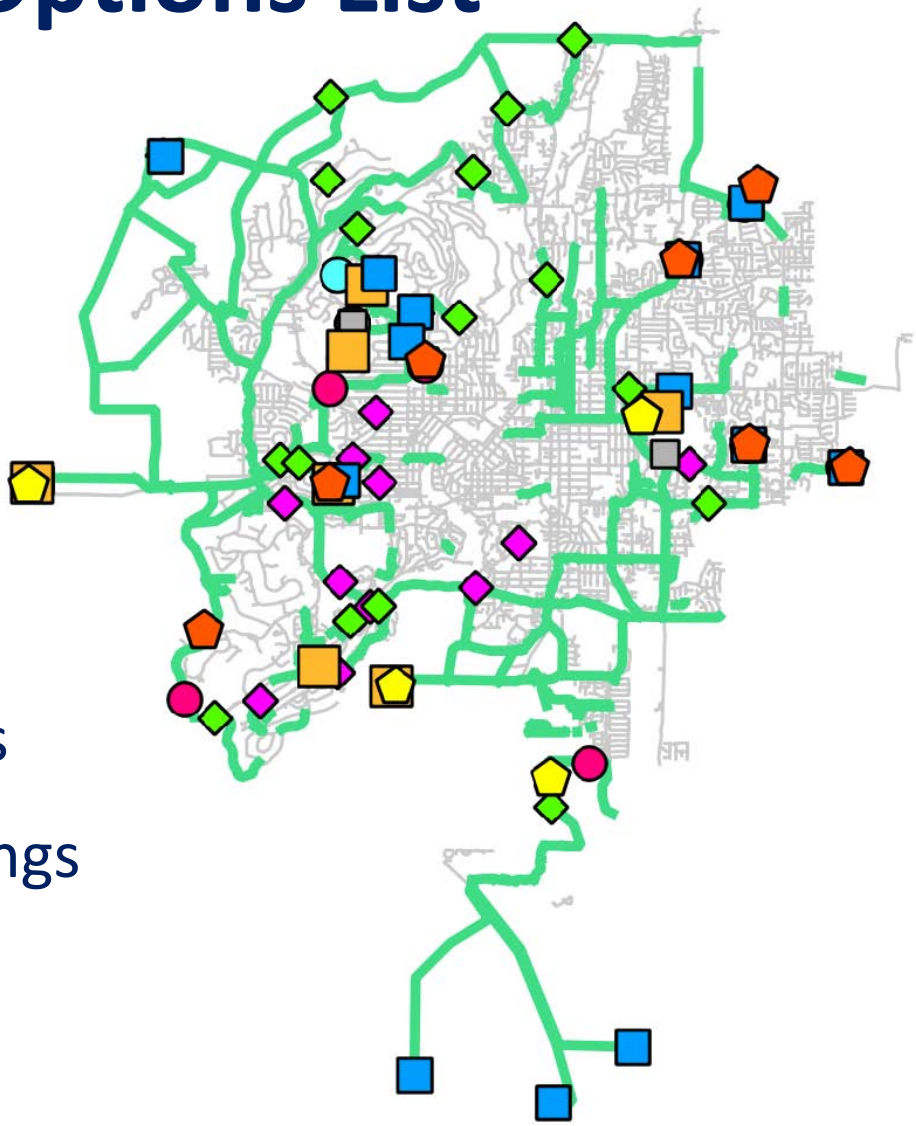
Build-out System Optimization

- Previous Master Plan updated in 2007

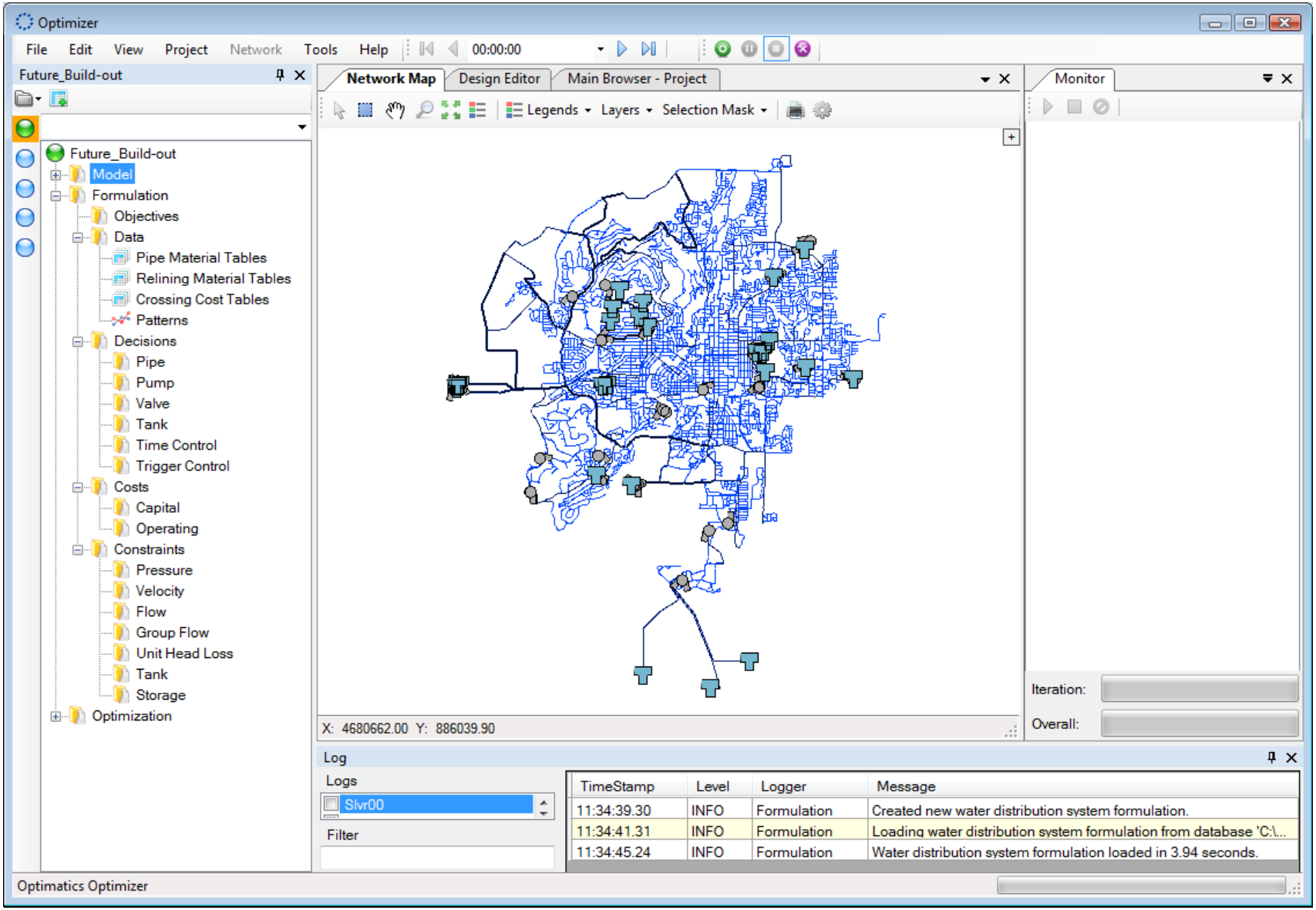
- Optimization study:
  - Updated, calibrated hydraulic model
  - Updated demand projections
  - Changes to surface water supply assumptions

A Comprehensive Options List

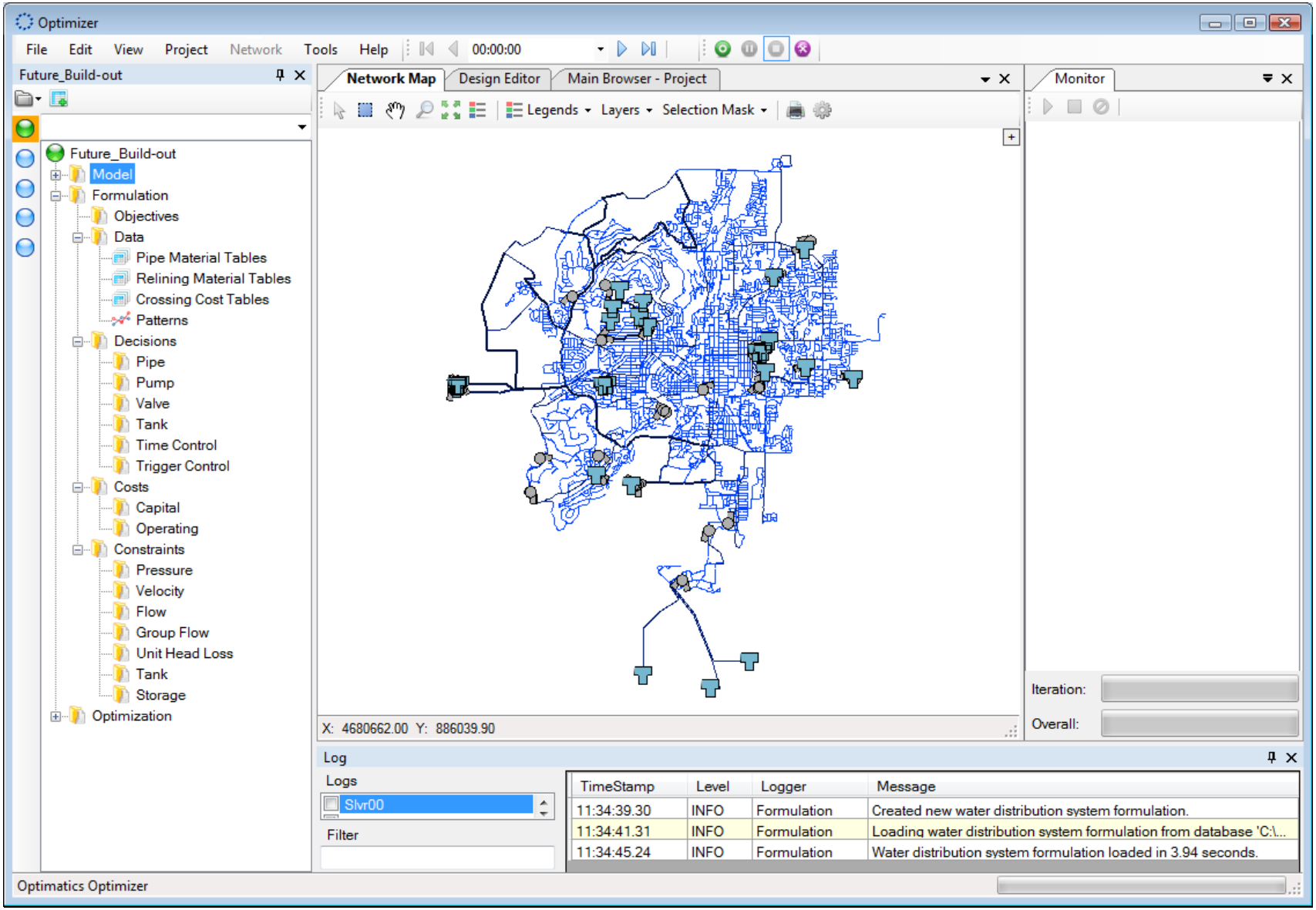
- Location of new wells to supplement surface water
- New and replacement trans- mission and distribution pipe
- New and upgraded PSs
- New and upgraded storages
- Revised pressure zone settings
- Incorporation of new development areas



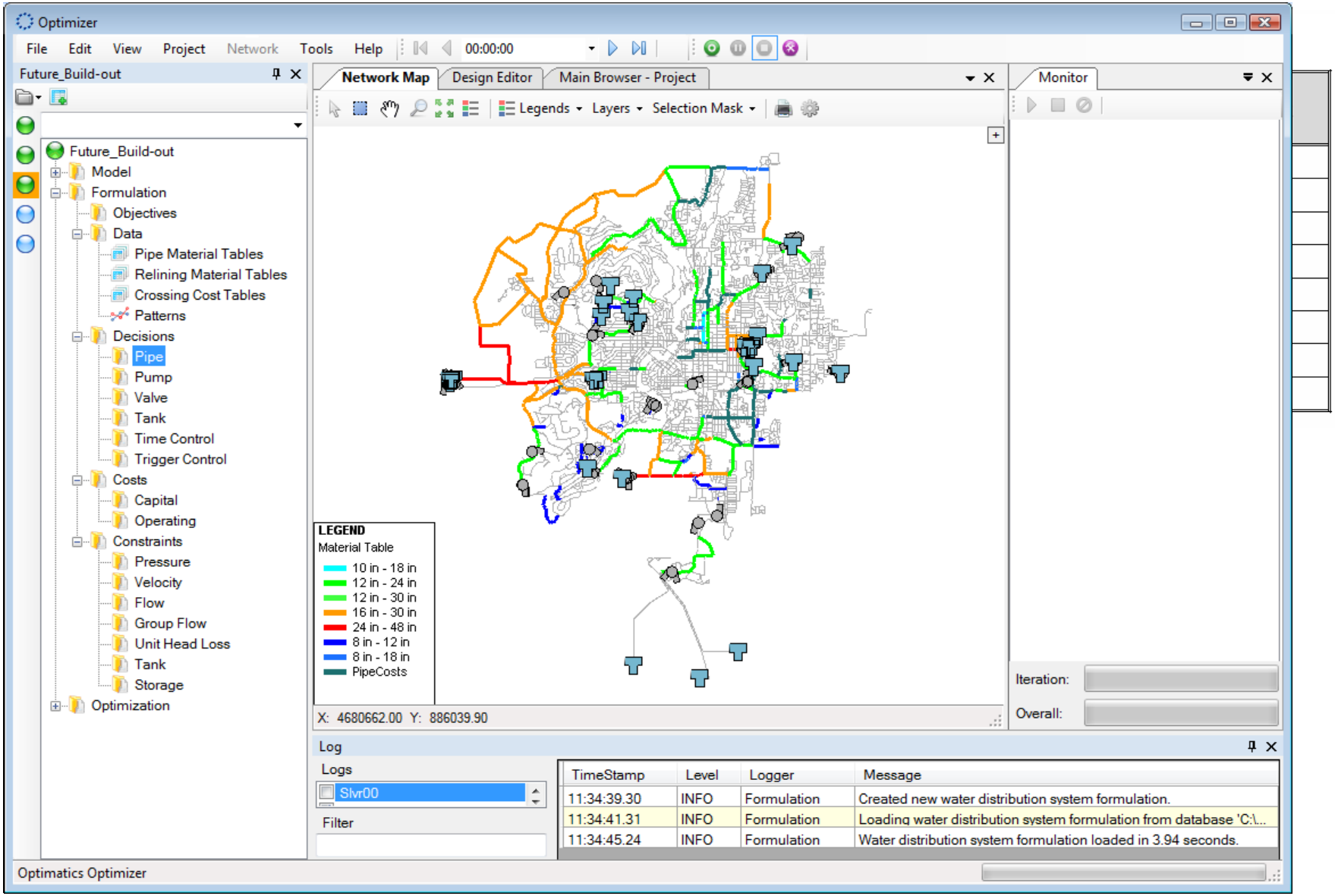
Formulate Optimization Model - ***Optimizer WDS***



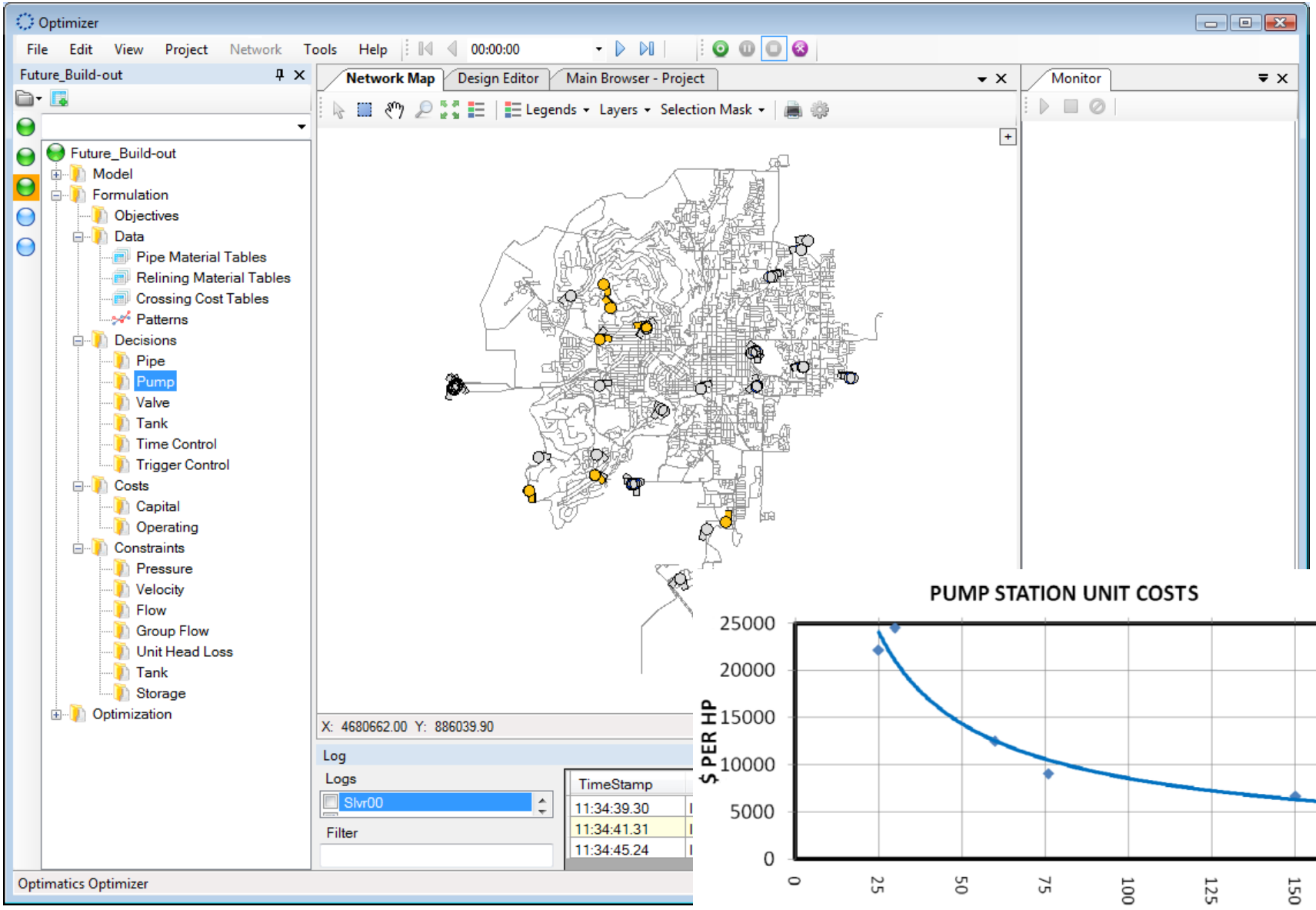
Formulate Optimization Model - *Import Hydraulic Model*



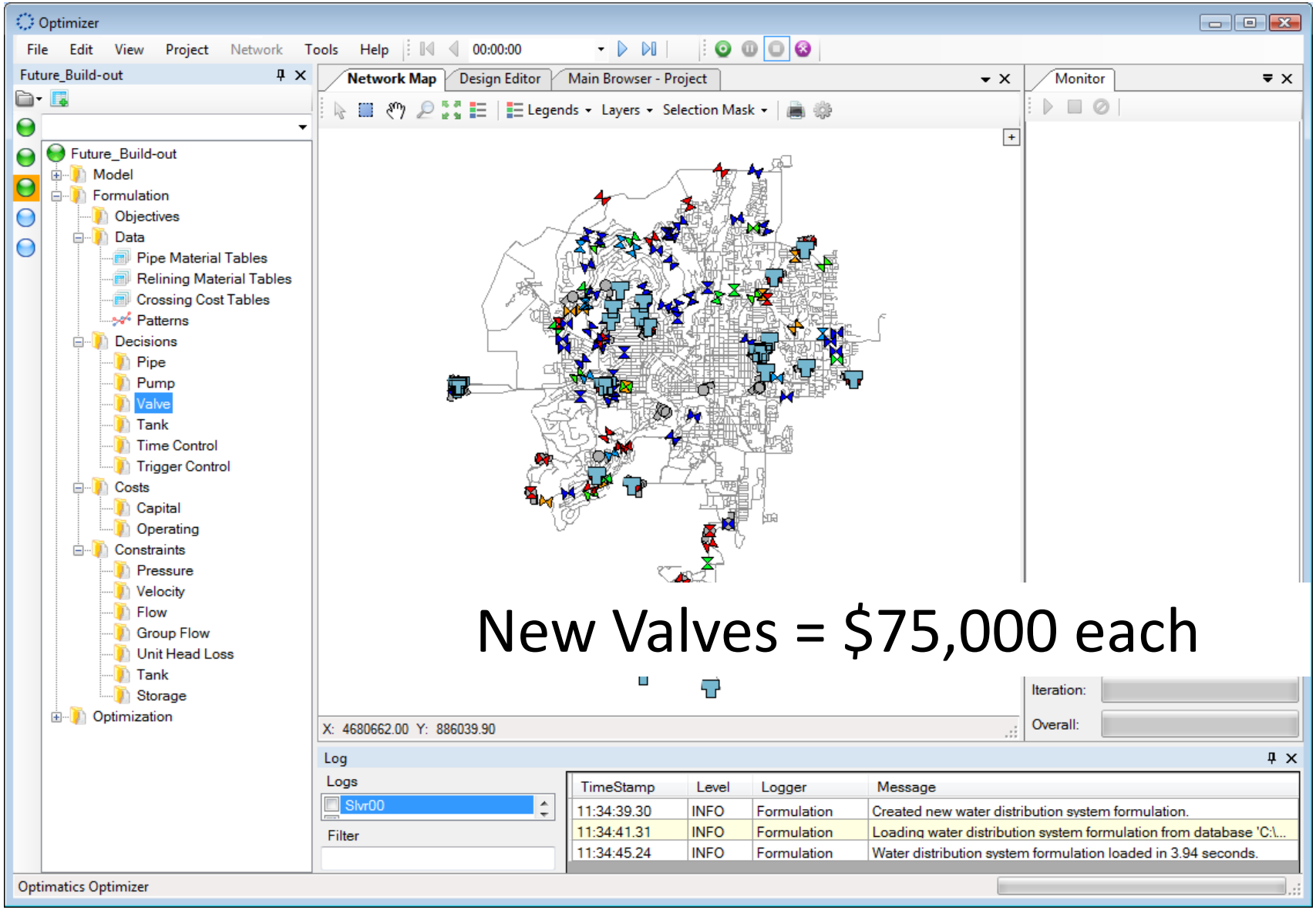
Formulate Optimization Model - *Define Pipe Costs & Decisions*



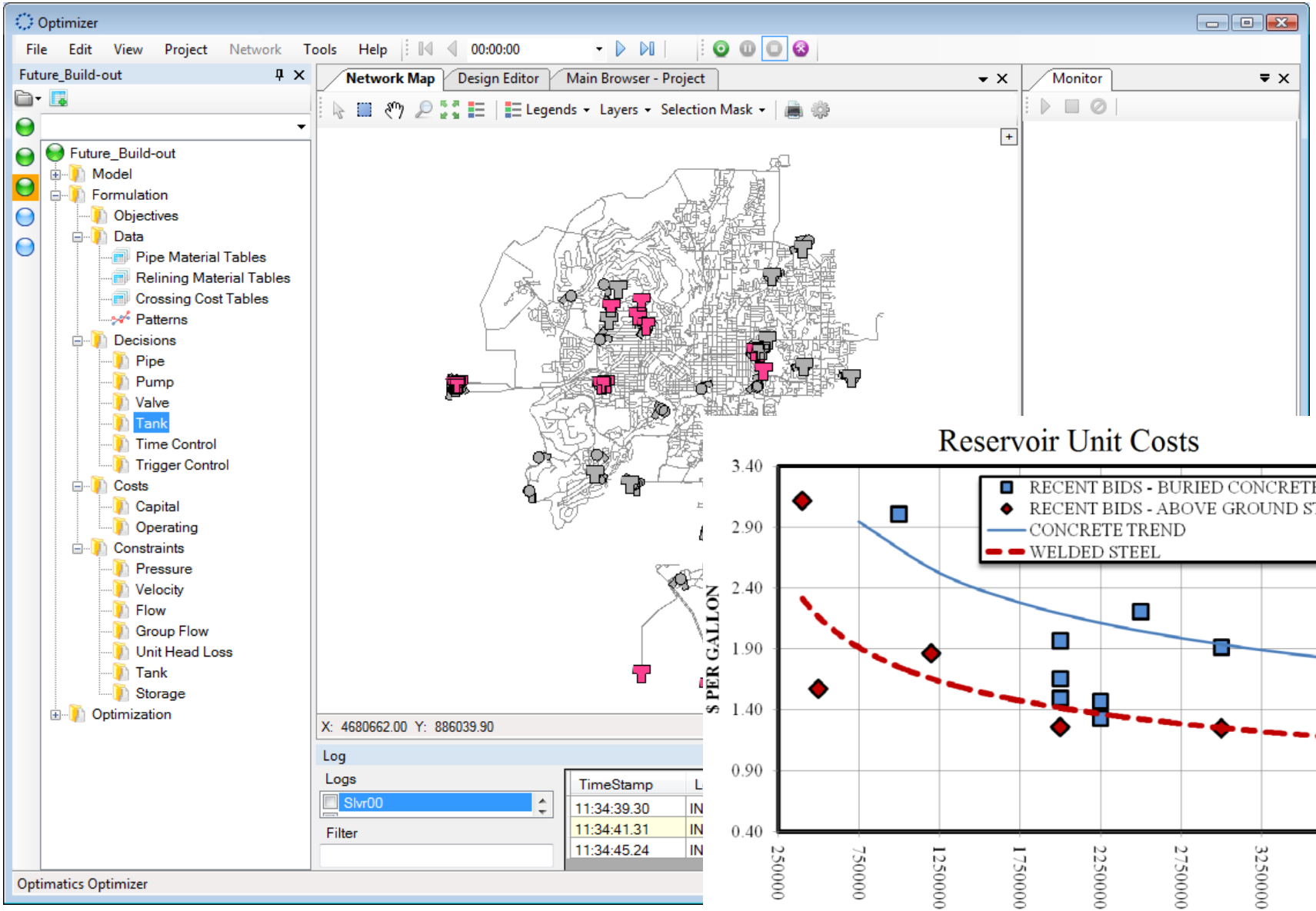
Formulate Optimization Model - *Define Pump Costs & Decisions*



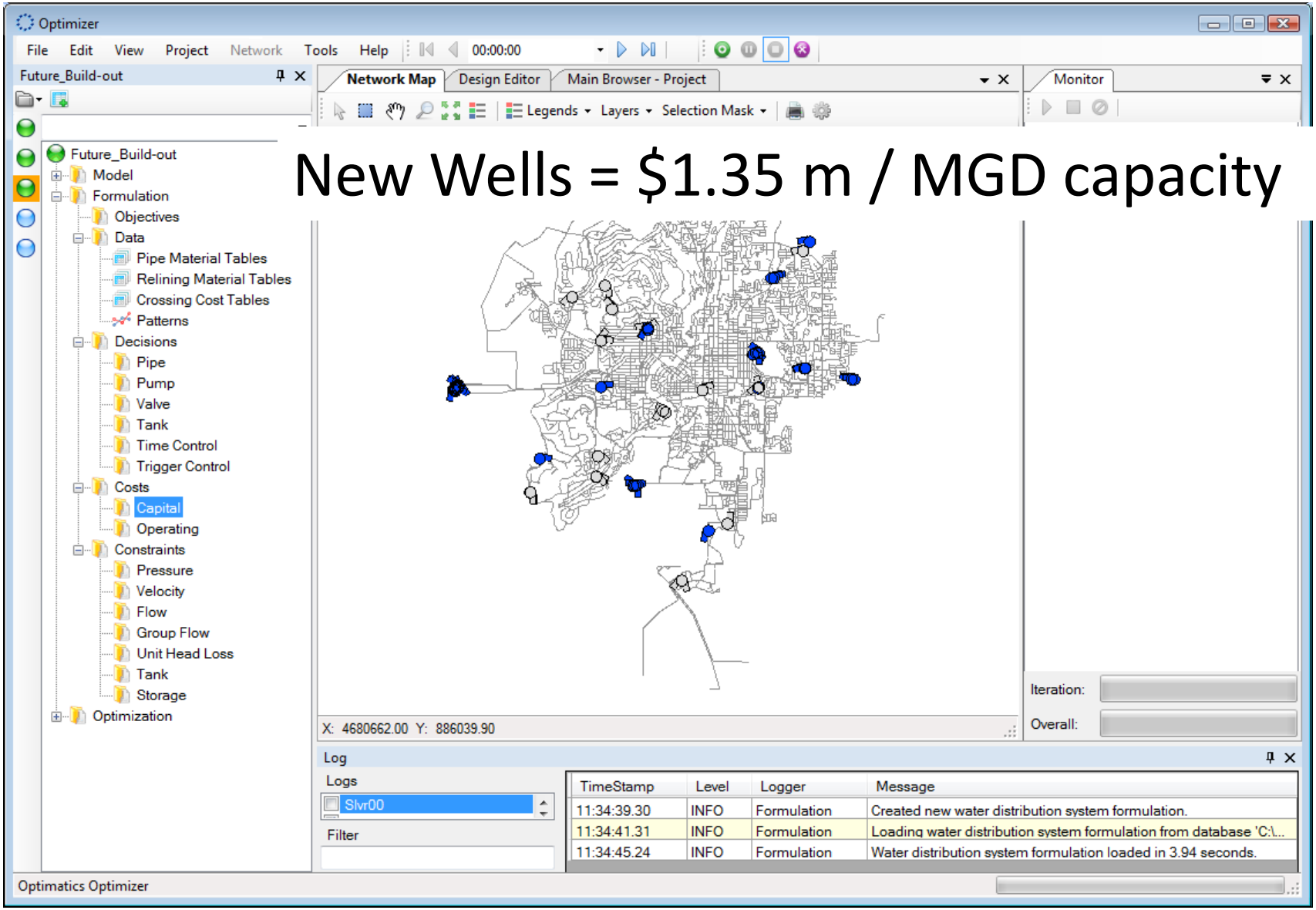
Formulate Optimization Model - *Define Valve Costs & Decisions*



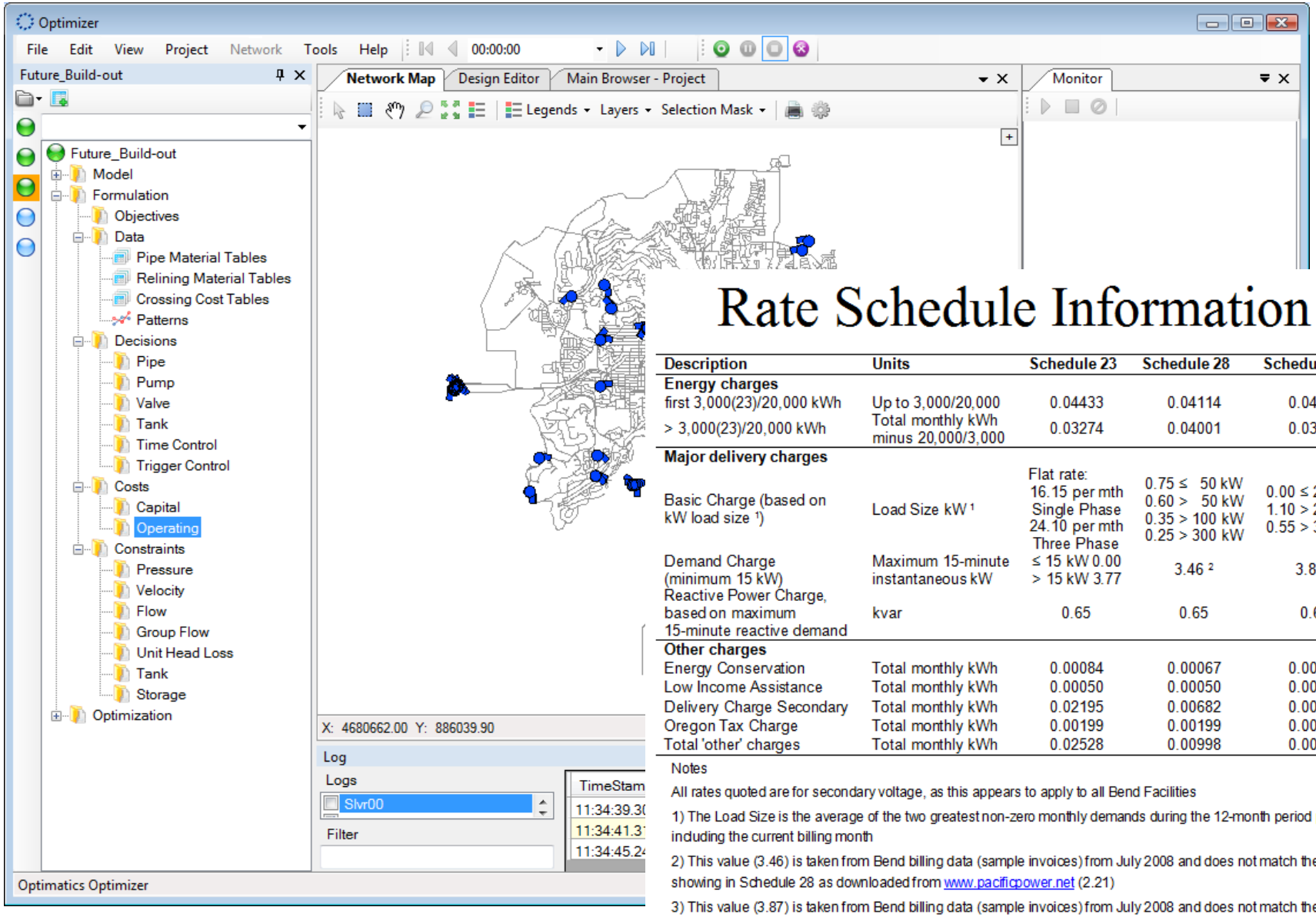
Formulate Optimization Model - *Define Tank Costs & Decisions*



Formulate Optimization Model - *Define Well Costs & Decisions*



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

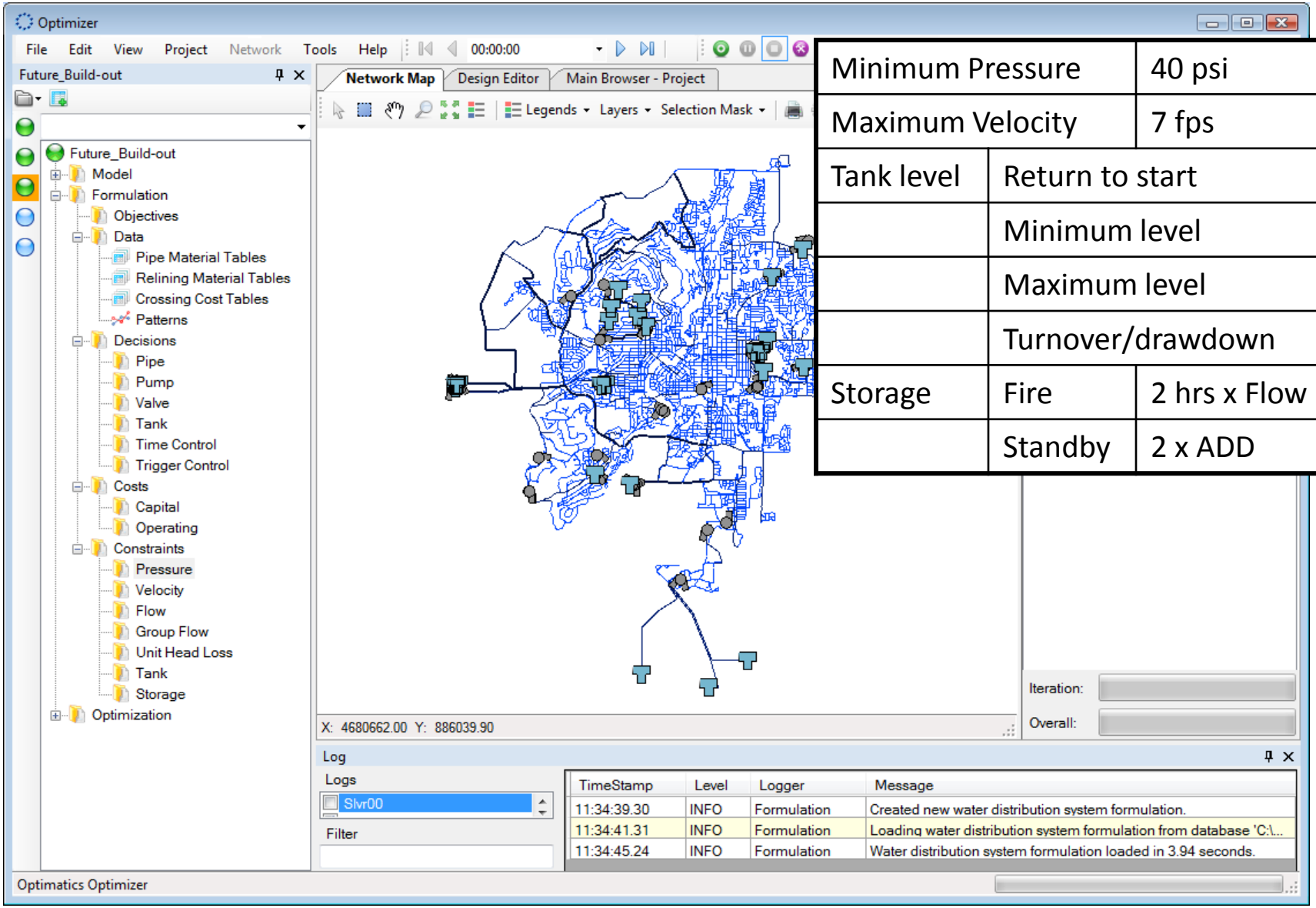
All rates quoted are for secondary voltage, as this appears to apply to all Bend Facilities

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*

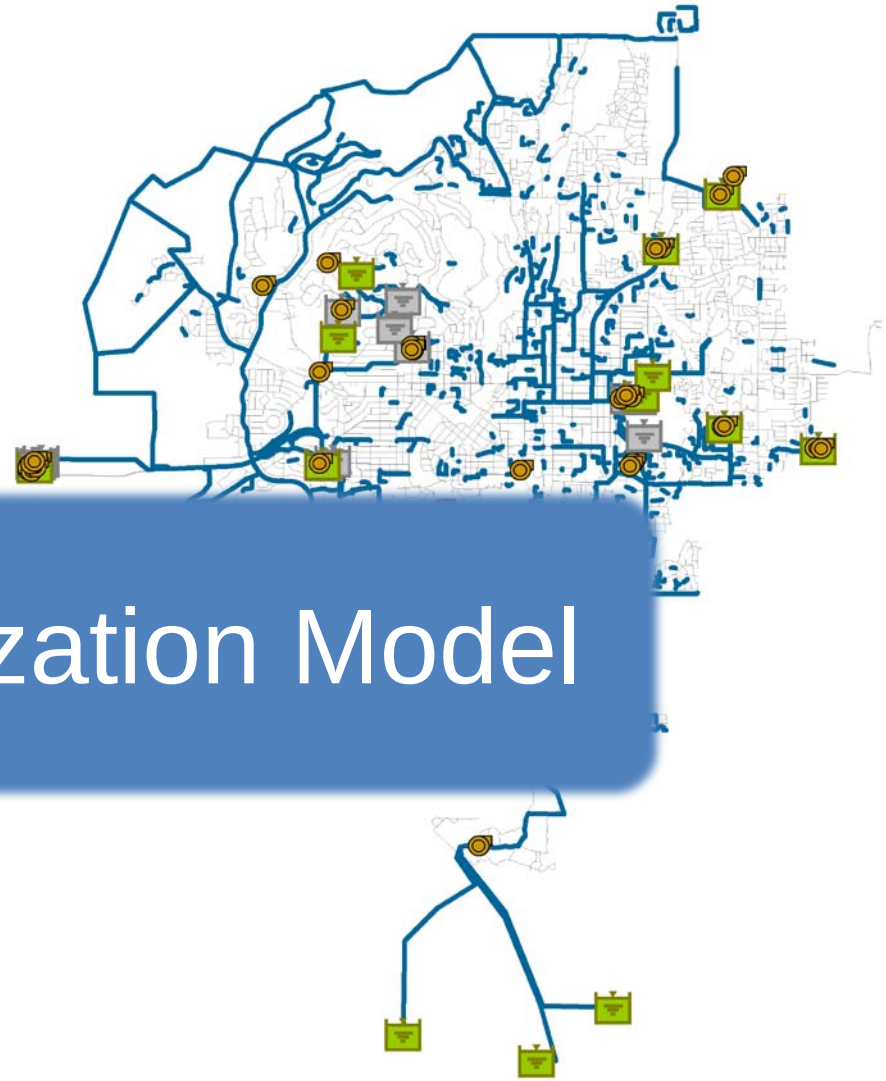


Minimum Pressure		40 psi
Maximum Velocity		7 fps
Tank level	Return to start	
	Minimum level	
	Maximum level	
	Turnover/drawdown	
Storage	Fire	2 hrs x Flow
	Standby	2 x ADD

Current Solution – Being Processed

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

- Processing 1
- Performing f
  simulations c



Run Optimization Model

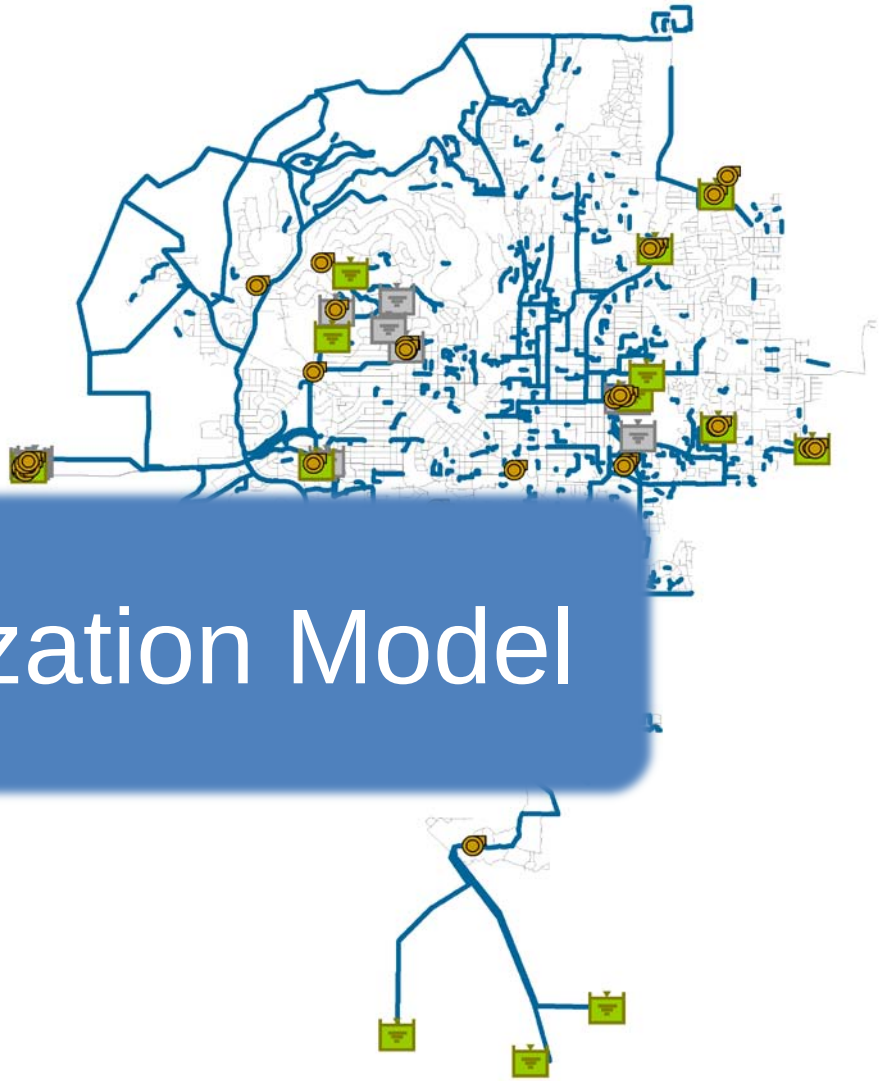
Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)	Tanks (MG)	Pump (gpm)
Existing	Existing	Existing
Decision Option	Decision Option	Decision Option

Current Solution – Being Processed

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

- Processing 1
- Performing f
  simulations c



Run Optimization Model

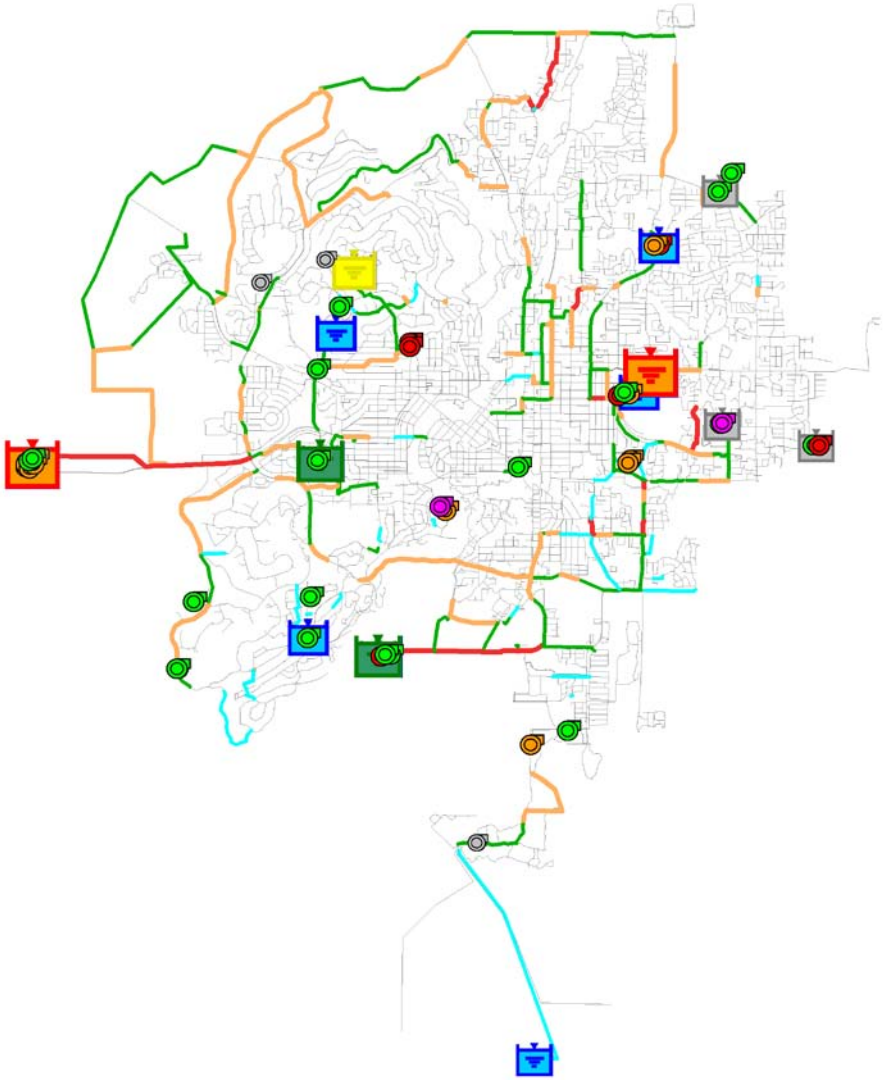
Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)	Tanks (MG)	Pump (gpm)
Existing	Existing	Existing
Decision Option	Decision Option	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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

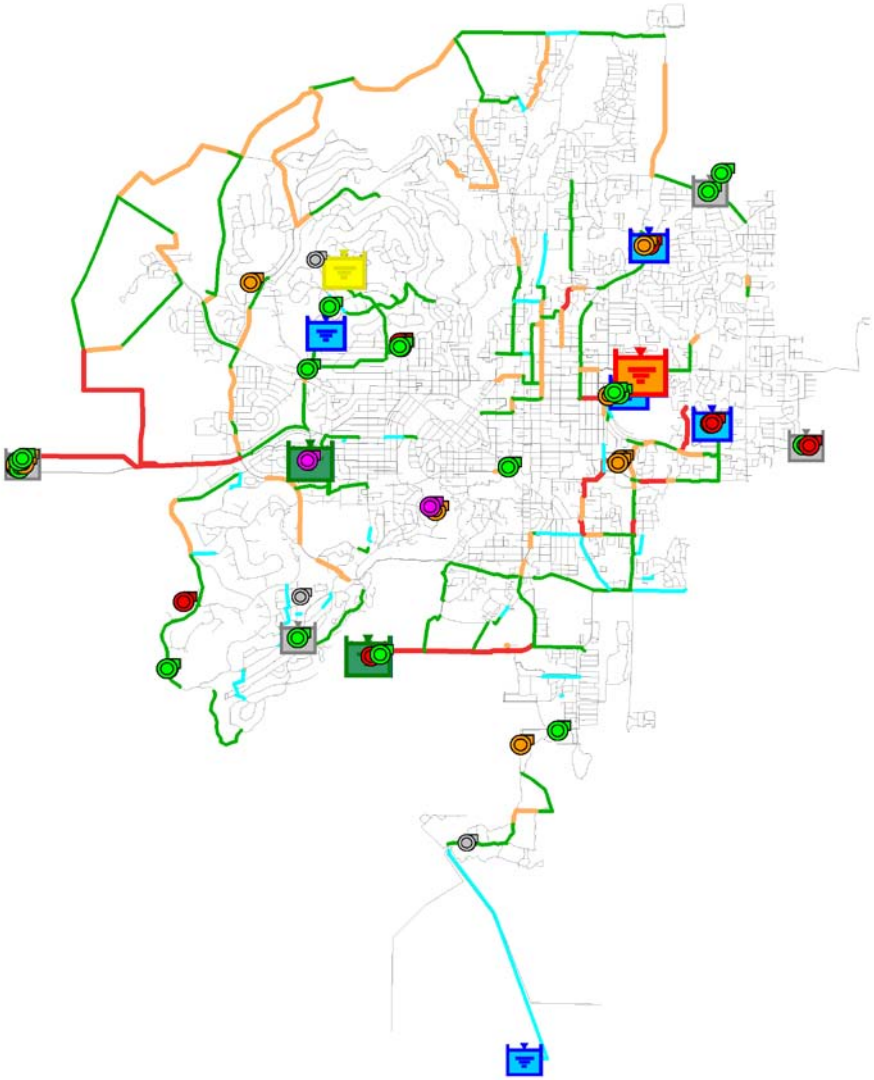
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $249.7 M

Cost Item	Total Cost ($M)
Pipes	102.6
Pumps	2.7
Tanks	39.8
Valves	0.6
Wells	76.2
Energy	27.7
TOTAL ($M)	249.7

- Best solution in 2nd generation
- Total of 400 trial solutions evaluated
- Actual processing time: 0.08 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

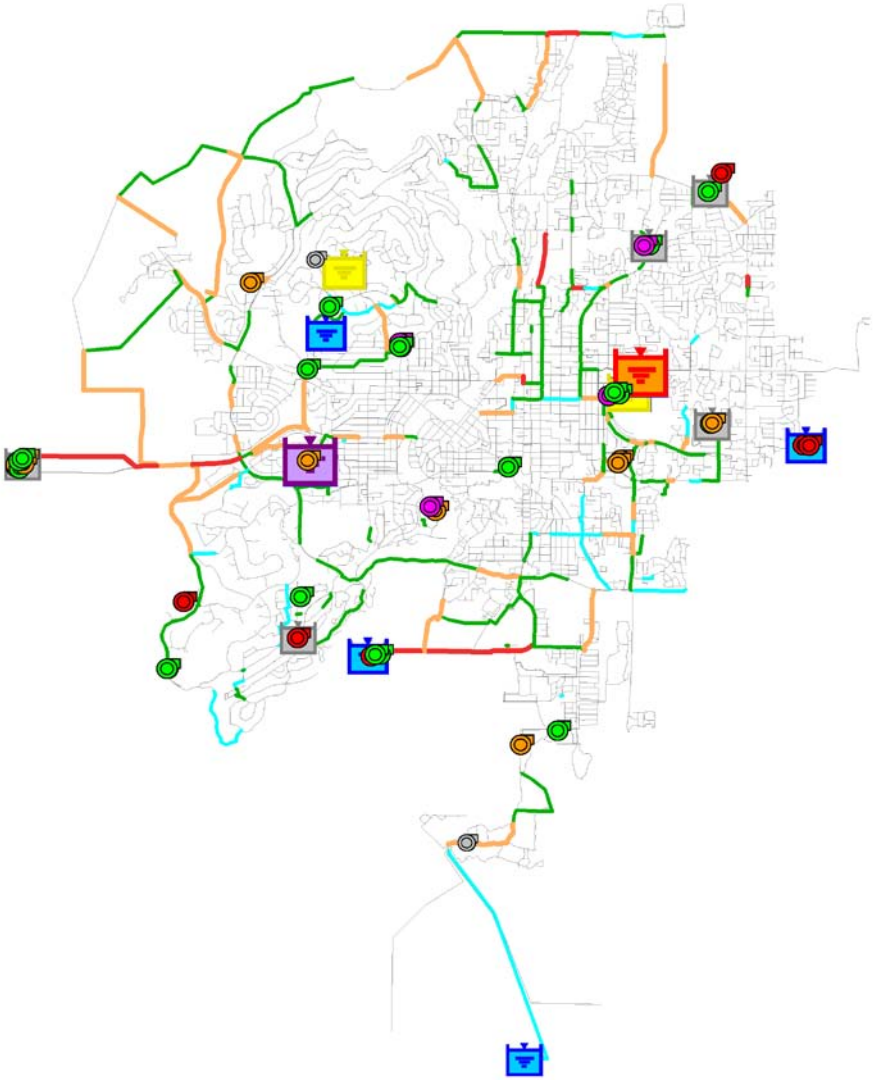
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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

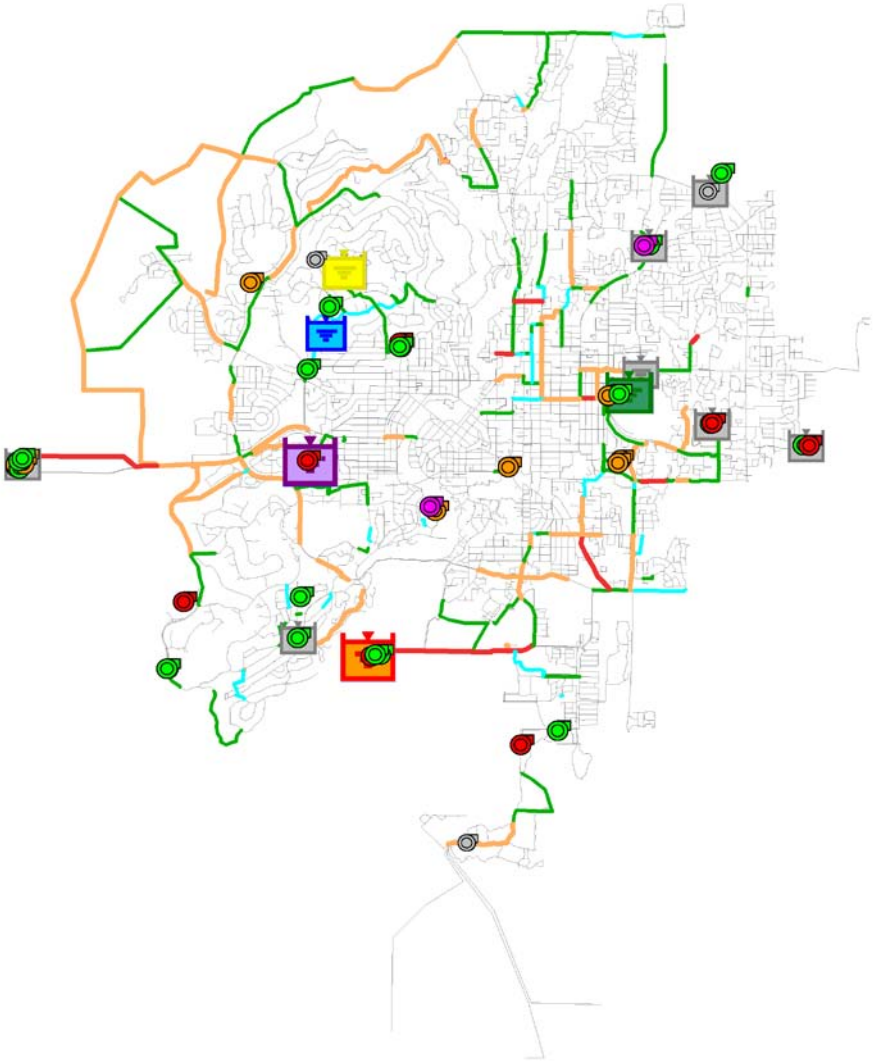
- Best solution in 4th generation
- Total of 800 trial solutions evaluated
- Actual processing time: 0.14 hours (72 cores)



Current Solution - $256.2 M

Cost Item	Total Cost ($M)
Pipes	106.3
Pumps	0.9
Tanks	31.6
Valves	0.6
Wells	86.1
Energy	30.8
TOTAL ($M)	256.2

- Best solution in 8th generation
- Total of 1,600 trial solutions evaluated
- Actual processing time: 0.25 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

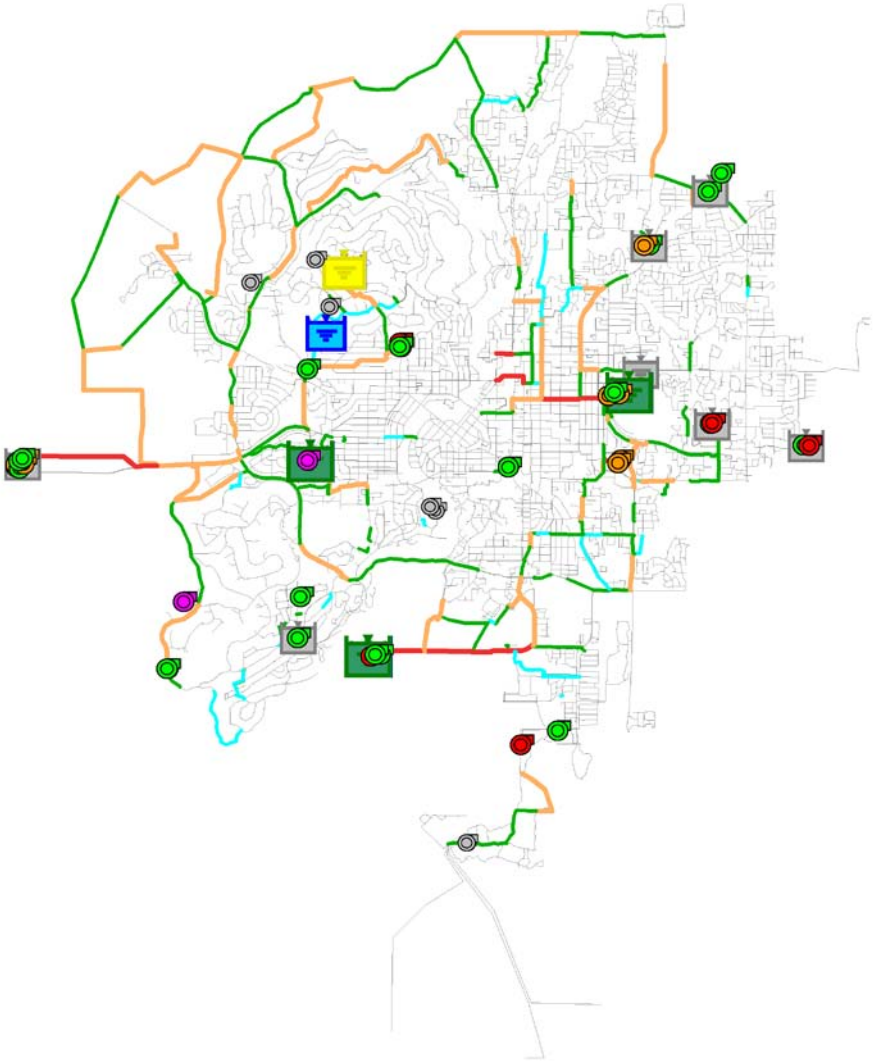
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

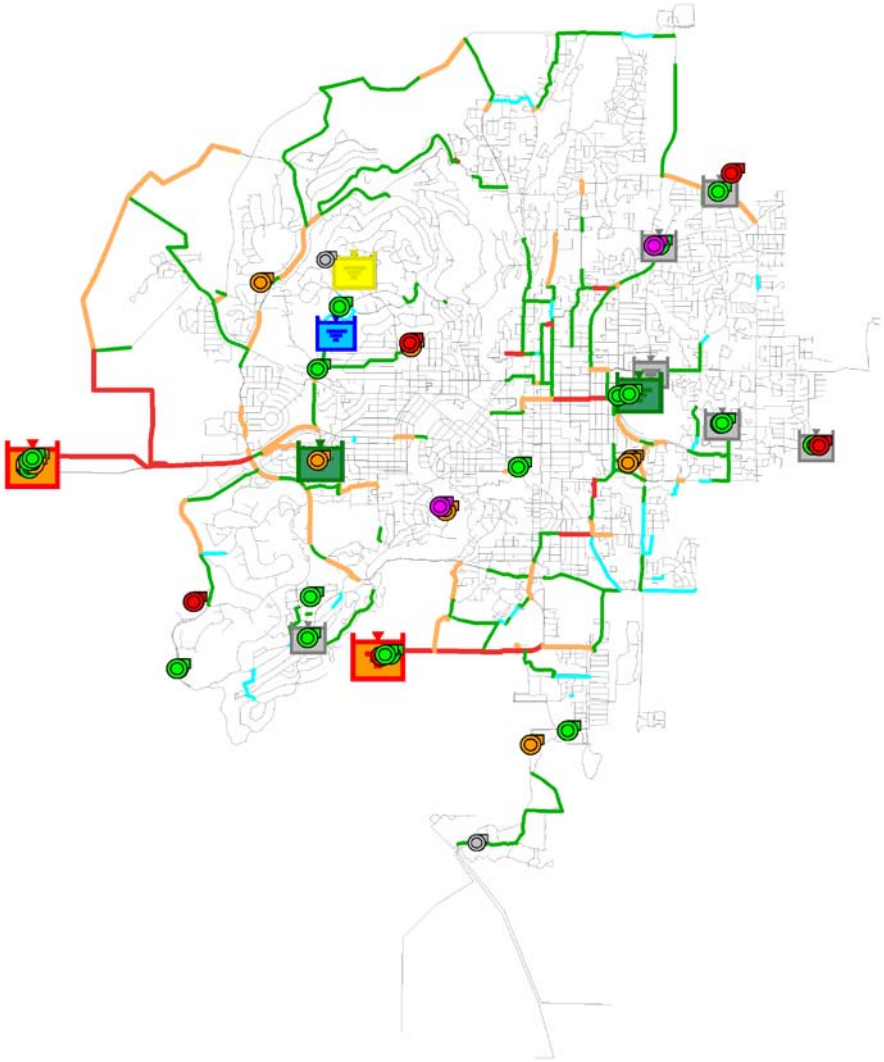
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $233.9 M

Cost Item	Total Cost ($M)
Pipes	98.6
Pumps	0.9
Tanks	29.2
Valves	0.6
Wells	73.9
Energy	30.7
TOTAL ($M)	233.9

- Best solution in 32nd generation
- Total of 6,400 trial solutions evaluated
- Actual processing time: 0.92 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

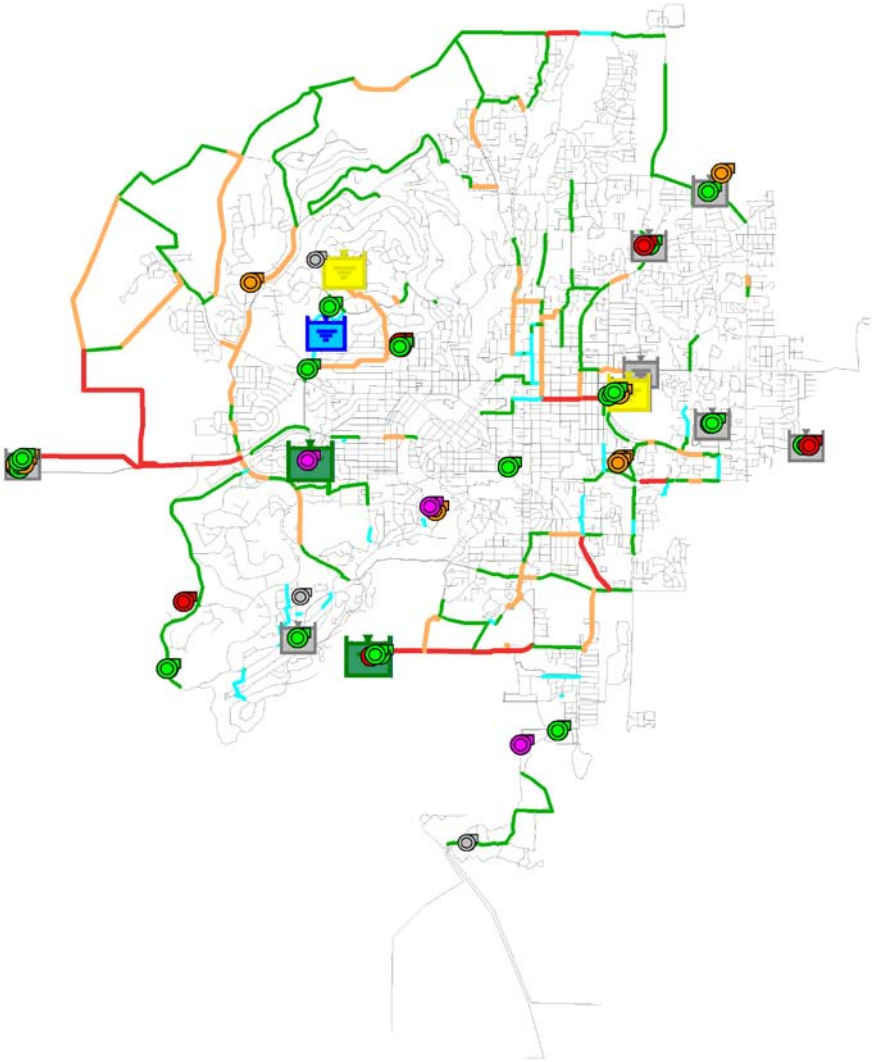
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

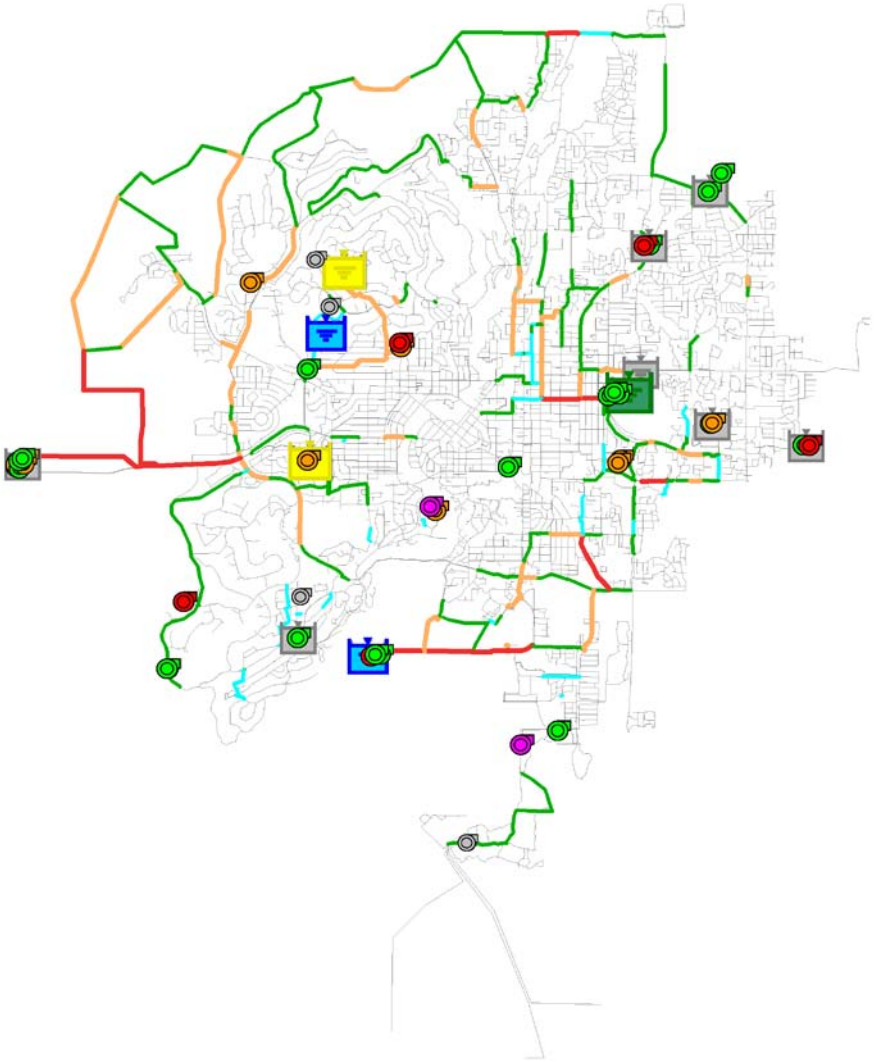
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $197.7 M

Cost Item	Total Cost ($M)
Pipes	81.3
Pumps	0.8
Tanks	20.5
Valves	0.6
Wells	65.6
Energy	28.8
TOTAL ($M)	197.7

- Best solution in 100th generation
- Total of 20,000 trial solutions evaluated
- Actual processing time: 2.81 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

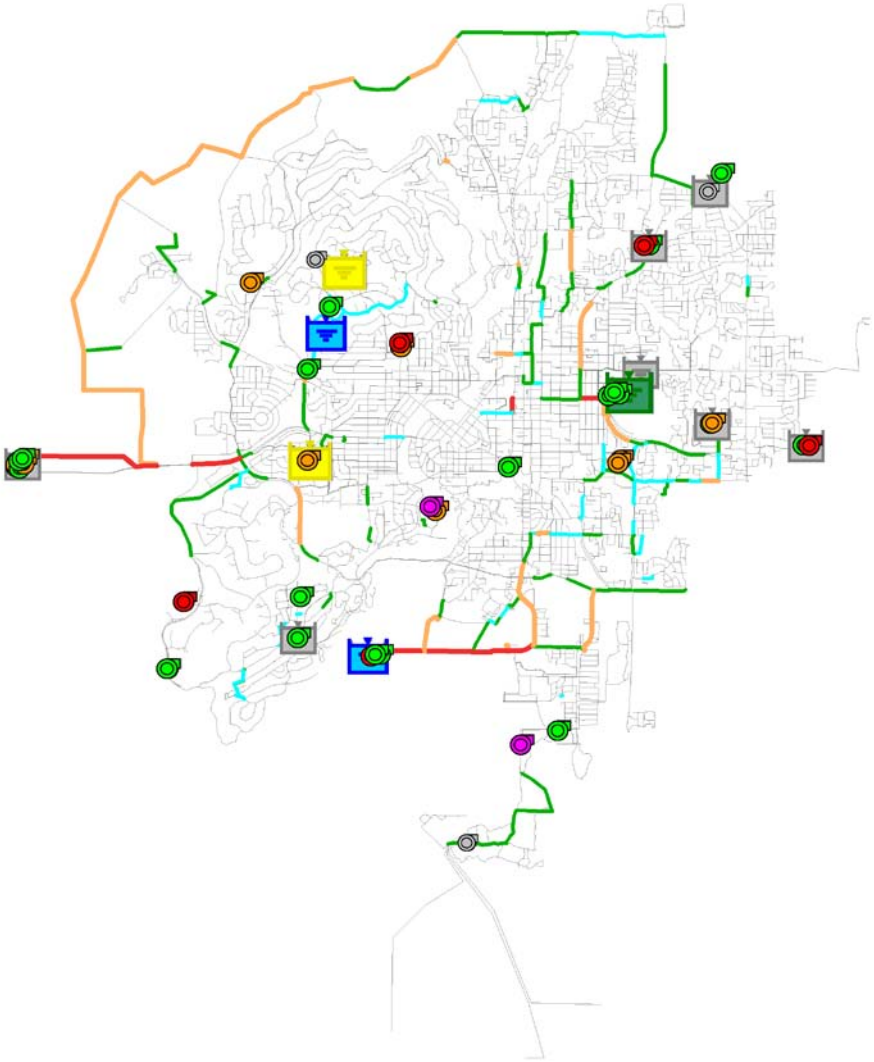
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

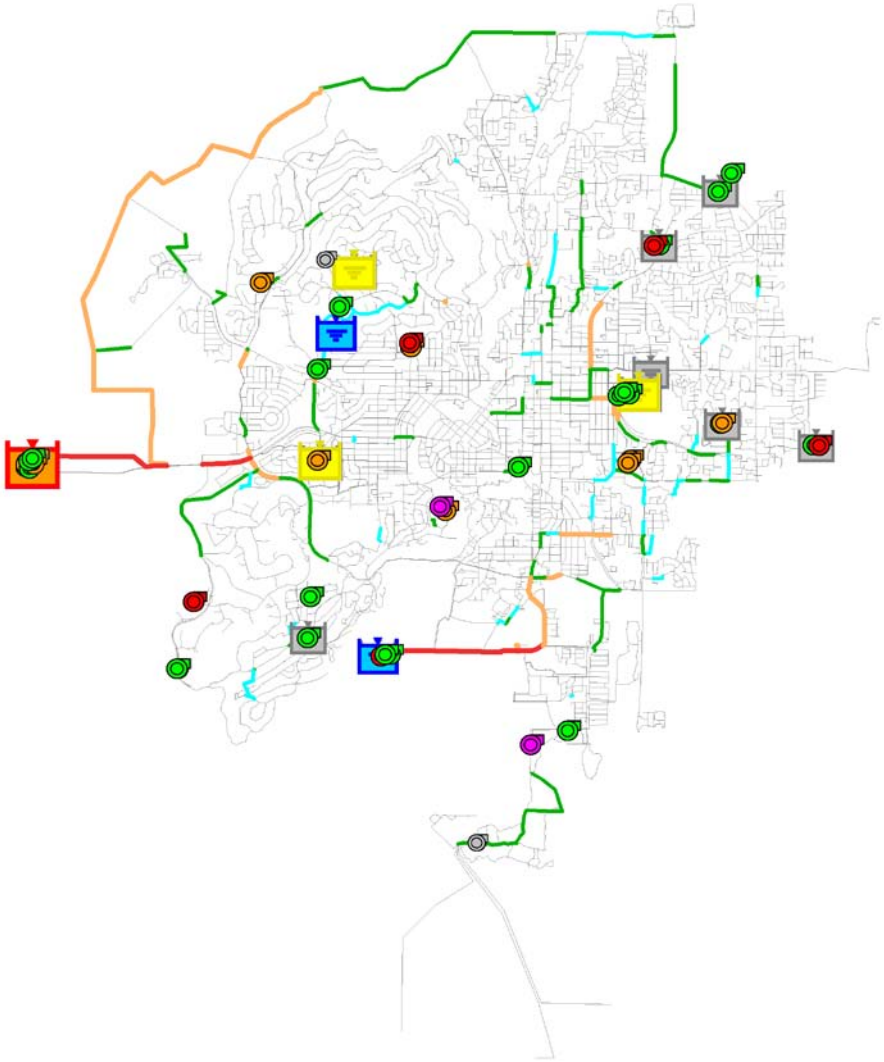
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $168.3 M

Cost Item	Total Cost ($M)
Pipes	55.8
Pumps	1.0
Tanks	19.4
Valves	0.6
Wells	62.6
Energy	28.8
TOTAL ($M)	168.3

- Best solution in 200th generation
- Total of 40,000 trial solutions evaluated
- Actual processing time: 5.58 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

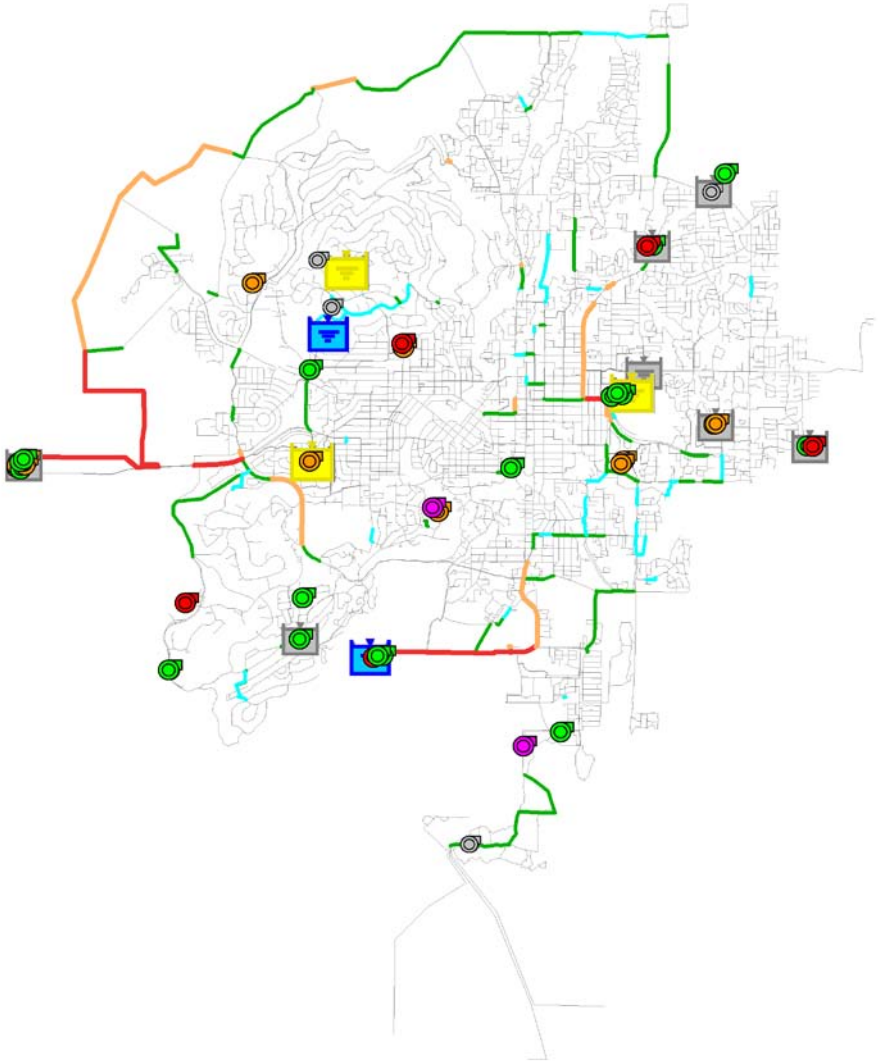
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

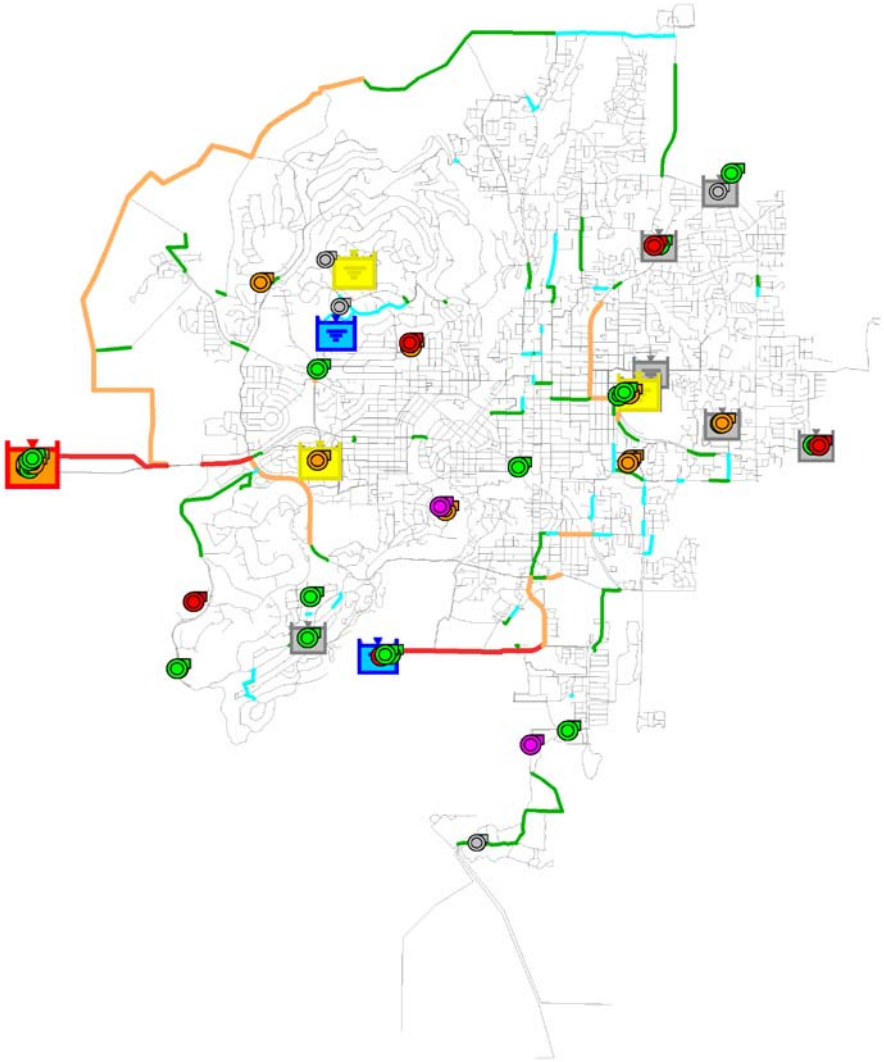
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $161.6 M

Cost Item	Total Cost ($M)
Pipes	50.2
Pumps	0.9
Tanks	19.4
Valves	0.6
Wells	61.8
Energy	28.7
TOTAL ($M)	161.6

- Best solution in 300th generation
- Total of 60,000 trial solutions evaluated
- Actual processing time: 8.36 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

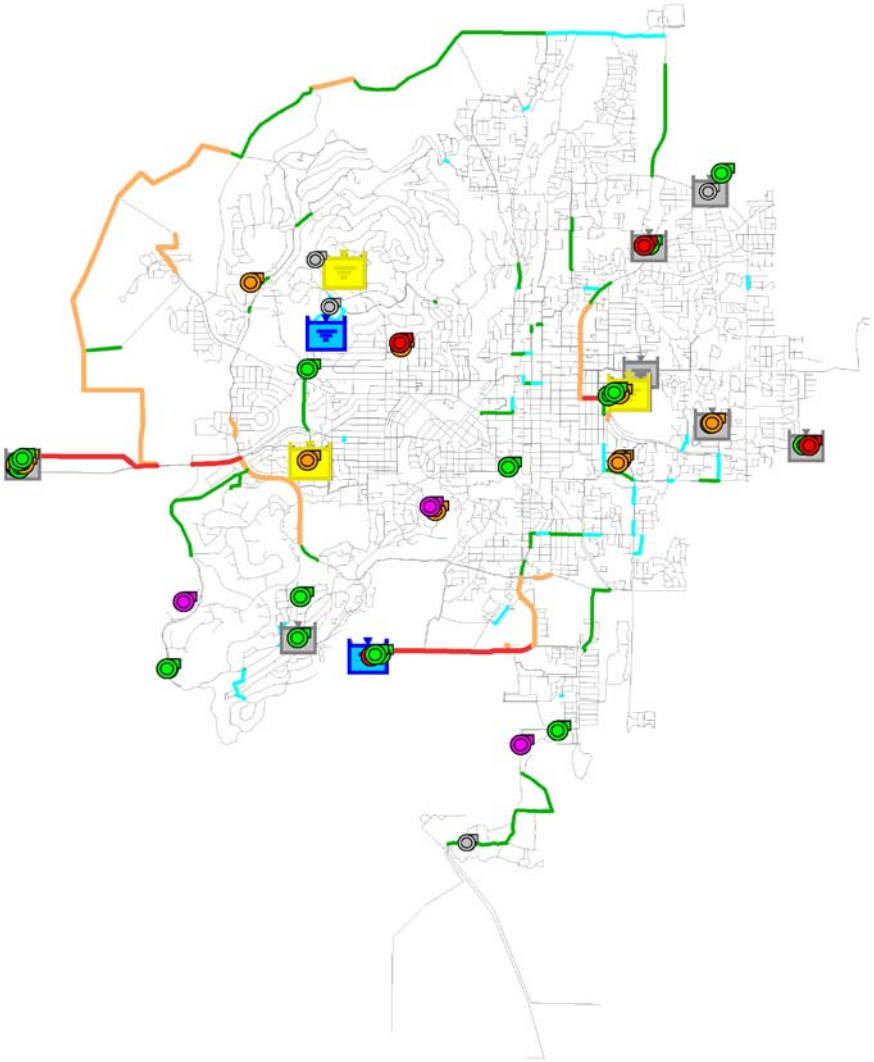
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

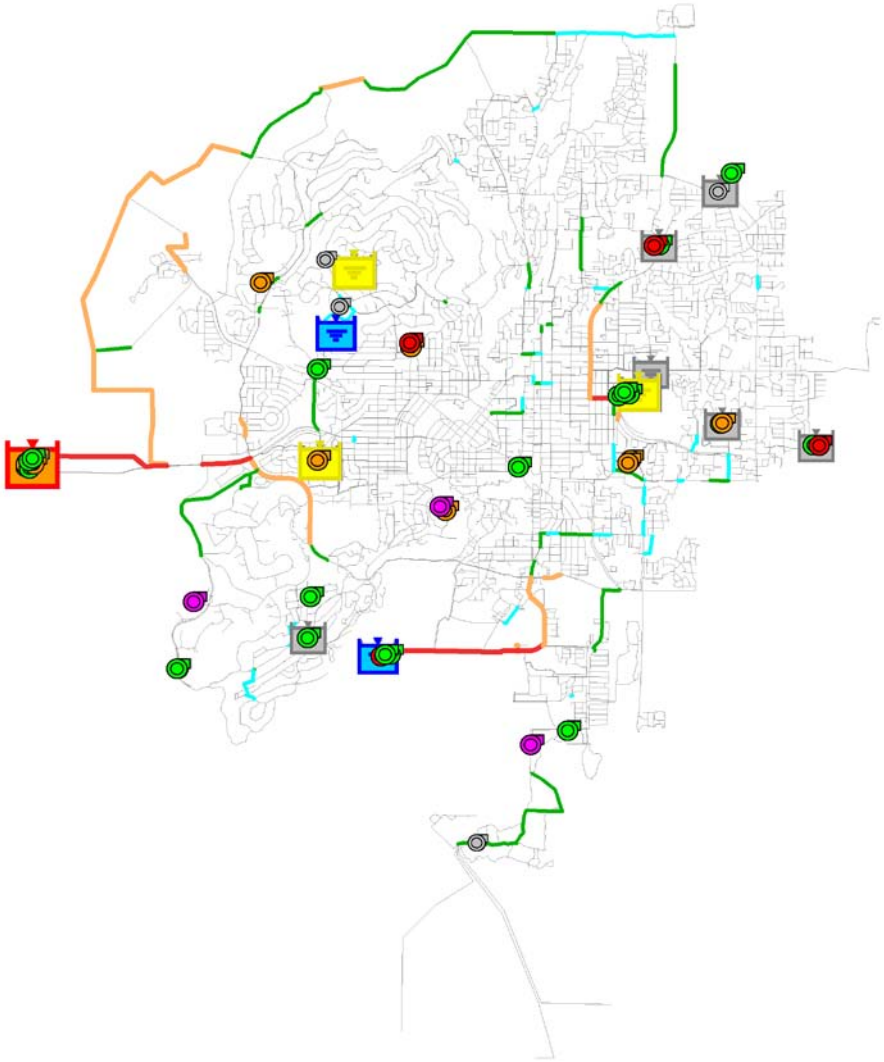
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

Current Solution - $155.4 M

Cost Item	Total Cost ($M)
Pipes	46.1
Pumps	0.8
Tanks	19.4
Valves	0.6
Wells	59.9
Energy	28.6
TOTAL ($M)	155.4

- Best solution in 500th generation
- Total of 100,000 trial solutions evaluated
- Actual processing time: 13.92 hours (72 cores)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

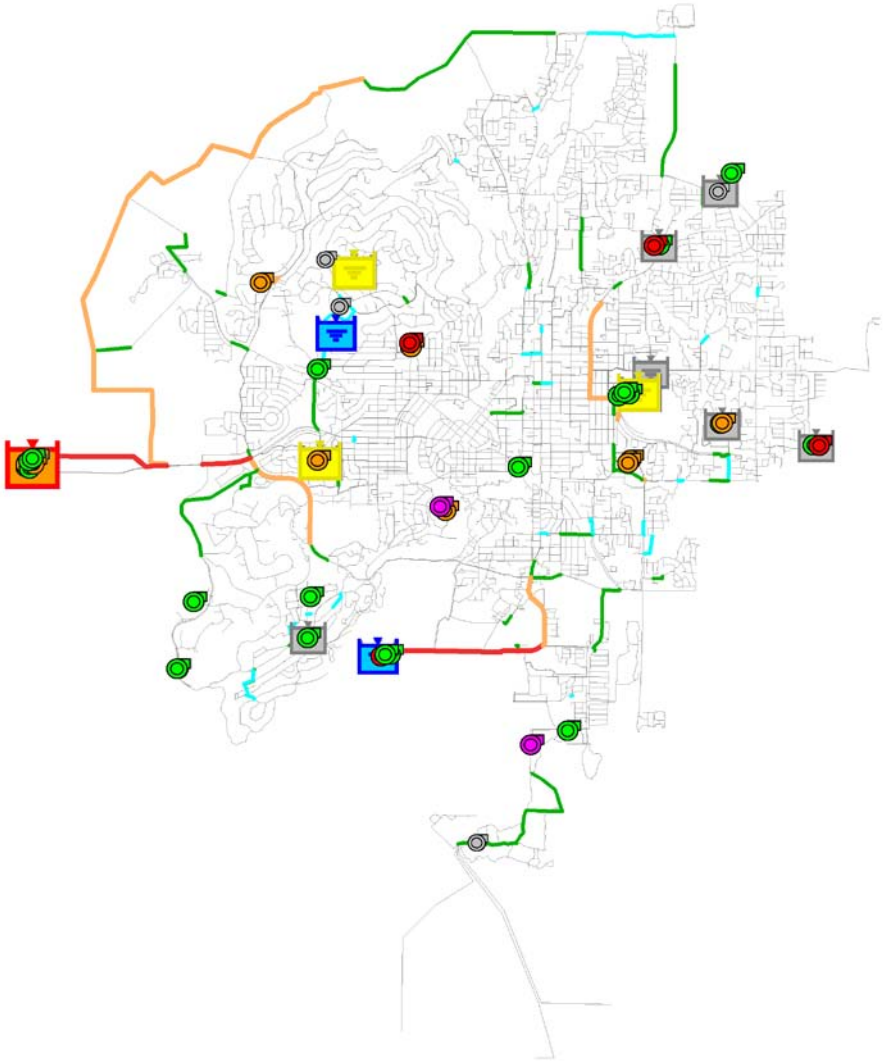
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

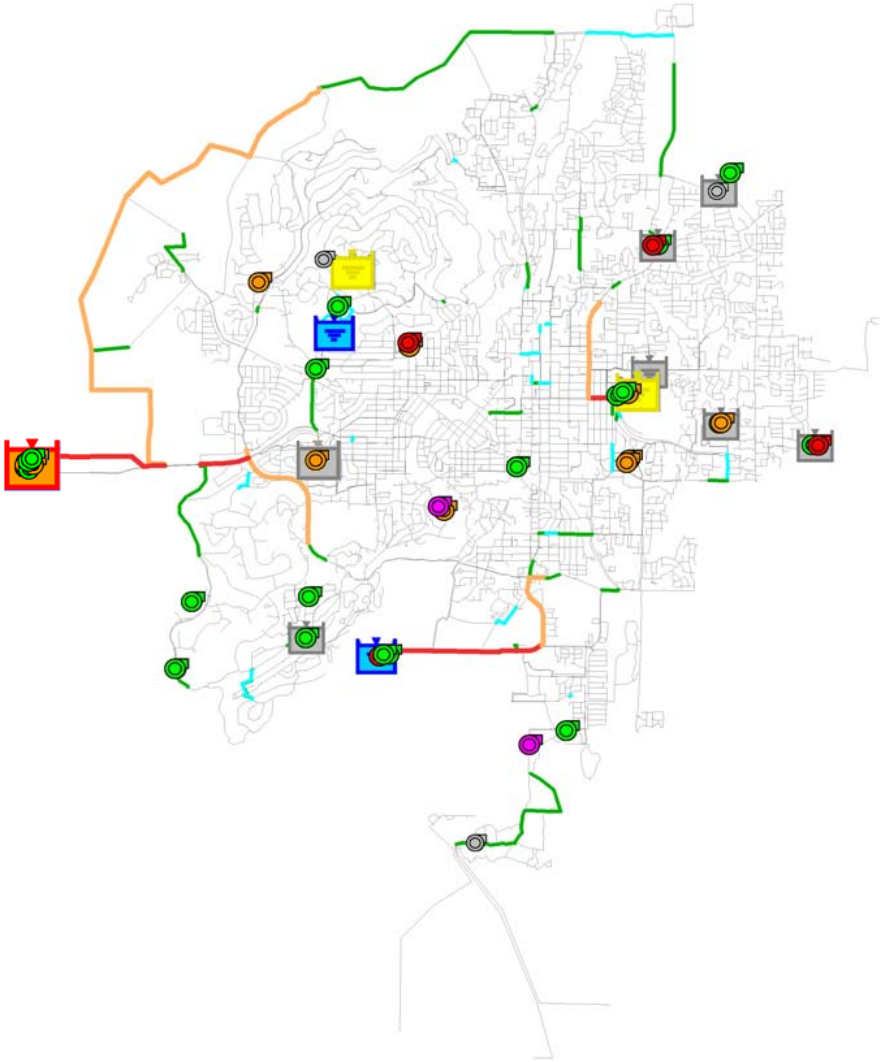
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

Tanks (MG)

- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

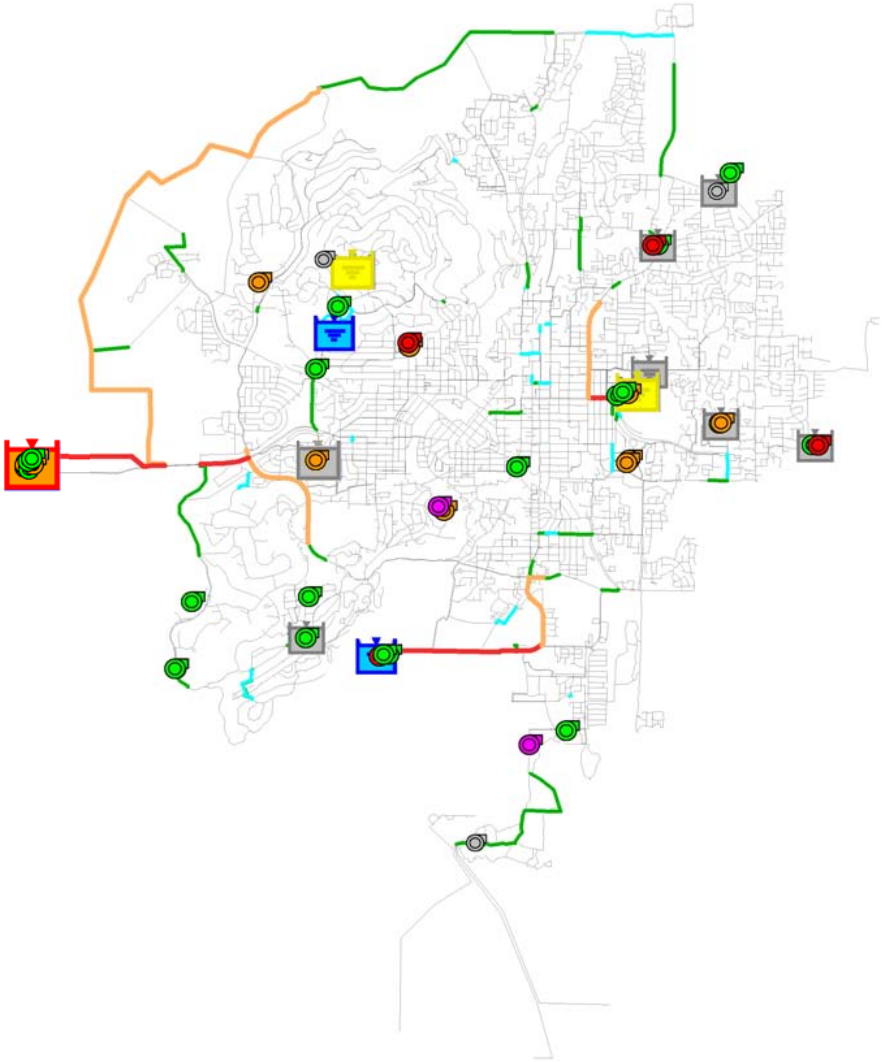
Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

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)



Total Cost
Pipe Costs
Well Costs
Tank Costs
Energy Costs

Water Main (in)

- >36
- >24 - 36
- >12 - 24
- <12
- Existing

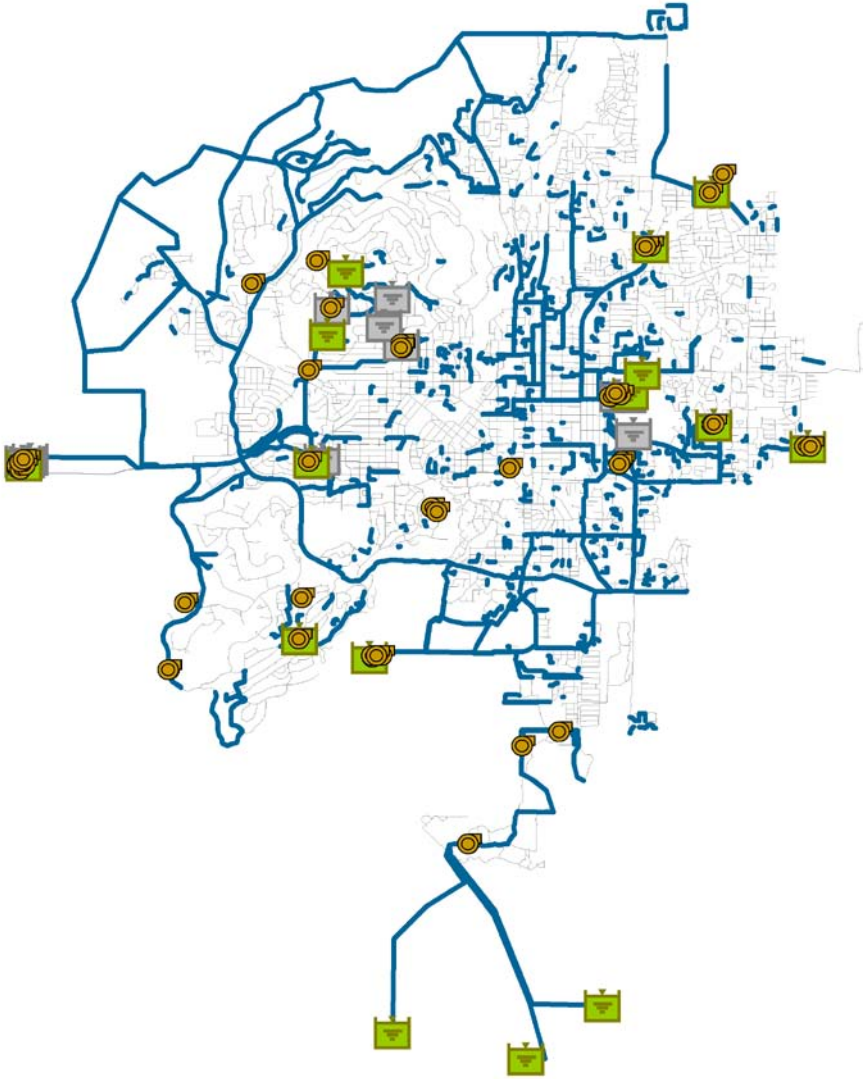
Tanks (MG)

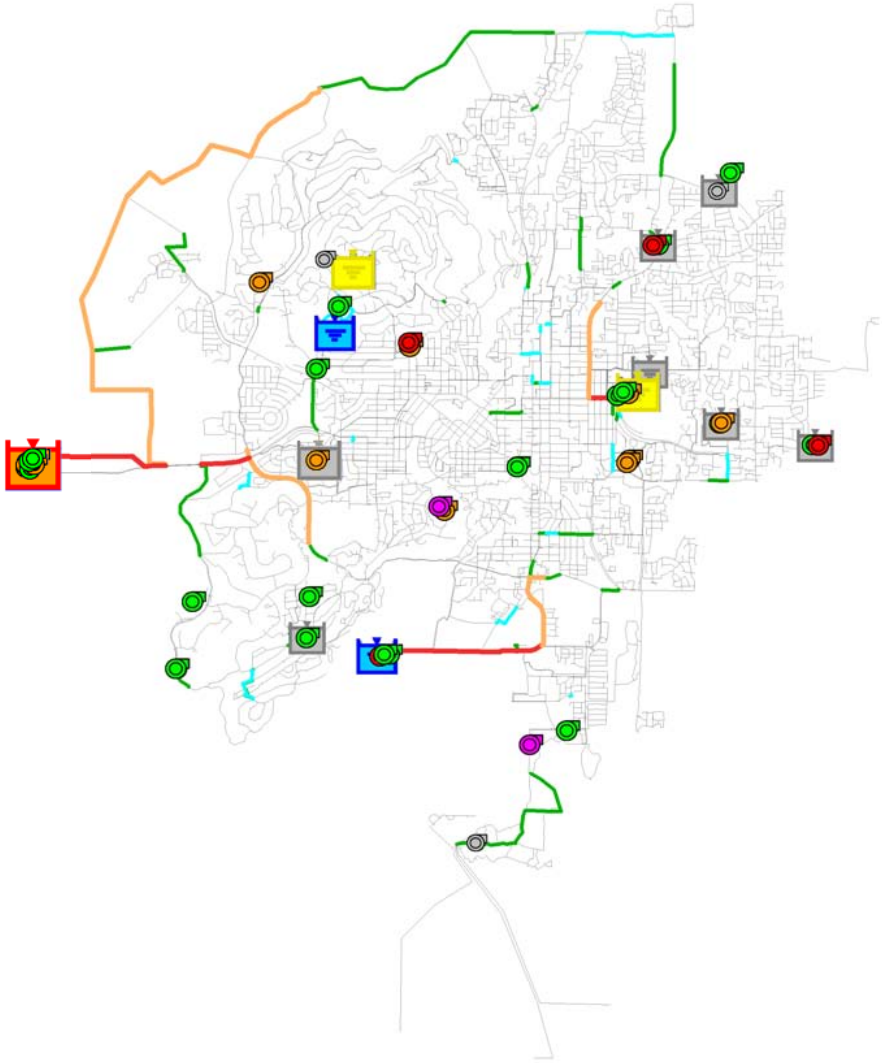
- >5
- <2-3
- <4-5
- <2
- <3-4
- Existing

Pump (gpm)

- >4000
- >3000-4000
- >2000-3000
- <2000
- Existing

From many options… few are selected



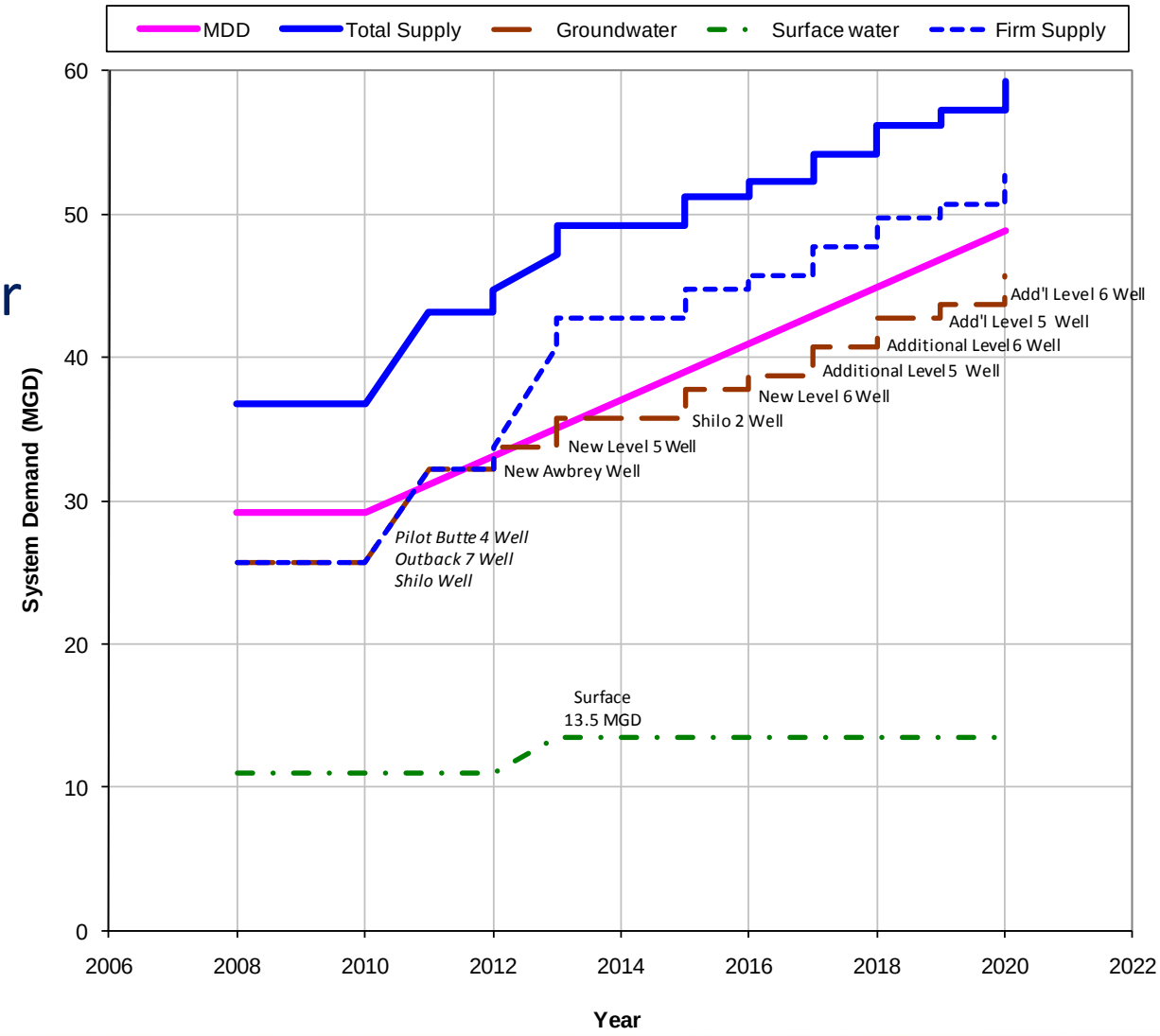


Comparison – 2007 vs Optimized MP

- Demands 15% higher (MDD: 83.5 vs 71.5 MGD)
- Unit costs approx 8% higher
- Higher supply volume necessitates more wells and more extensive transmission improvements
- Comparison of total cost estimates ($168m in 2006 dollars vs $197m in 2009 dollars) indicates likely savings due to optimization
- A 1% saving on the $197 million total cost would pay for $500k study multiple times

CIP Development

- Firm supply
  - Surface
  - Groundwater
- Transmission
- Storage
- Fire flow improvements



Alternative Design Scenarios

- Modifications to surface water capacity
- Restrictions on new well locations
- Staging – 10-year plan
- Alternative development scenarios
- Conservation – impacts of reducing build-out demands

Optimization Benefits

- Wide range of options evaluated
- Ability to analyze multiple scenarios
- Involvement of Planning, Operations and Water Resources staff in decision making
- Results relevant to near-term planning
- Confidence on path forward meeting future needs

Conclusions

- Confidence in Decision Making
- Support from Council and Development
- Confidence from Operators in making system changes
- Support for use of dual water supply and use of a gravity supply
- Difficult for opposition to argue

Optimatics

optimizing water systems

Thank you – Questions

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