# Smart Sewers:

## Real Time Intelligence and Optimization for South Bend's Sewers

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# Introduction

"We have the smartest sewers in the world."

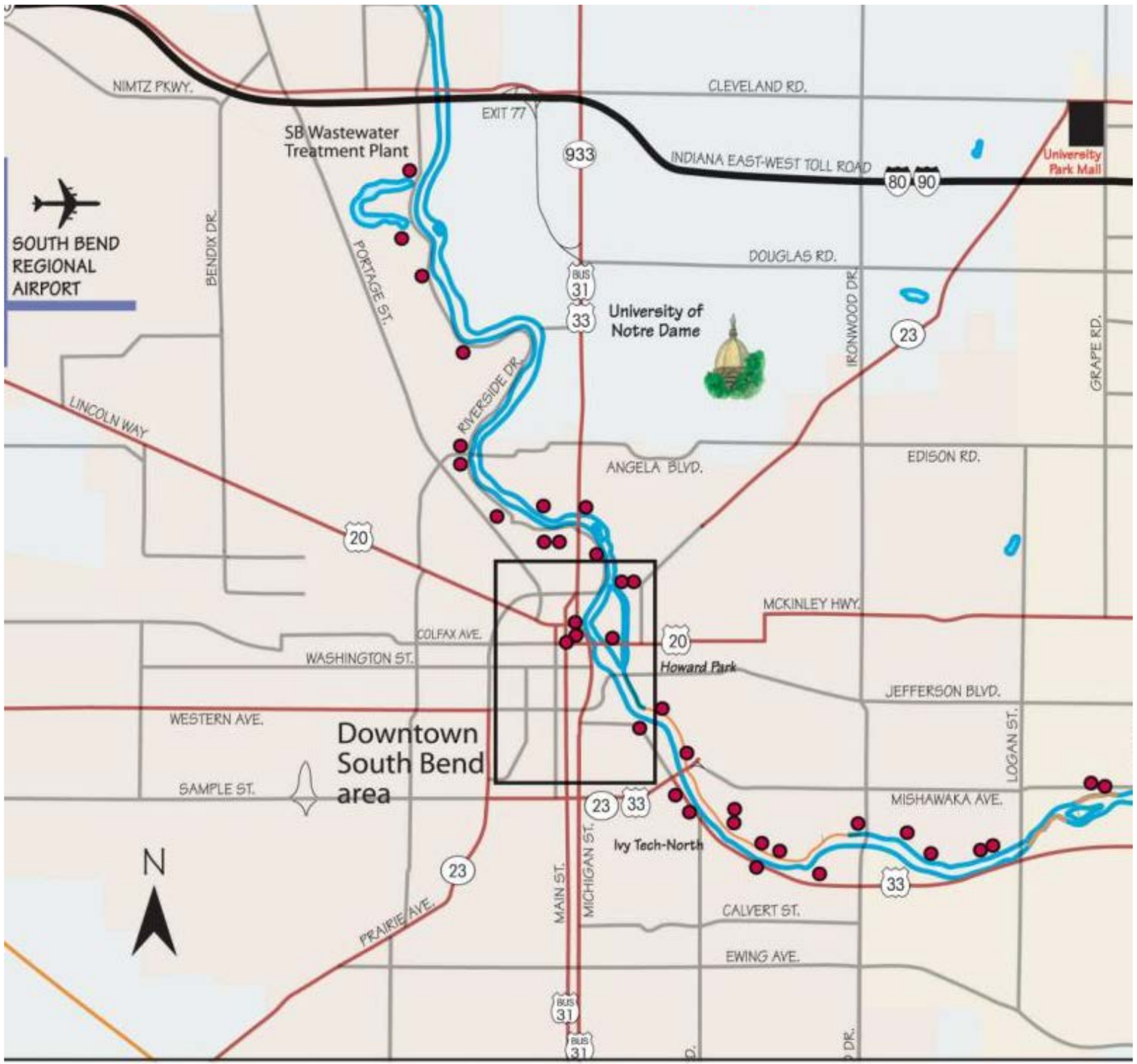
Mayor Pete Buttigieg

South Bend, IN named one of the country's 10 Smartest Cities

(Cisco Systems)

# Built on the **South Bend** of the St. Joseph River

# South Bend
# Combined Sewer Overflows




- 40 $mi^2$
- 20 $mi^2$ Combined
- >1 BG overflow/year
- 77 MGD WWTP
- $500M LTCP

# Goal: More with less = Smart

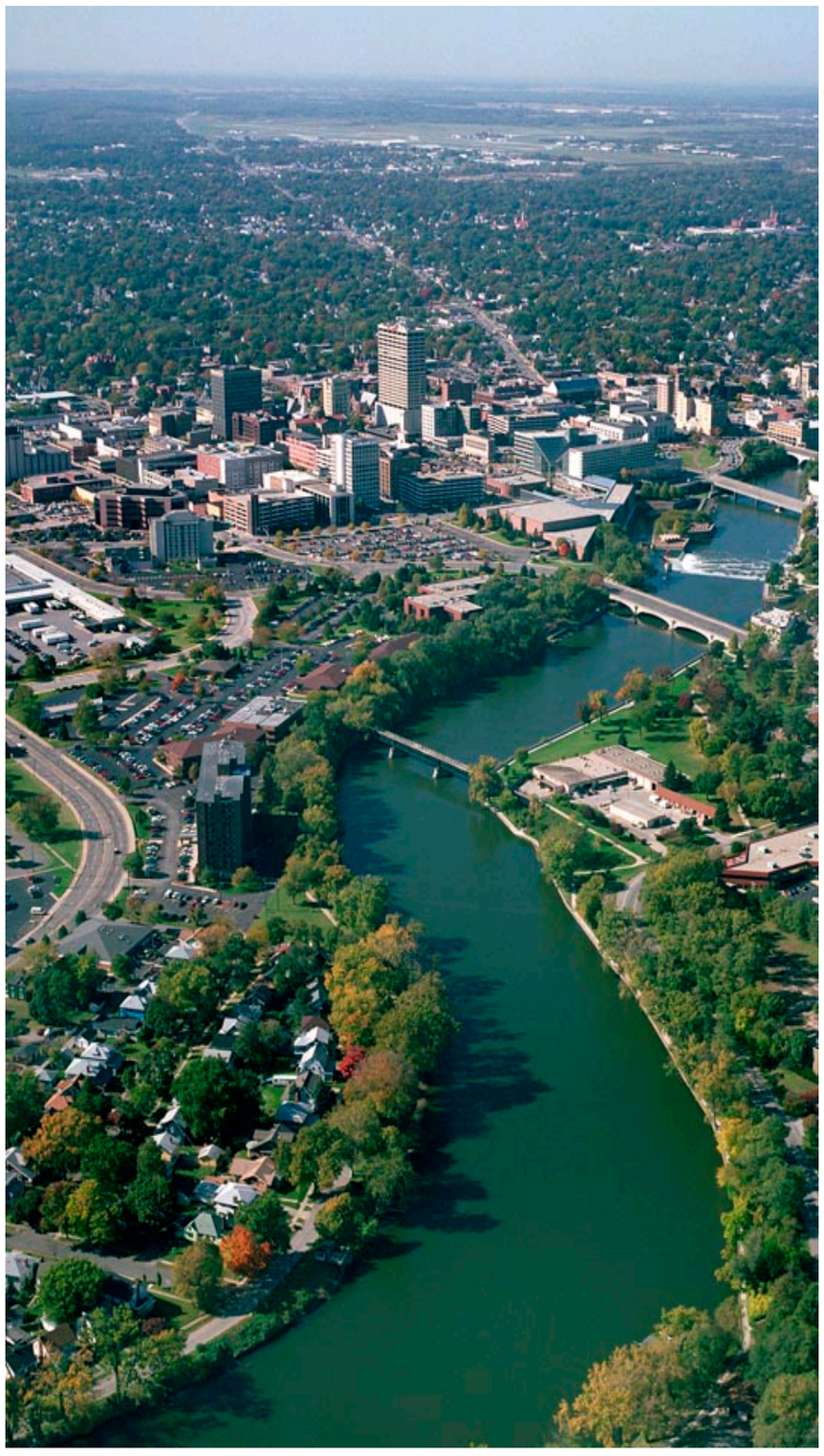
Key Question:

Are we making the MOST out of our EXISTING infrastructure?


Our first answer:

We don’t know!

# South Bend's Solution



Utilize Existing Infrastructure

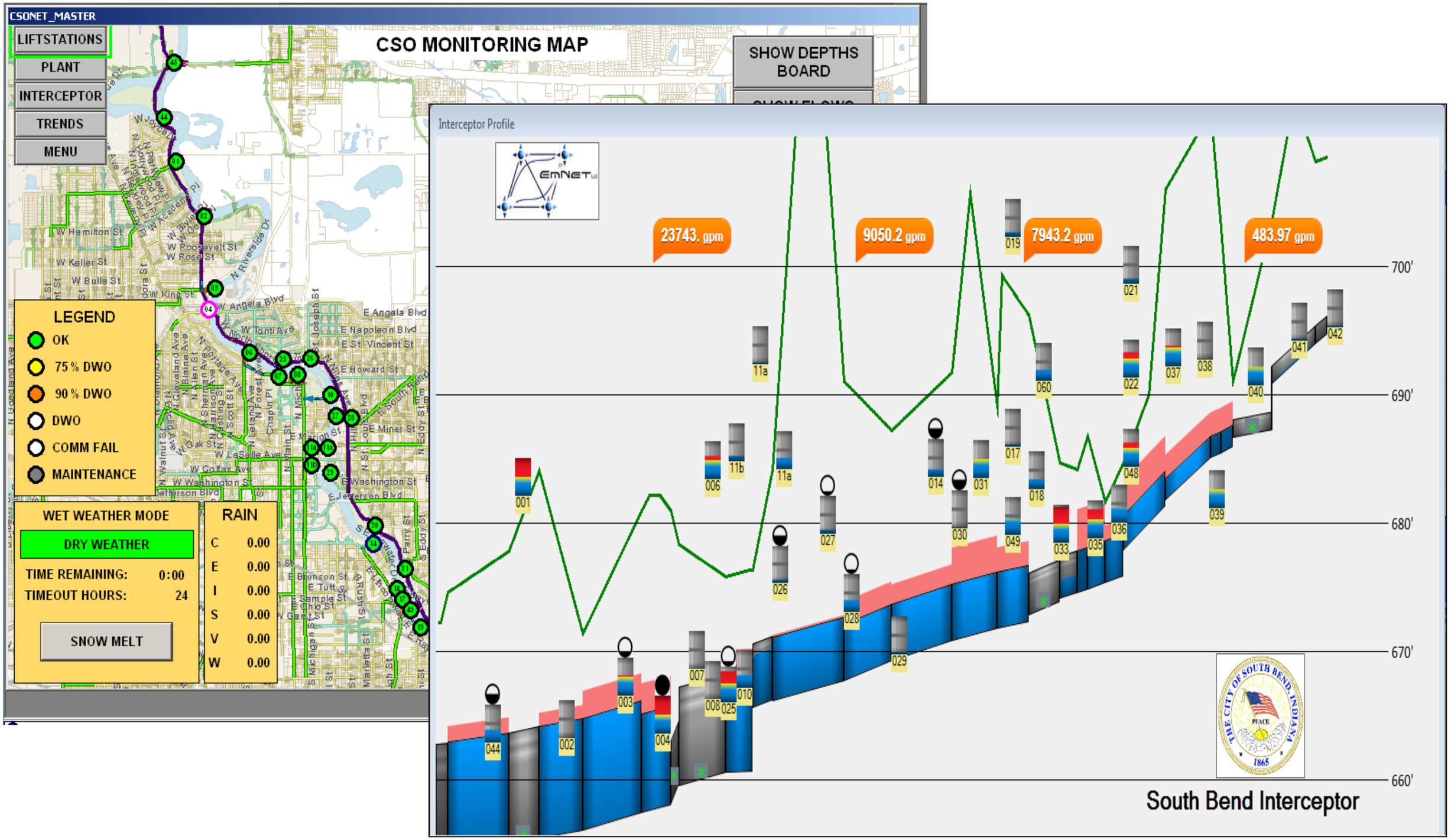
Eliminate DWO's

Prevent Basement Back-Ups

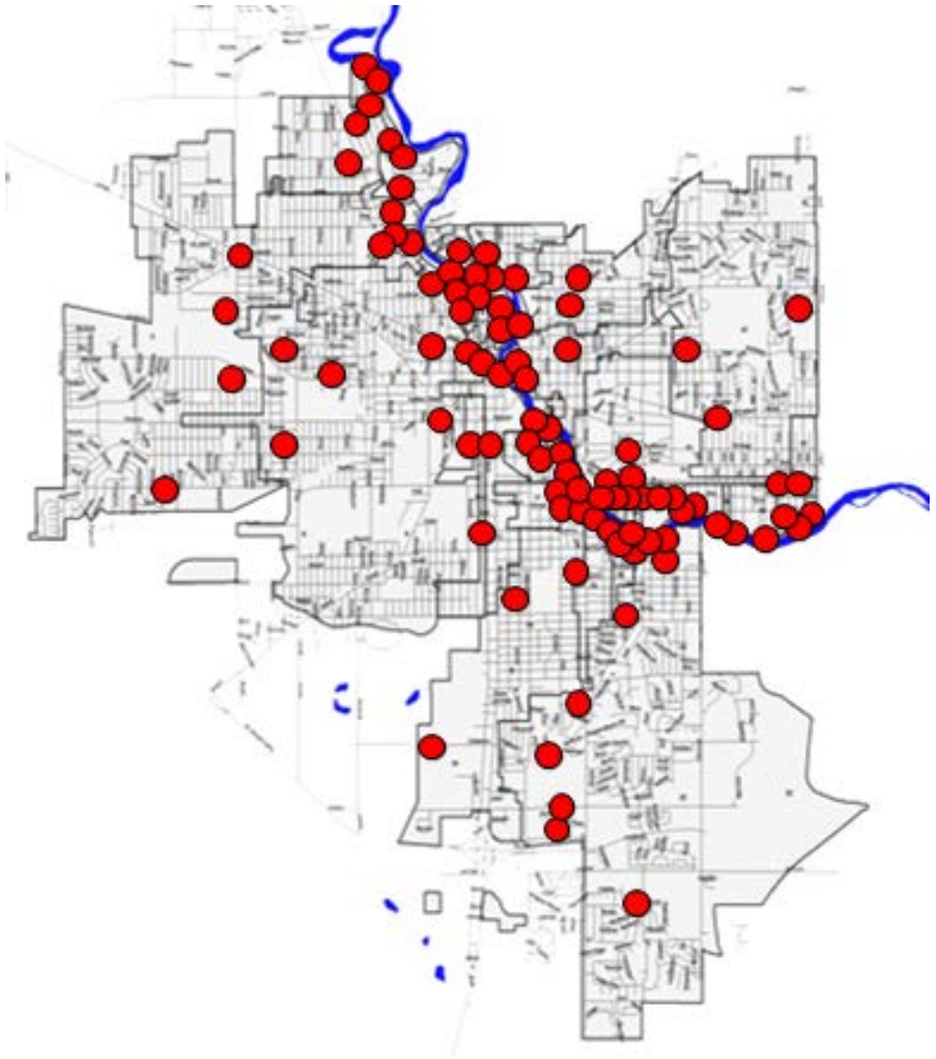
Minimize CSO's to River

Maximize Flow to WWTP

# Step 1: Turn data into information

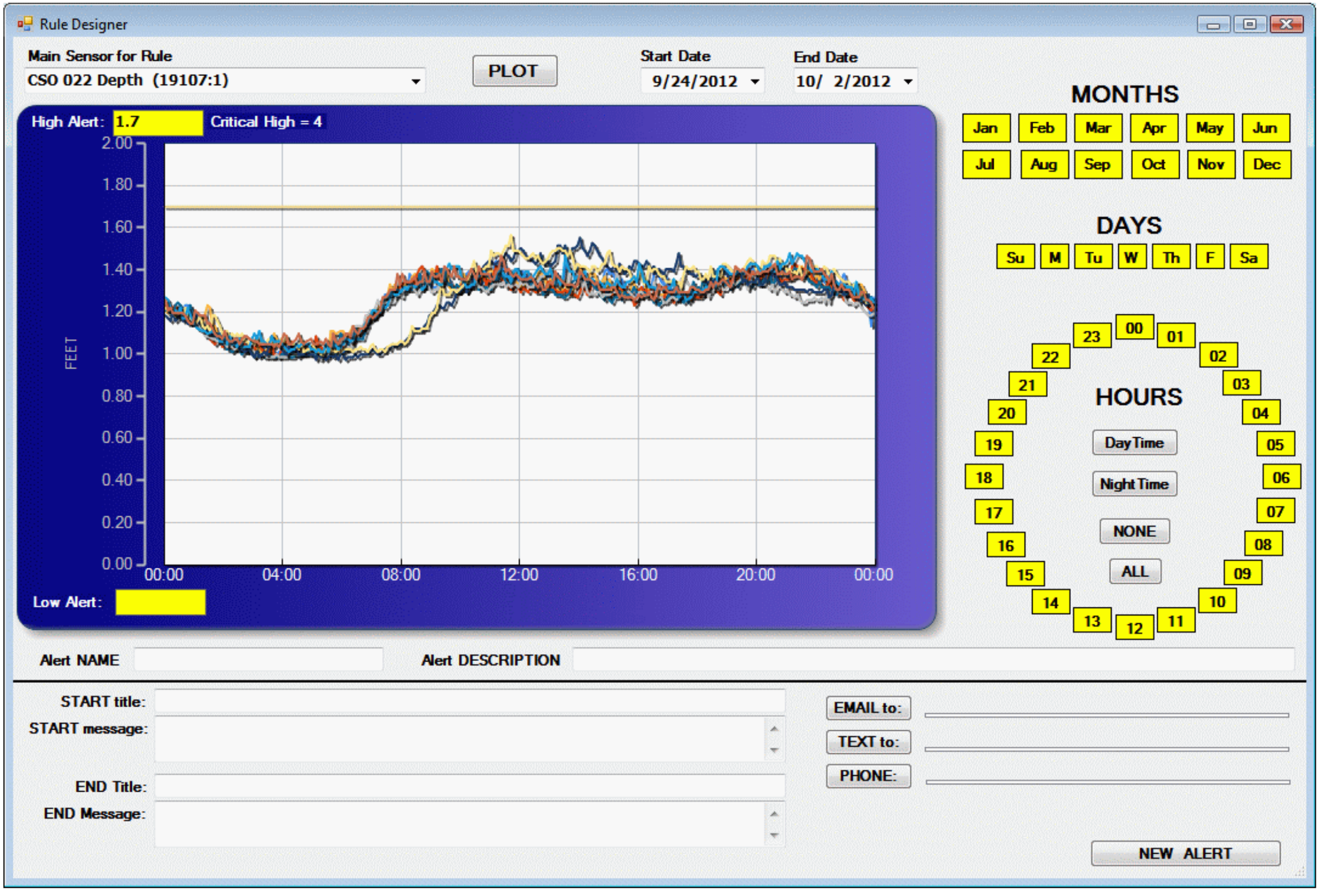


# CSONet System



- Installed extensive real time monitoring of the combined sewer system
- 120 monitoring points, 5 min data
- 9 control valves
- Focused along river
- Integrated with SCADA and CSONet Website
- Objectives
  - System Characterization
  - Blockage Detection/ DWO Reduction
  - Model Calibration
  - Proactive Maintenance
  - Real Time Control

# Condition Based Maintenance Tools



# Increased O&M Benefits (Direct)

Use of vactor trucks 50 additional days annually
= $133K

Clean 2,000 additional catch basins annually
= $40K

Increase number of sewer inspections by 175%
= $29K

Same Staff

Total Dynamic Maintenance Value
= $202,000 Annually

# Increased O&M Benefits (Indirect)

Discover and eliminate I/I sources

= 10 MGD decrease

Find and address maintenance hotspots

= Clean what needs to be cleaned when it needs it

Pre-/post-construction monitoring

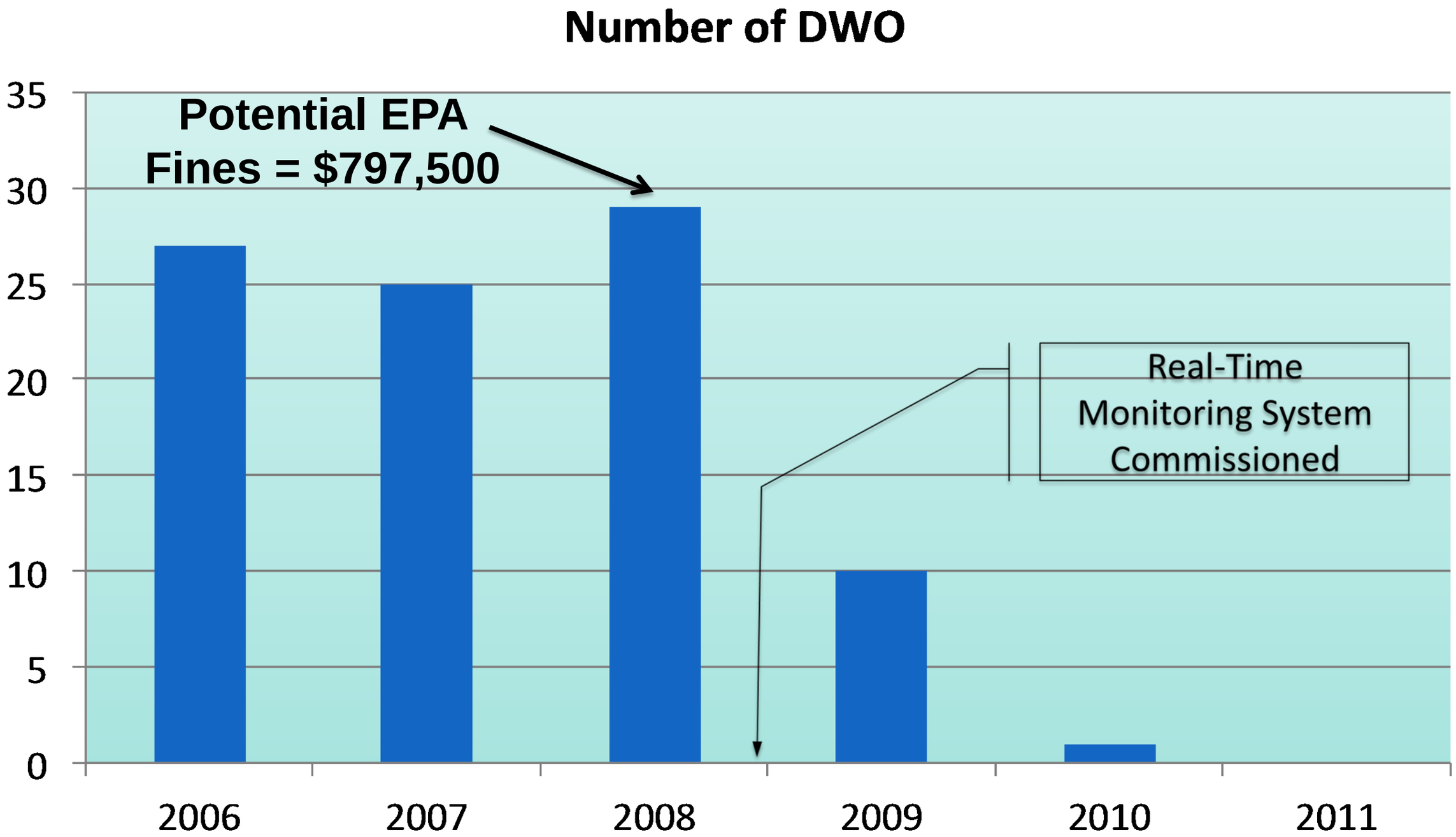
Flood/backup warning system

Indirect Value

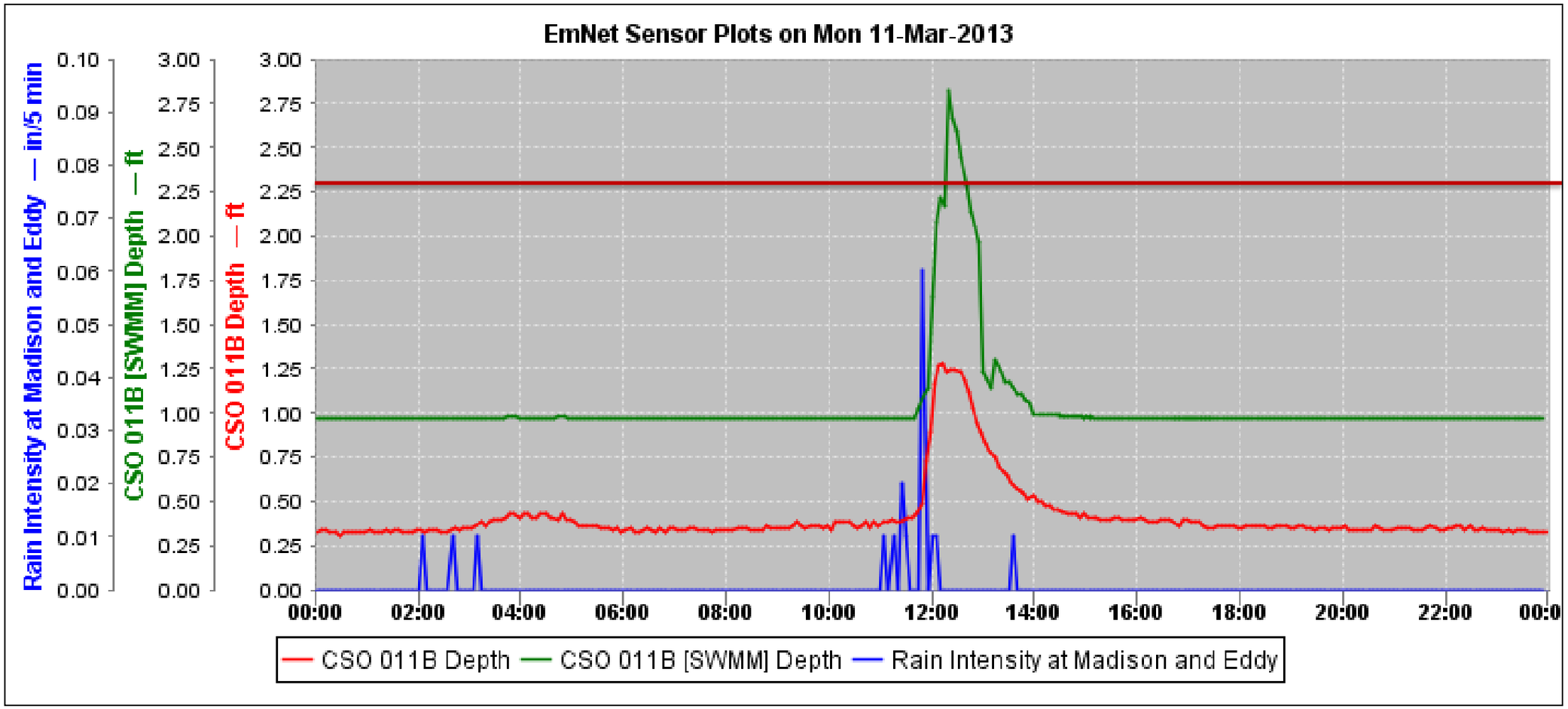
= $1.5 M Annually

# Dry Weather Overflow Elimination

100% DWO reduction from 2008 to 2011



# Step 2: Bring in the Model

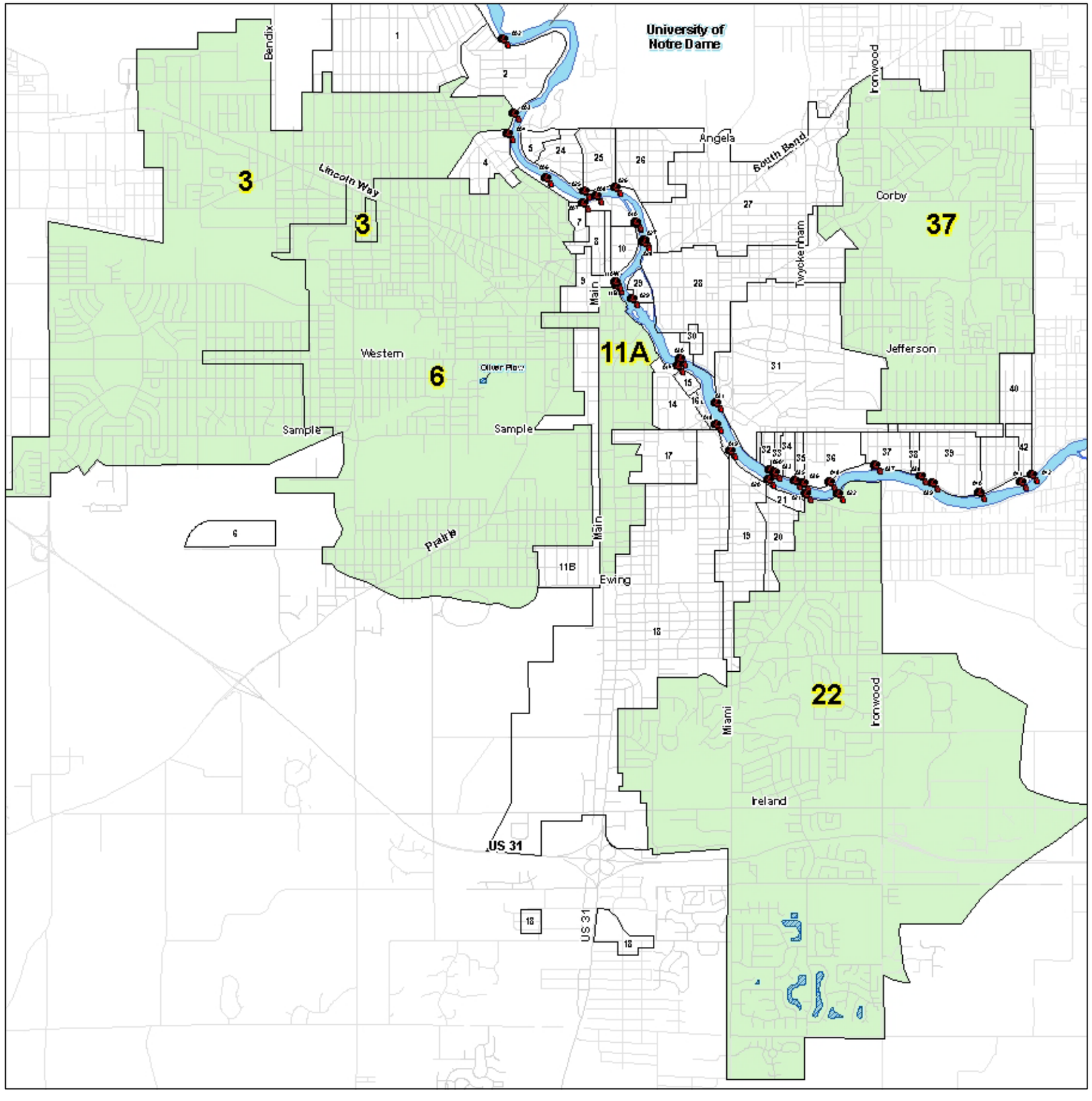



Focus on problem areas

Identify opportunities

Solve discrepancies between the model and RT Data

# 2005 Calibrated Areas – 003, 006, 11A, 022, 037



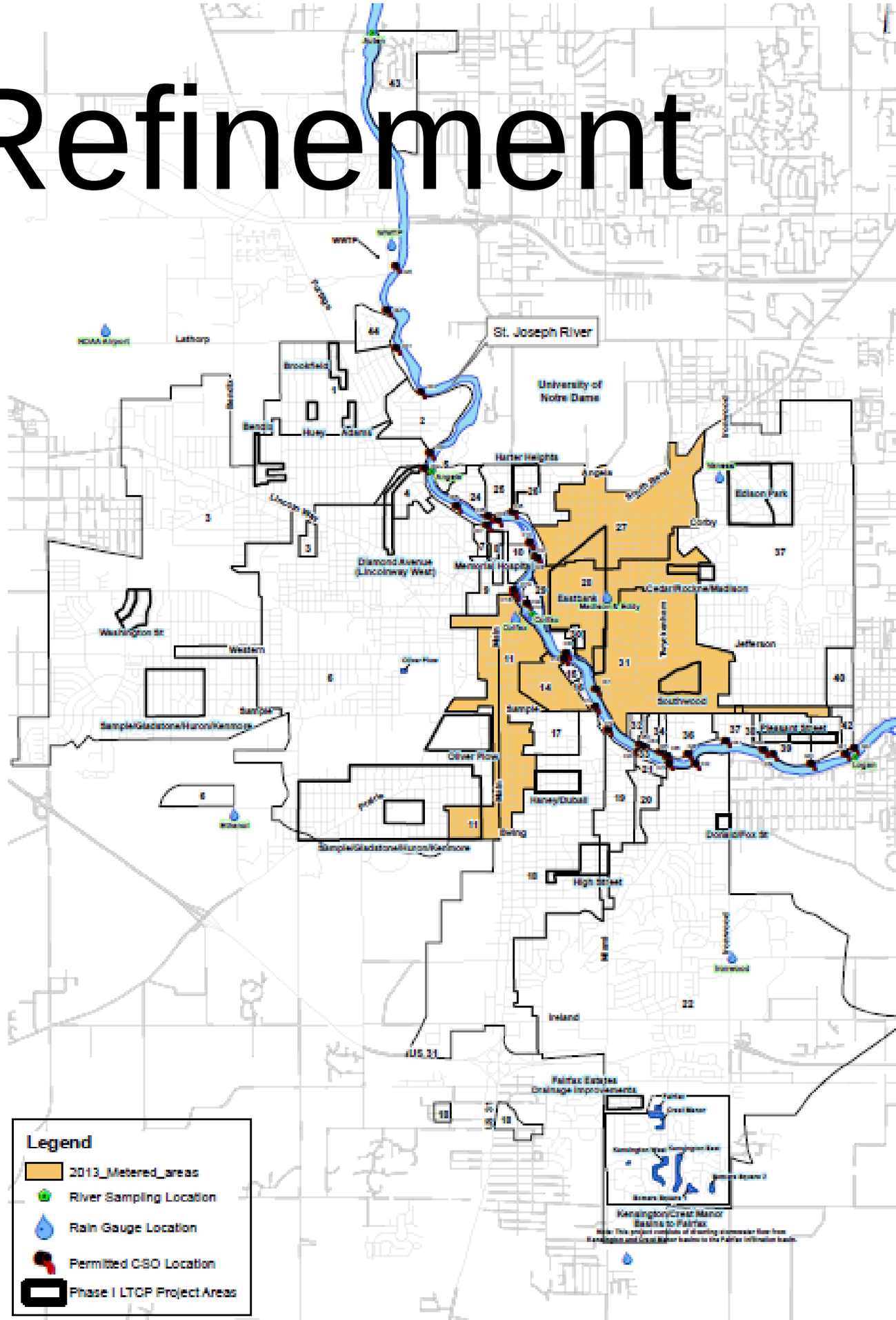
# Model vs CSOnet Comparison

| Leeper Park Service Area | Overflow Occurred? | | Overflow Duration (hrs) | | Peak Depth (ft) | | Conclusion (Based on Peak Depth) |
|---|---|---|---|---|---|---|---|
| | CSOnet | 2010 Model | CSOnet | 2010 Model | CSOnet | 2010 Model | |
| 11A | Y | Y | 14.8 | 26.8 | 2.6 | 6.9 | Model over estimates |
| 11B | Y | Y | 14.7 | 27.5 | 4.7 | 9.0 | Model over estimates |
| 010 | Y | Y | 15.0 | 16.5 | 7.3 | 5.7 | Model under estimates |
| 008 | Y | Y | 15.0 | 15.0 | 3.8 | 3.9 | Close |
| 007 | Y | Y | 15.5 | 18.5 | 3.9 | 2.0 | Model under estimates |

# Targeted Refinement

| CSO | LTCP Project Impacted | Combined Acres (Adjusted only) |
|---|---|---|
| 11A | Leeper Park | 187 |
| 11B | Leeper Park | 239 |
| 14 | Ice Rink | 91 |
| 27 | Storage Tunnel | 399 |
| 28 | Storage Tunnel | 230 |
| 31 | Ice Rink | 161 |
| | | 1,307 |

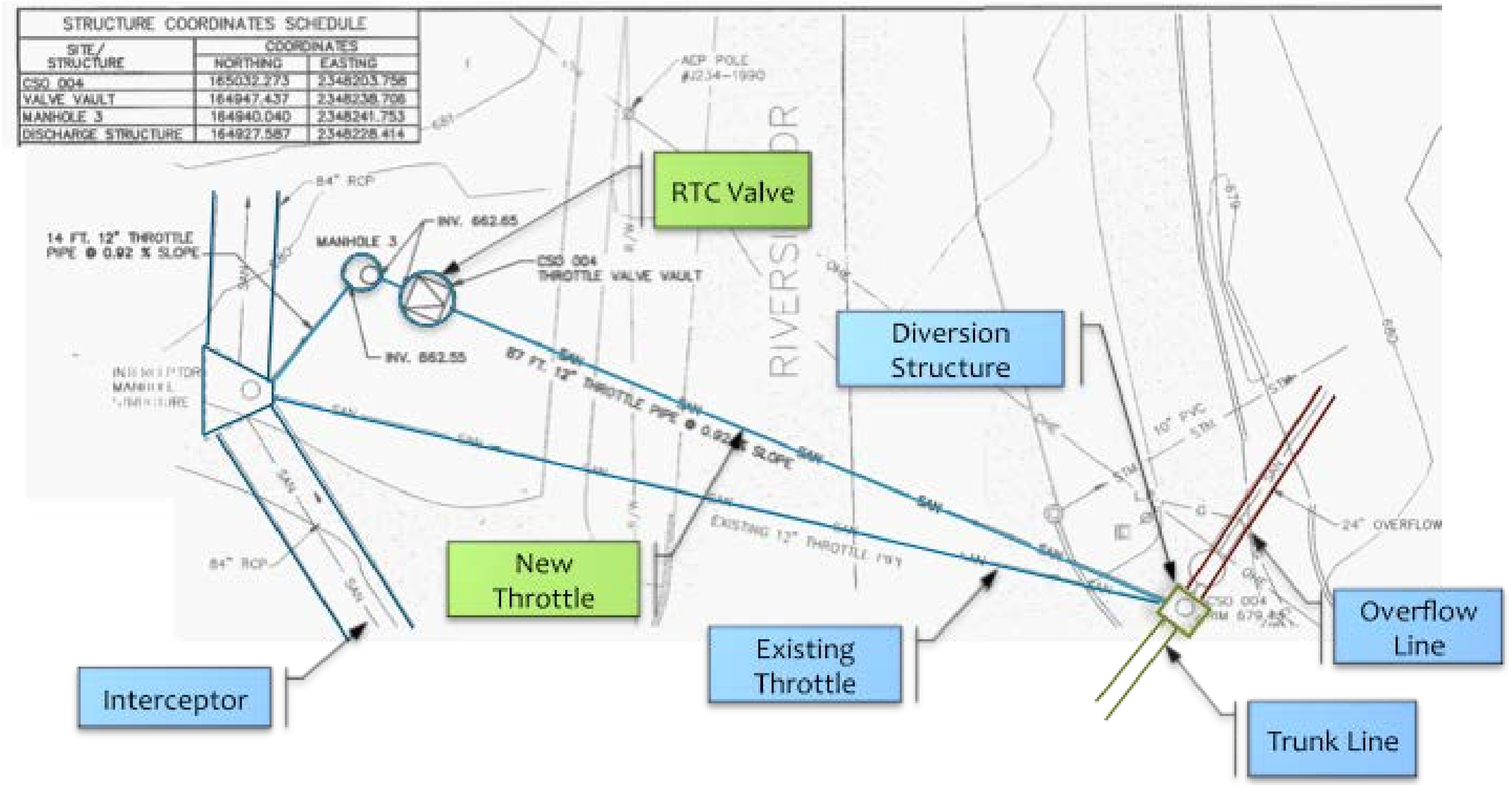
**System Acreage**
**11,863**
11% of Area to be Adjusted



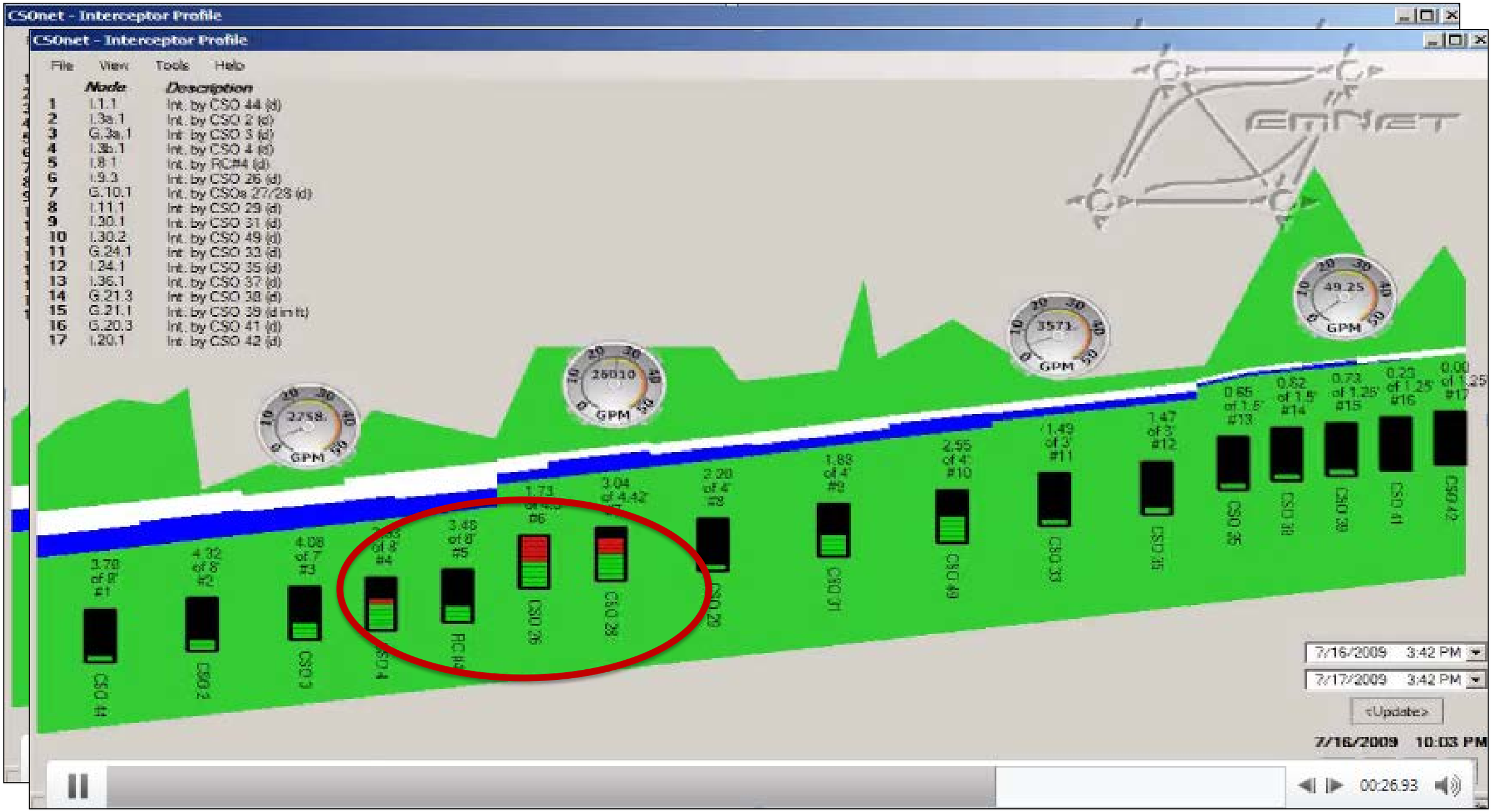
# 2013 Model Update Results

- Installed 11 new flow meters
- Integrated the system in CSONet
- 13 Storms Collected
- Adjusted SWMM model and verified with 9 storms
- Saw an impact on the LTCP
  - Potential Cost Savings
  - Needed Storage Volume Reduction (21%)

# Step 3: Global Real Time Optimization



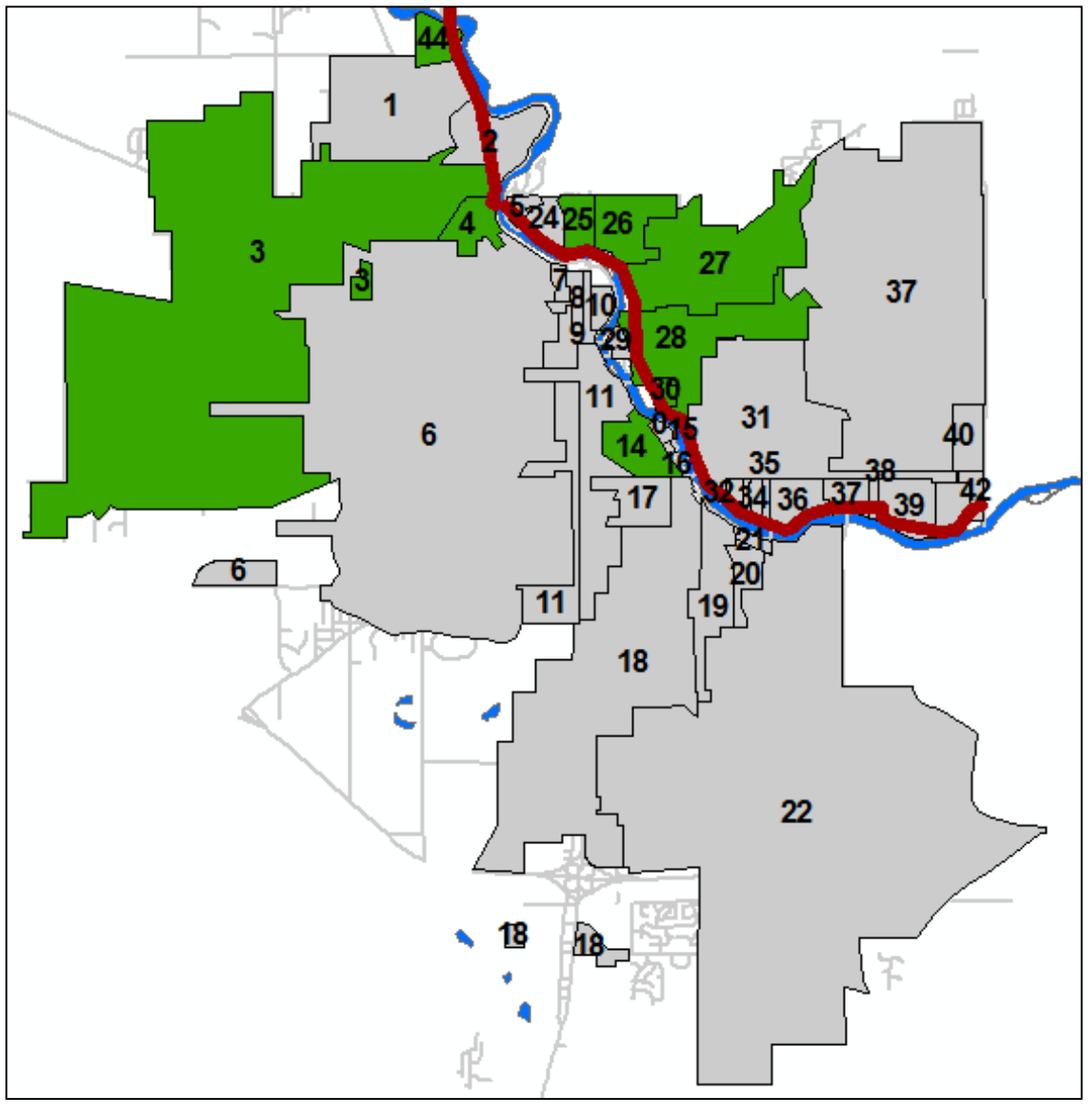
# Interceptor Utilization



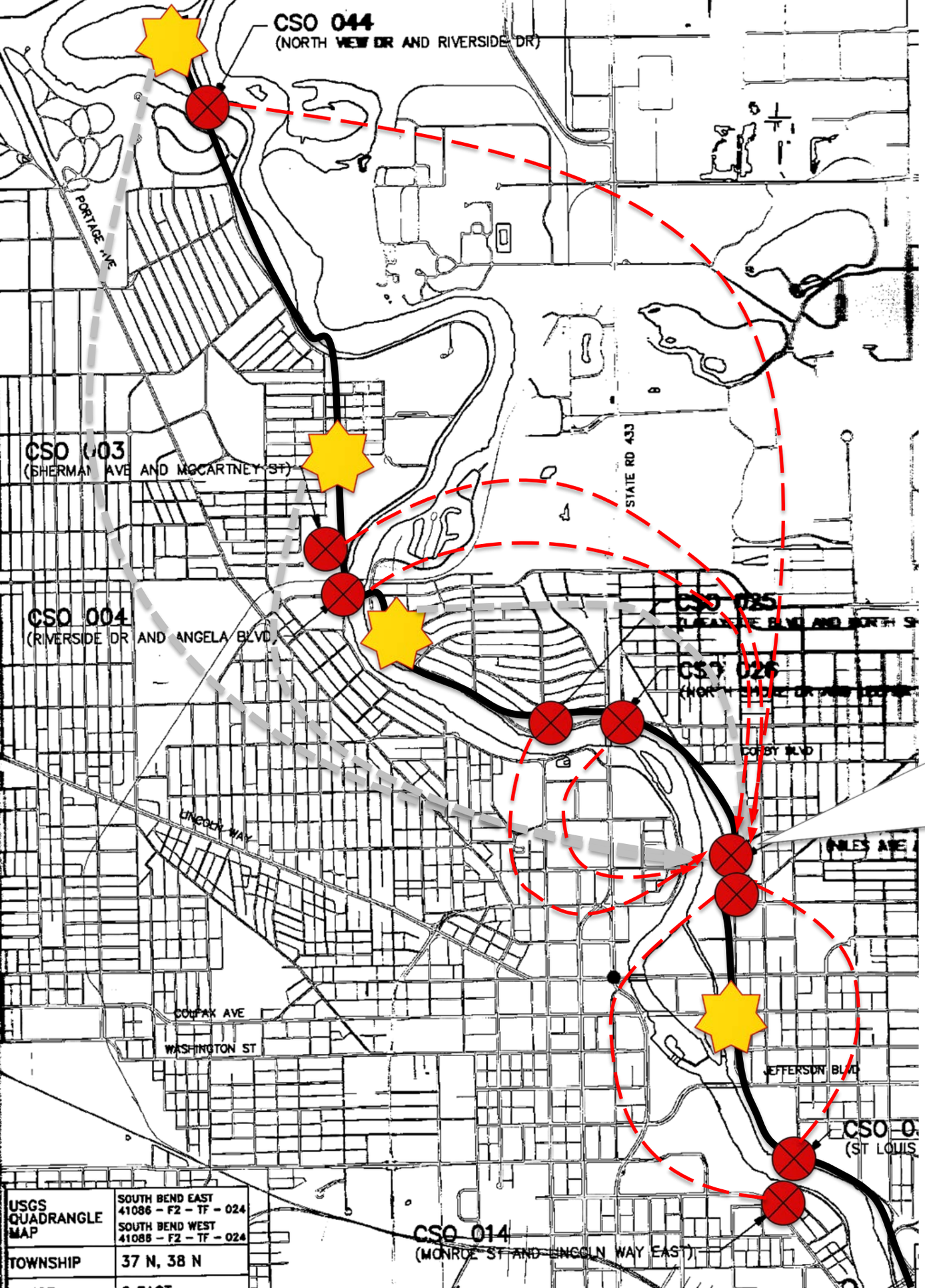
# Regulator Selection

Selection Criteria

- D/S Interceptor Capacity
- Size of existing throttle pipe
- Peak flow in CSO trunkline
- Overflow Volume
- Overflow Frequency
- Maintenance Hotspot




- 9 Regulators Selected
- 26% of Combined Area
- 85% of Total Potential Benefit




# Global Real Time Control

- Default is almost closed
- Likelihood of overflow
- Interceptor Capacity
- Downstream
- At “time of impact”
- Calc. Additional Flow
- Compete for Int. Capacity
- Open Valve

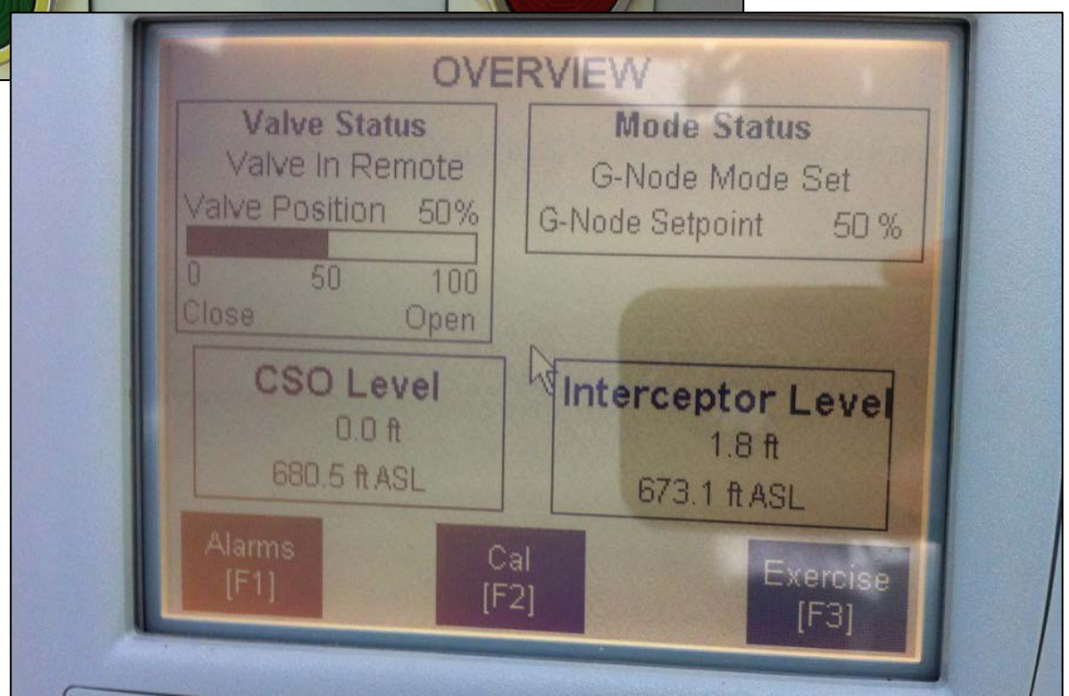
# Valve Installation


- 9 Control Valves
- 12” to 30” diameters
- $2.2 M
- Completed in Spring, 2011

**Start-up**

- Communication
- Battery backup
- Valves CCTV verified
- Valves partially open

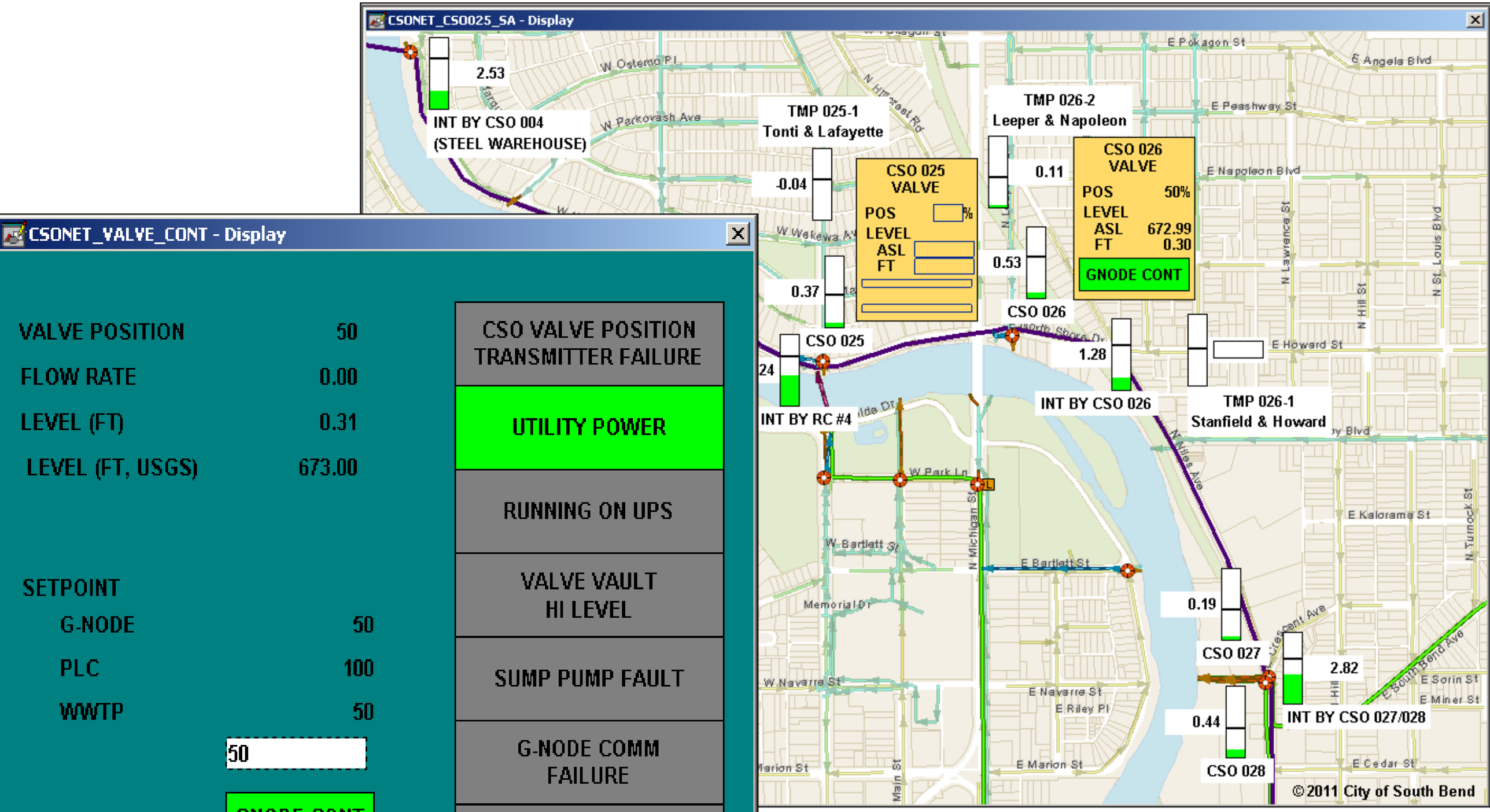
# Modes of Operation

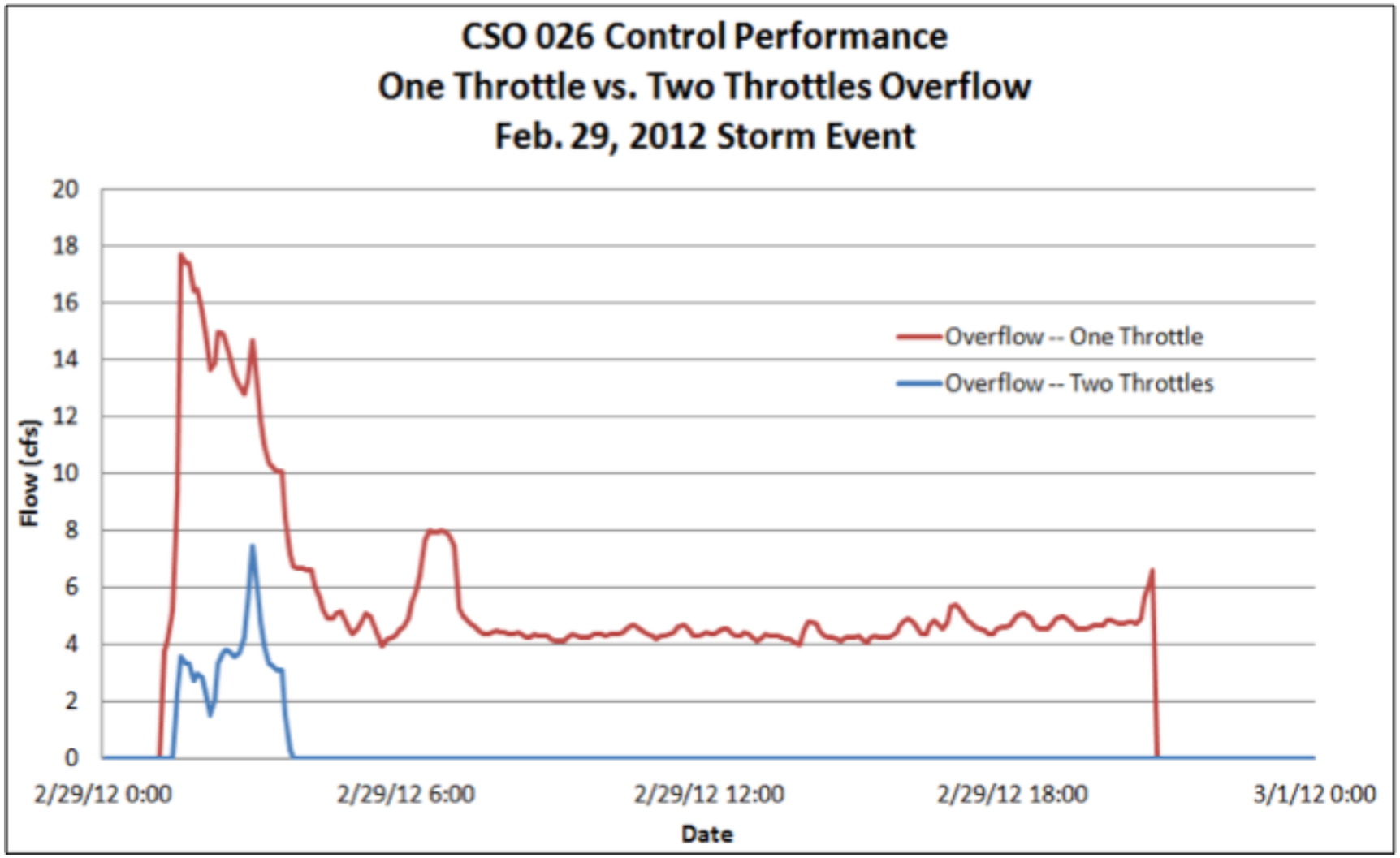

| | Manual | Auto |
|---|---|---|
| Local | From cabinet | Local Reactive |
| Remote | From SCADA | Distributed RTC |

- Weekly valve exercise
- Fail-Safe
  - UPS opens valve
  - default position
  - 30-50% open

# SCADA Integration



# Global Real Time Optimization



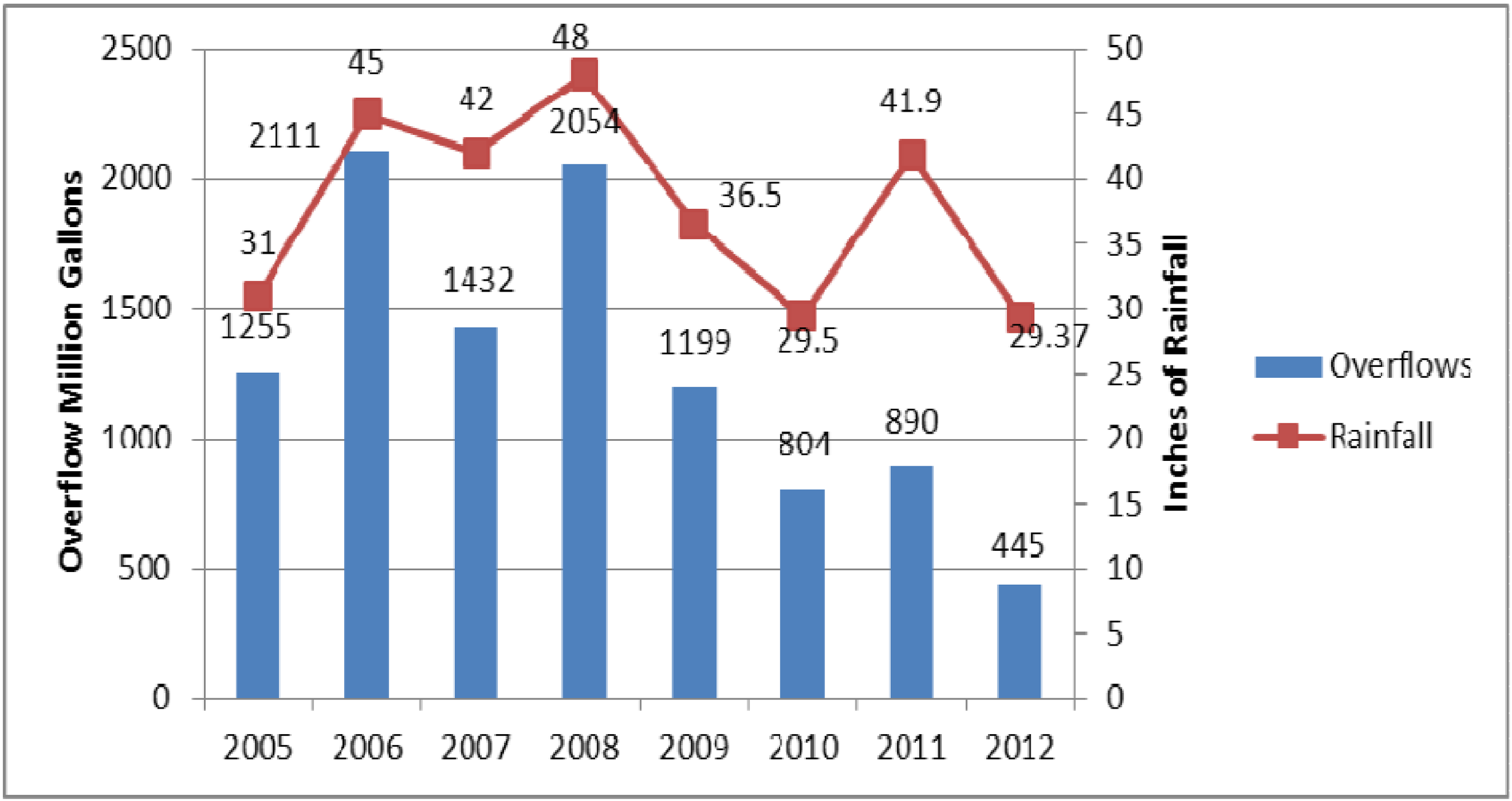

Overflow duration dropped from 19.5 hrs to 2.3 hrs
Overflow volume dropped 76% (0.87 MG to 0.21 MG)

# Outcomes

| CSO | Overflow Volume Original System | Overflow Volume RTC System | Volume Reduction | Percentage Reduction |
|---|---|---|---|---|
| **003** | 4.96 MG | 3.58 MG | 1.36 MG | 28% |
| **004** | 0.10 MG | 0.04MG | 0.06MG | 65% |
| **014** | 1.41 MG | 0.79 MG | 0.62 MG | 44% |
| **025** | 0.07 MG | 0.06 MG | 0.01 MG | 15% |
| **026** | 5.62 MG | 0.50 MG | 5.12 MG | 91% |
| **027** | 1.40 MG | 1.30 MG | 0.10 MG | 7% |
| **028** | 0.002 MG | 0.001 MG | 0.001 MG | 36% |
| **030** | 0.030 MG | 0.001 MG | 0.029 MG | 95% |
| **044** | 0.17 MG | 0.03 MG | 0.14 MG | 80% |
| **TOTAL** | **13.67 MG** | **6.39 MG** | **7.44 MG** | **54%** |

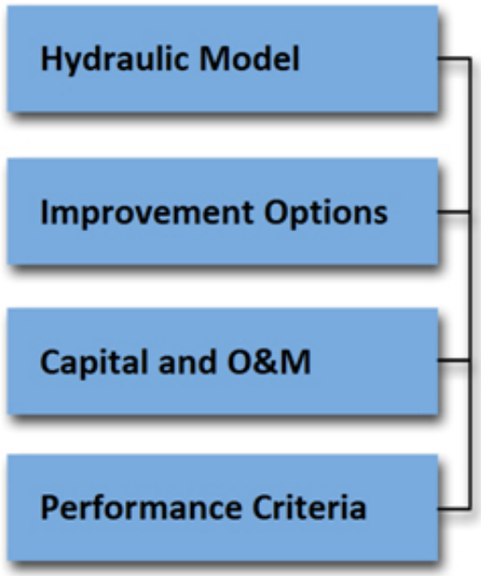
February-June 2012

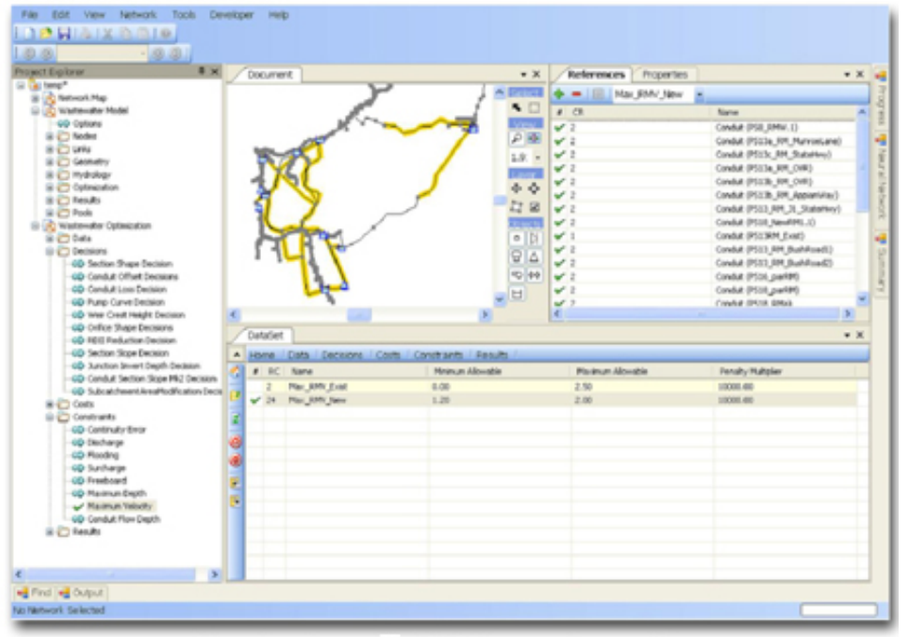
# Annual Overflow Reduction



# South Bend CSO Long Term Control Plan Optimization: Comparison of Grey-Only vs. Grey-Green Infrastructure Least-Cost Solutions

*Optimizer WCS™ uses a hybrid genetic algorithm optimization routine to perform an exhaustive analysis of feasible improvement alternatives.*



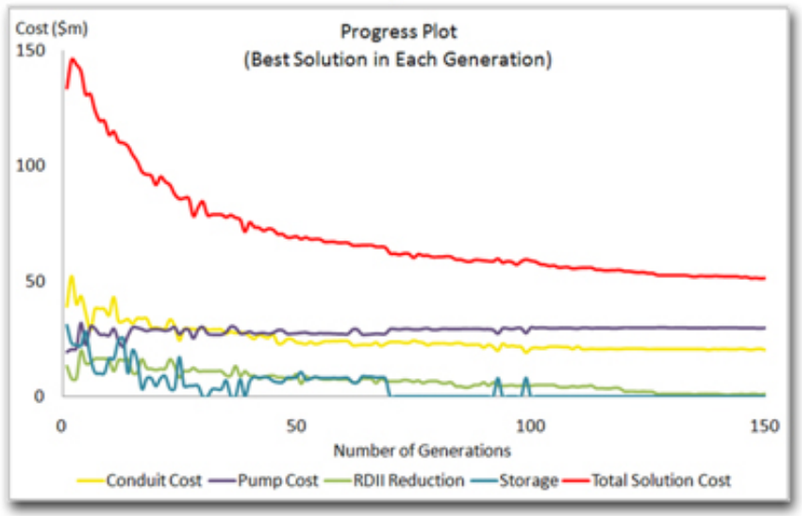



Optimizer WCS User Interface

Sensitivity Evaluations

| Improvement Category | Baseline Solution Cost ($M) | Optimized Solution Cost ($M) |
|---|---|---|
| Gravity Sewer | 6.7 | 5.2 |
| Rising Main | 19.3 | 13.8 |
| Pump Station (Capital) | 9.1 | 6.5 |
| Pump Station (O&M) | 24.0 | 21.5 |
| Storage Facility | 4.4 | 0.0 |
| Rehabilitation | 0.0 | 0.0 |
| **Total Project Cost** | **63.5** | **47.1** |

Optimization Solution Cost Summary




Optimization Progress

# Objectives of the South Bend LTCP Optimization Project

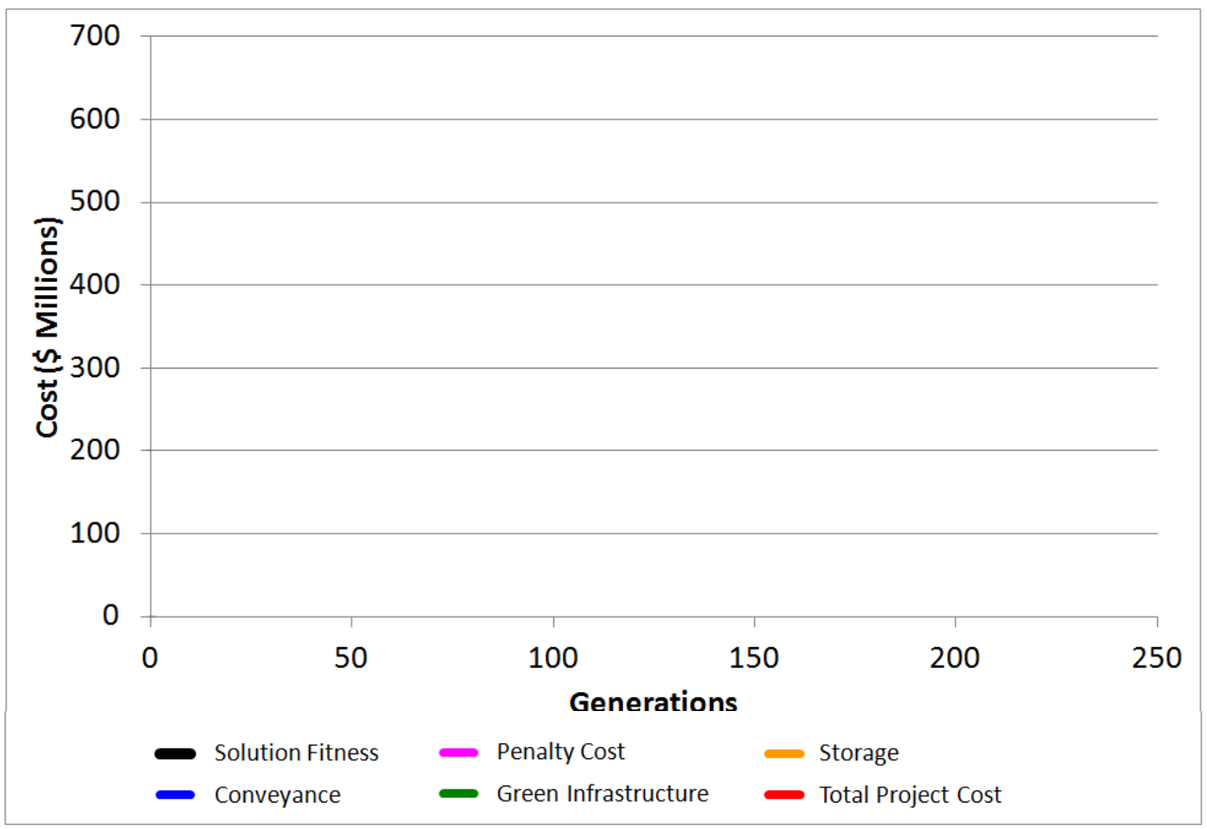
- Look at many options
- Optimize grey infrastructure and determine most cost-effective conveyance/storage strategy
- Identify Cost Effective LID on a basin level
- Optimize real time controls (RTC) to maximize utilization of existing and future infrastructure
- Prioritize improvement projects to achieve maximum CSO volume reduction within available budget for each planning horizon

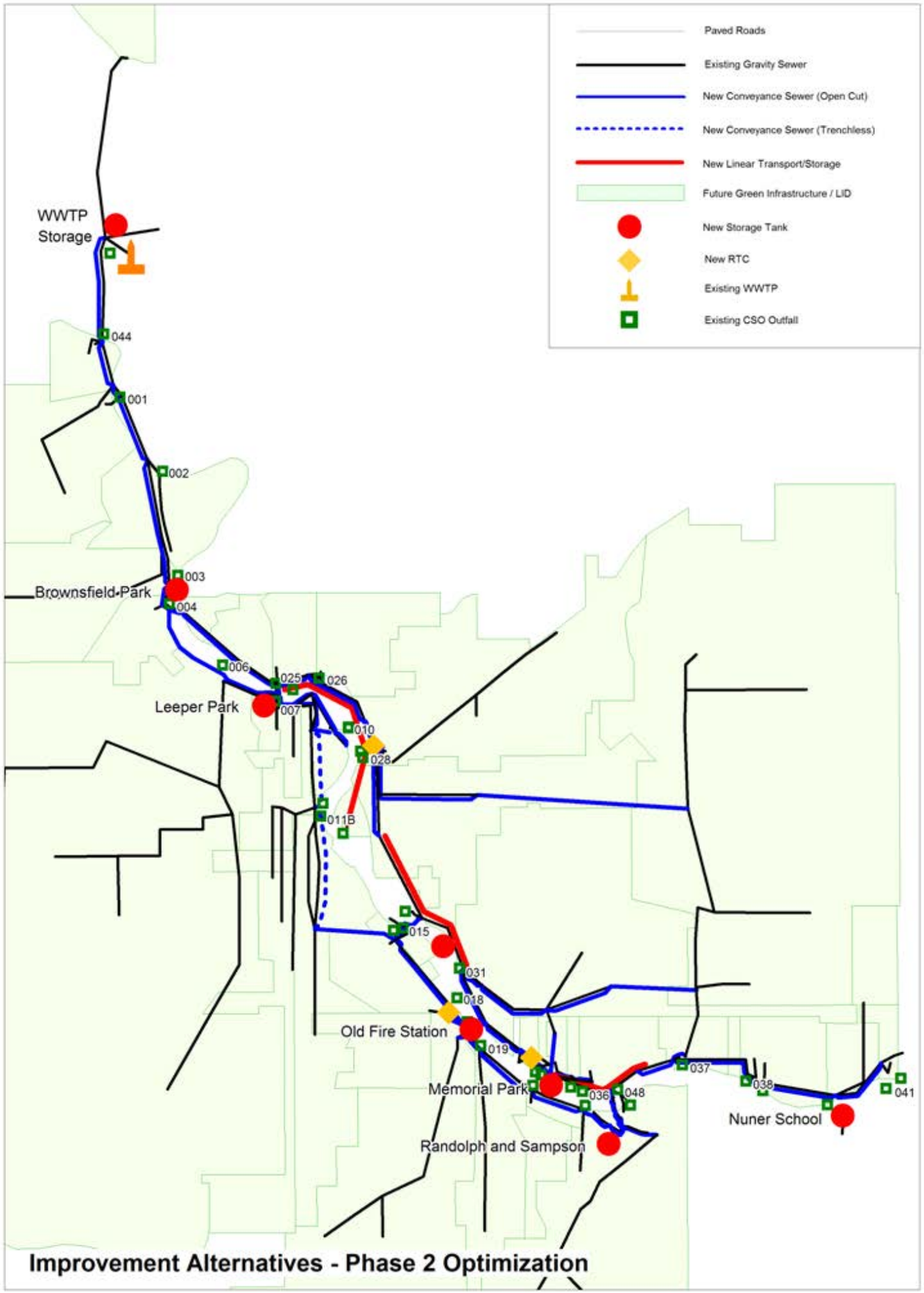
# Objectives of the South Bend LTCP Optimization Project - LID

- Rooftop Disconnection
- Rain Gardens
- Bioretention Lawn Extensions
- Bioretention Bumpouts
- Porous Paving Systems

# Animation of Optimizer WCS™ Run

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | | | |
| Storage (Tanks & Linear T/S) | | | |
| Green Infrastructure | | | |
| **Total Project Cost** | | | |
| Performance Violation Penalty Cost | | | |
| **Total Solution Fitness** | | | |

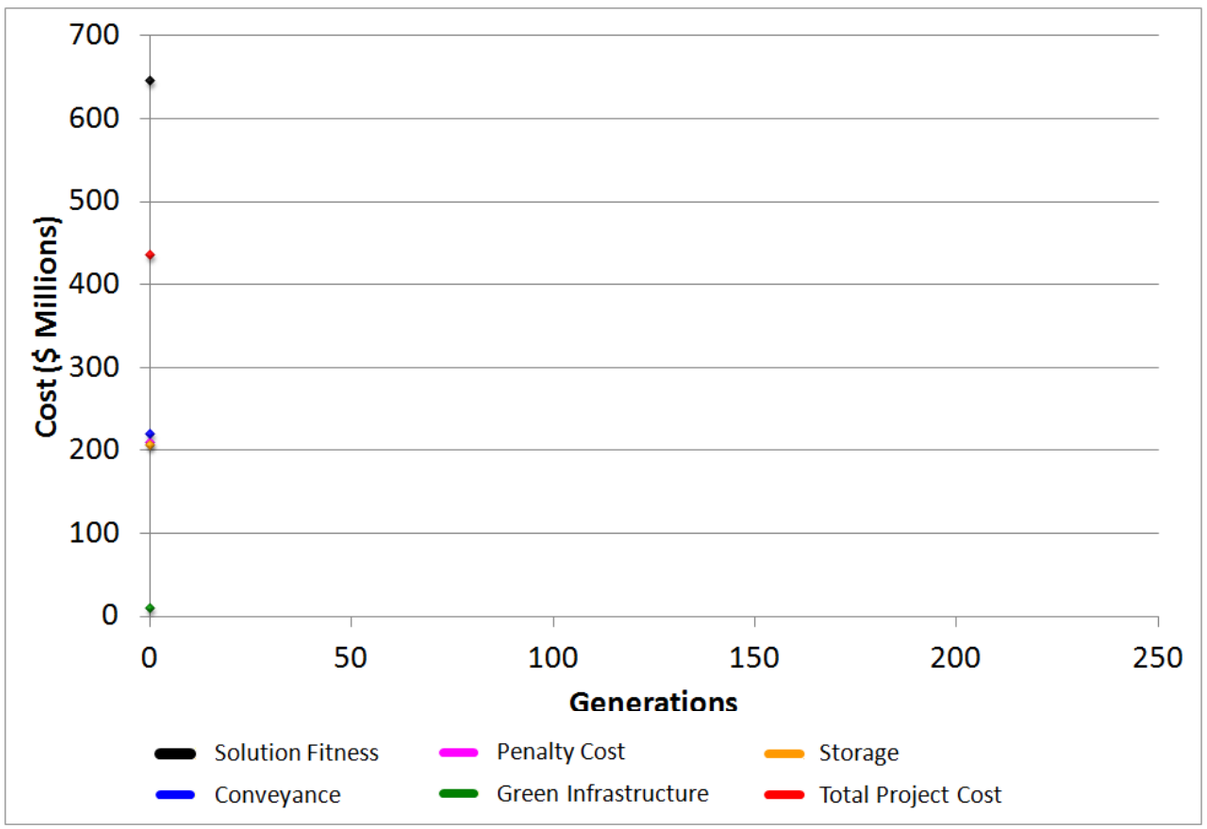


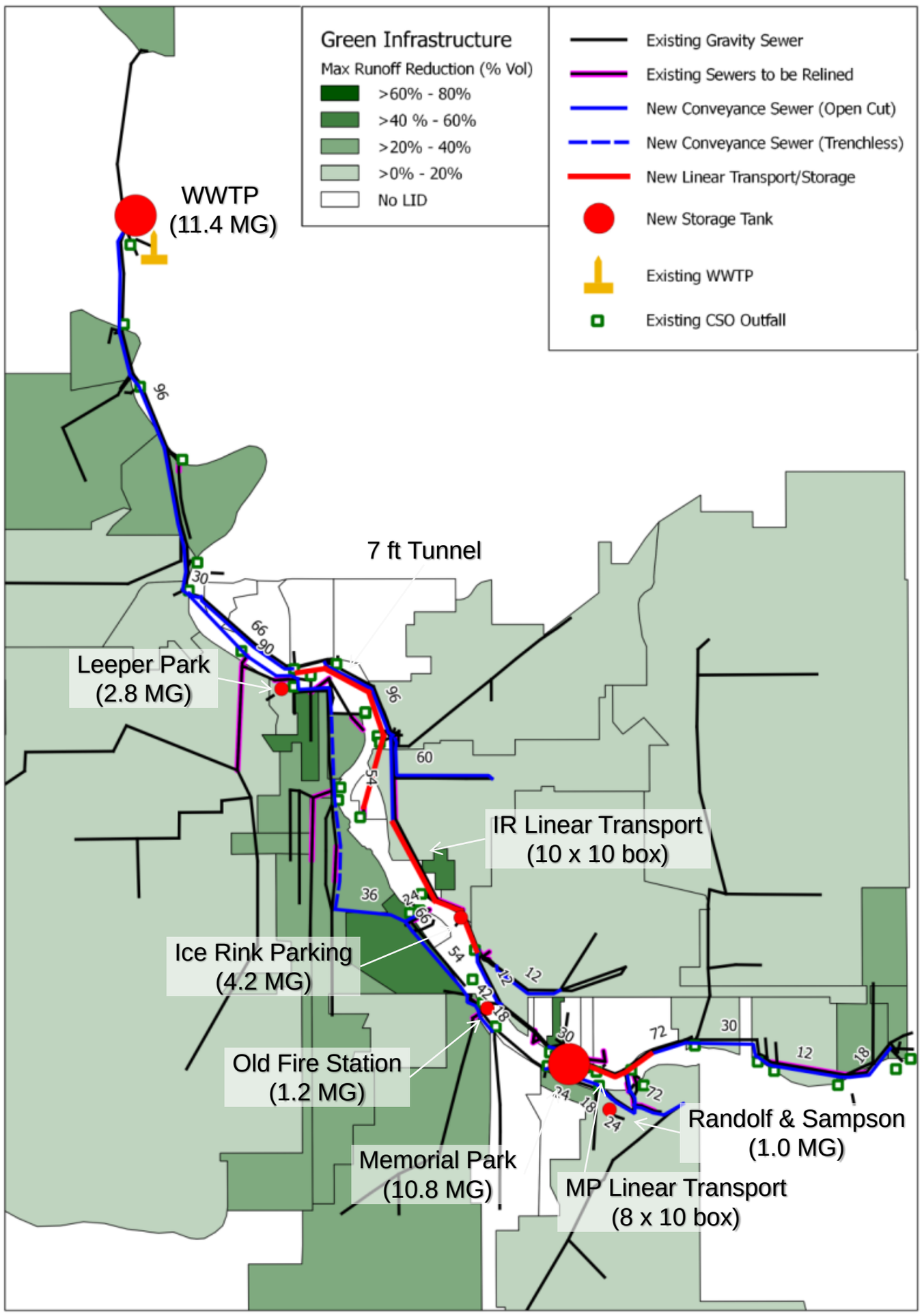



# Generation 1

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 212.58 | 6.97 | 219.55 |
| Storage (Tanks & Linear T/S) | 164.79 | 41.22 | 206.01 |
| Green Infrastructure | 8.99 | 0.79 | 9.78 |
| **Total Project Cost** | **386.36** | **48.98** | **435.33** |
| Performance Violation Penalty Cost | - | - | 209.17 |
| **Total Solution Fitness** | **-** | **-** | **644.50** |

- Best solution in 1st generation
- Total of 200 trial solutions evaluated
- Actual processing time: 0:15 hours (104 cores)

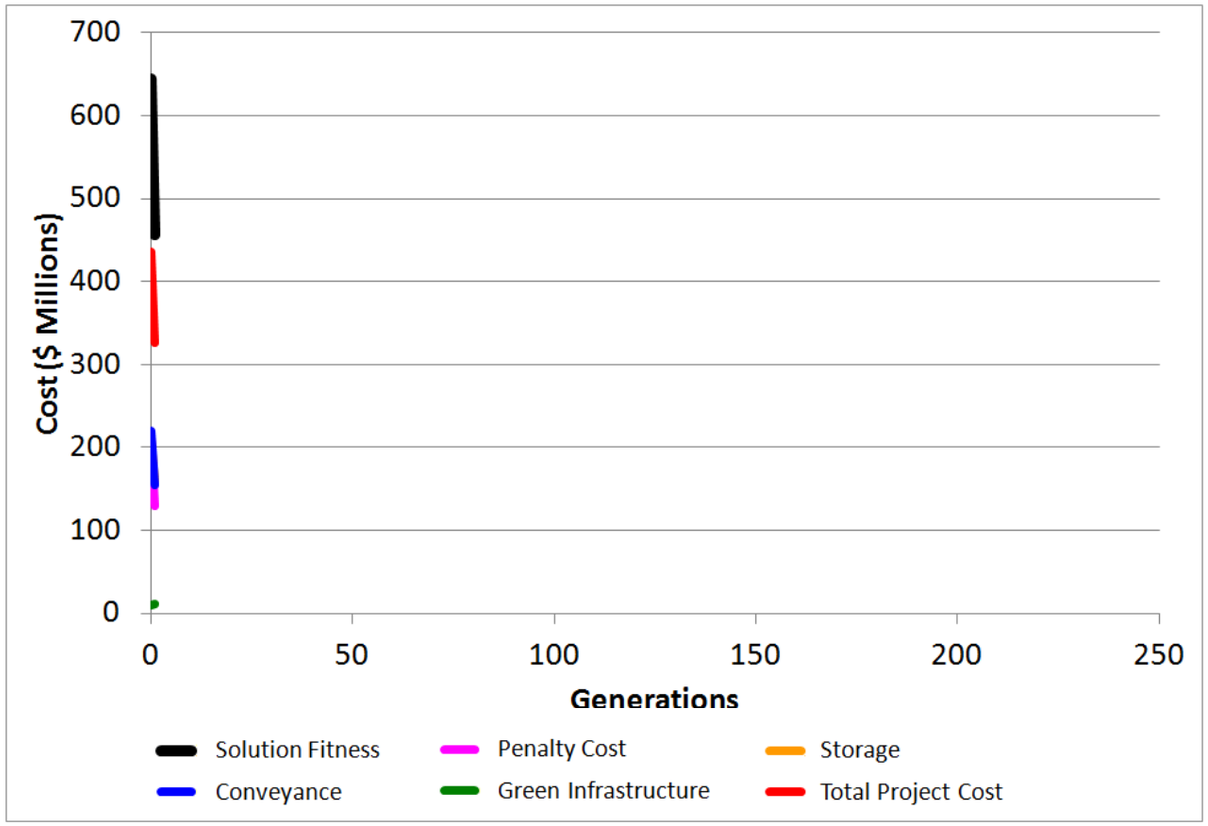


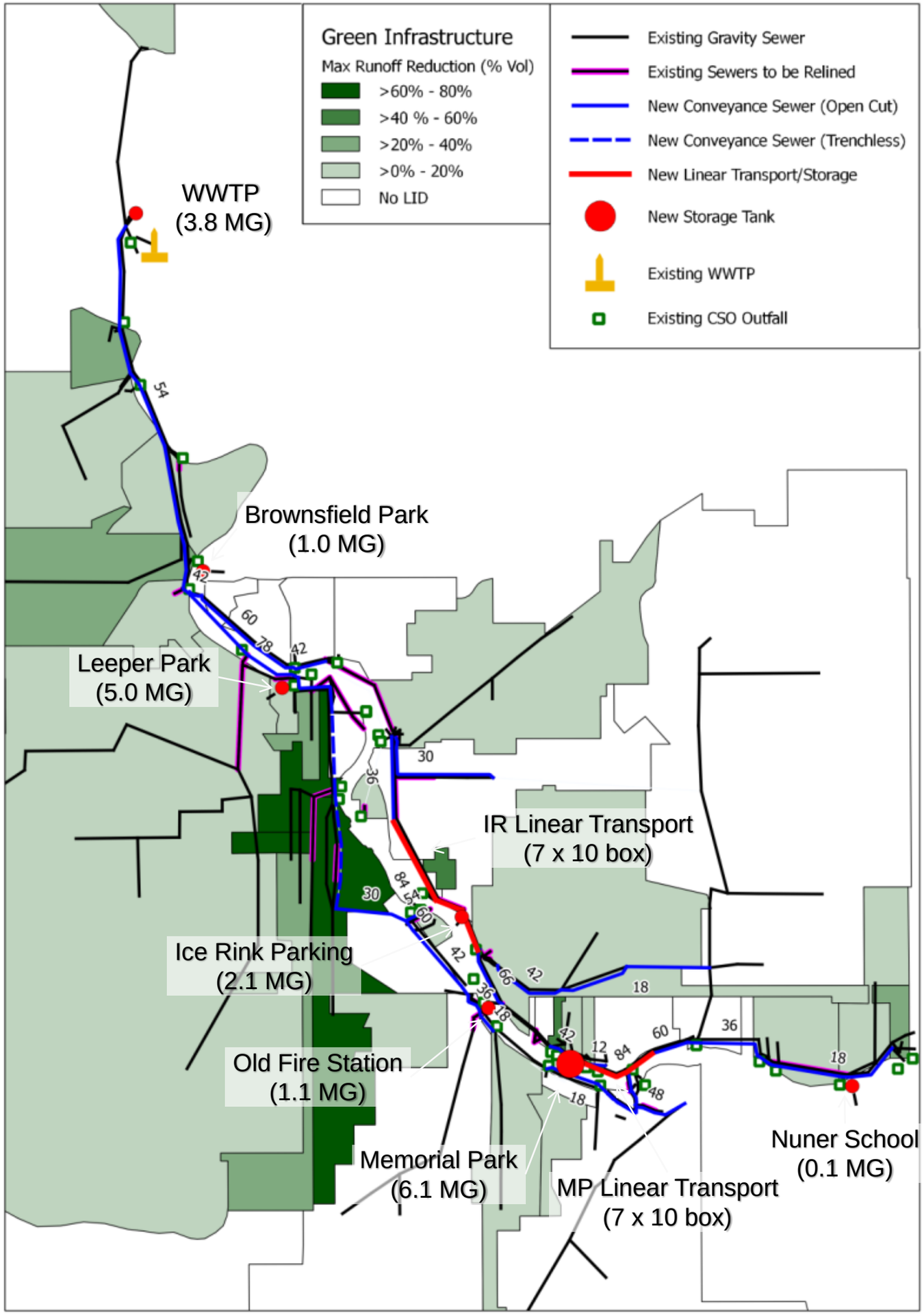



# Generation 2

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 151.34 | 4.06 | 155.40 |
| Storage (Tanks & Linear T/S) | 129.47 | 30.22 | 159.69 |
| Green Infrastructure | 10.44 | 0.92 | 11.35 |
| **Total Project Cost** | **291.25** | **35.19** | **326.44** |
| Performance Violation Penalty Cost | - | - | 129.46 |
| **Total Solution Fitness** | - | - | **455.90** |

- Best solution in 2nd generation
- Total of 400 trial solutions evaluated
- Actual processing time: 0:32 hours (104 cores)

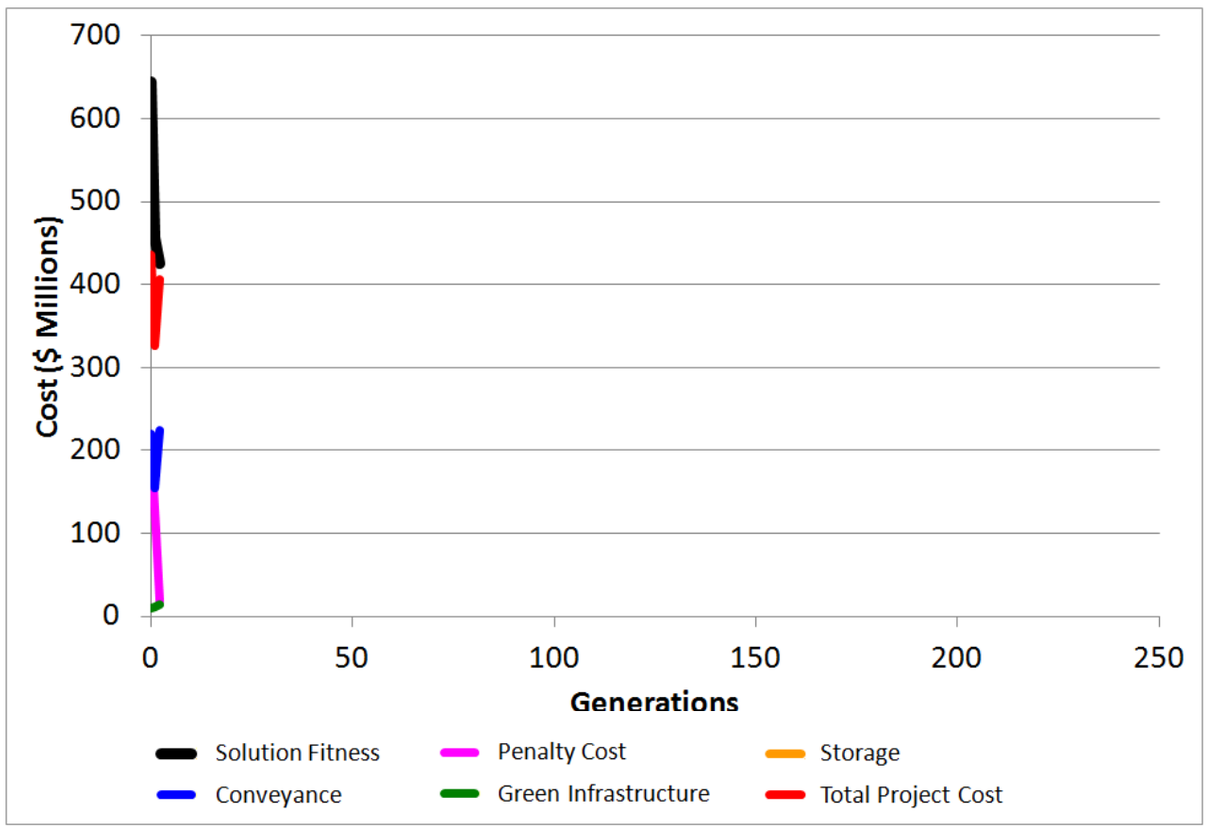


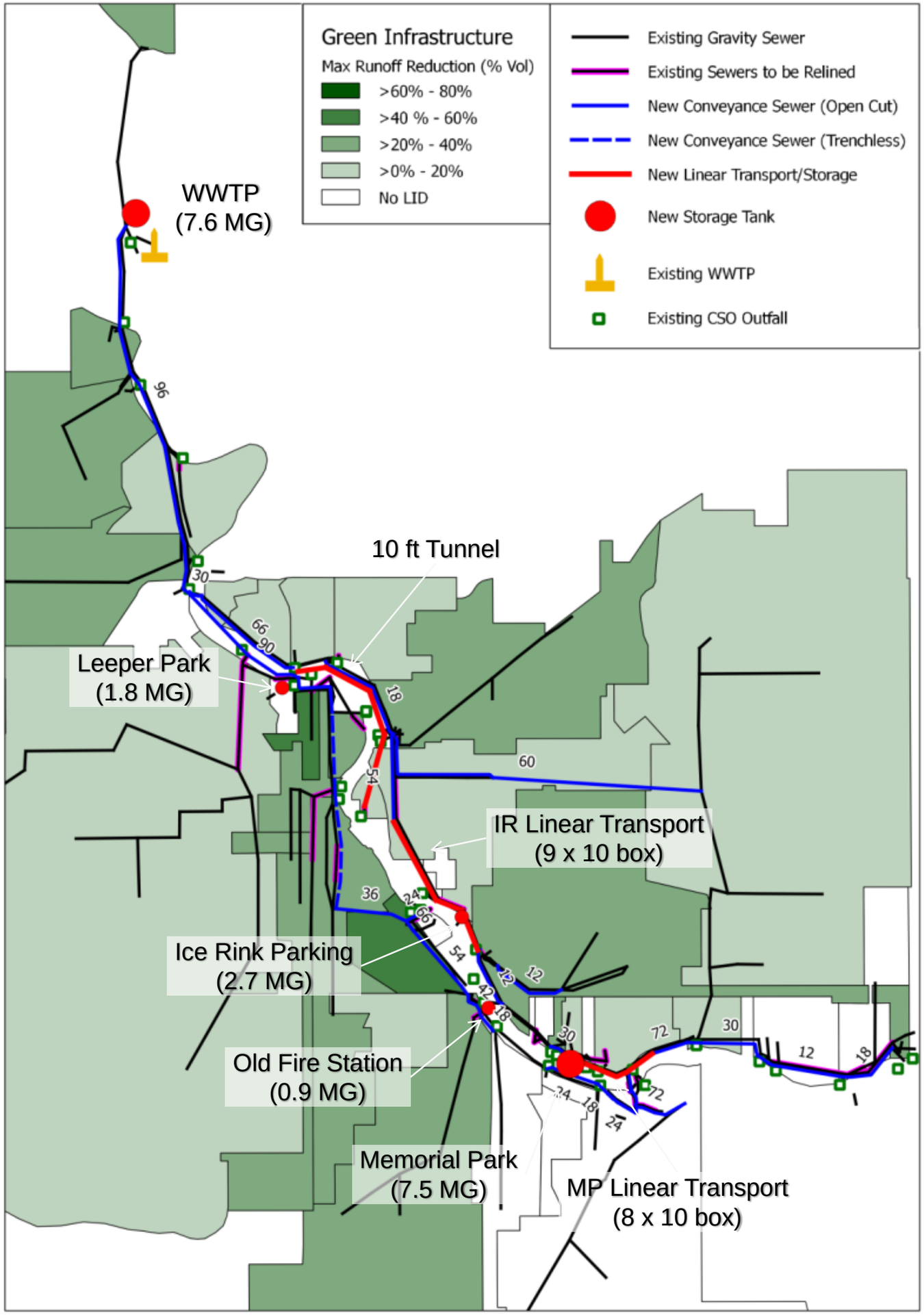



# Generation 3

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 217.79 | 7.23 | 225.02 |
| Storage (Tanks & Linear T/S) | 136.04 | 30.76 | 166.81 |
| Green Infrastructure | 12.85 | 1.11 | 13.97 |
| **Total Project Cost** | **366.68** | **39.11** | **405.79** |
| Performance Violation Penalty Cost | - | - | 19.27 |
| **Total Solution Fitness** | - | - | **425.06** |

- Best solution in 3rd generation
- Total of 600 trial solutions evaluated
- Actual processing time: 0:48 hours (104 cores)

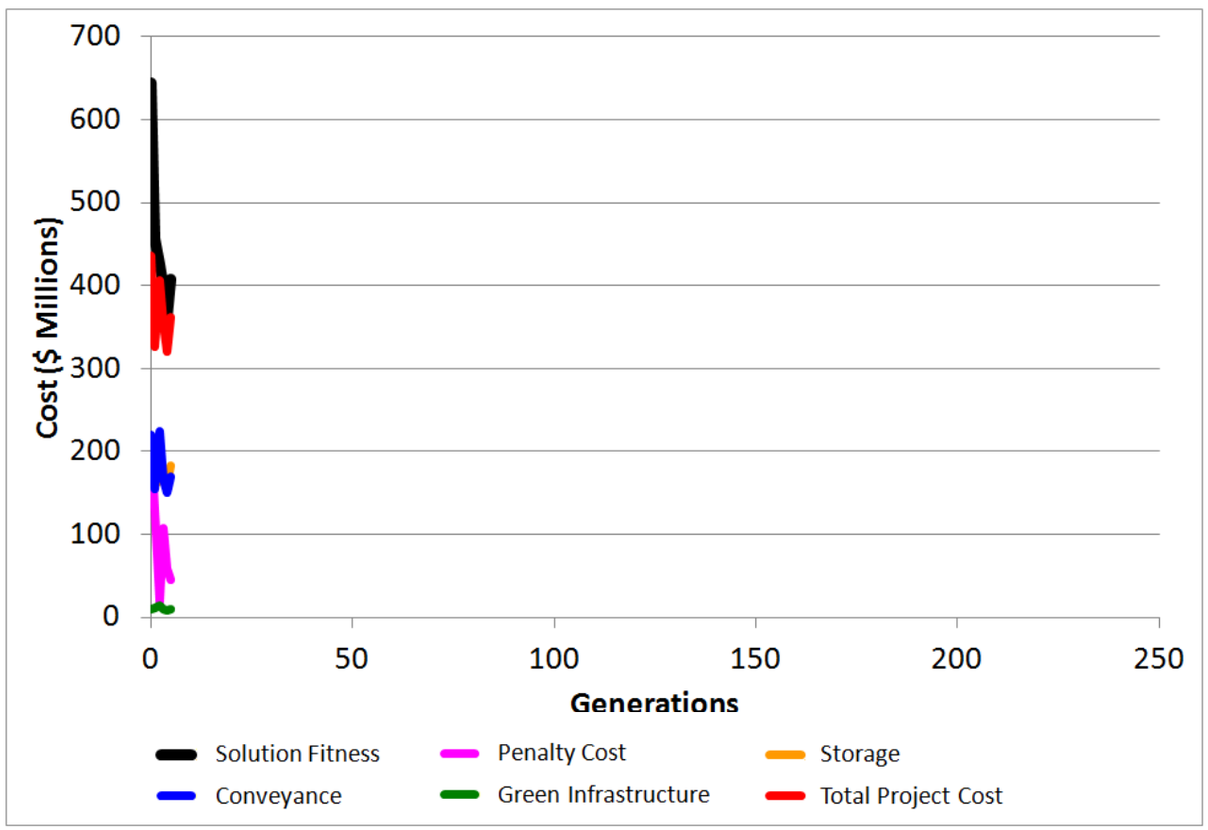


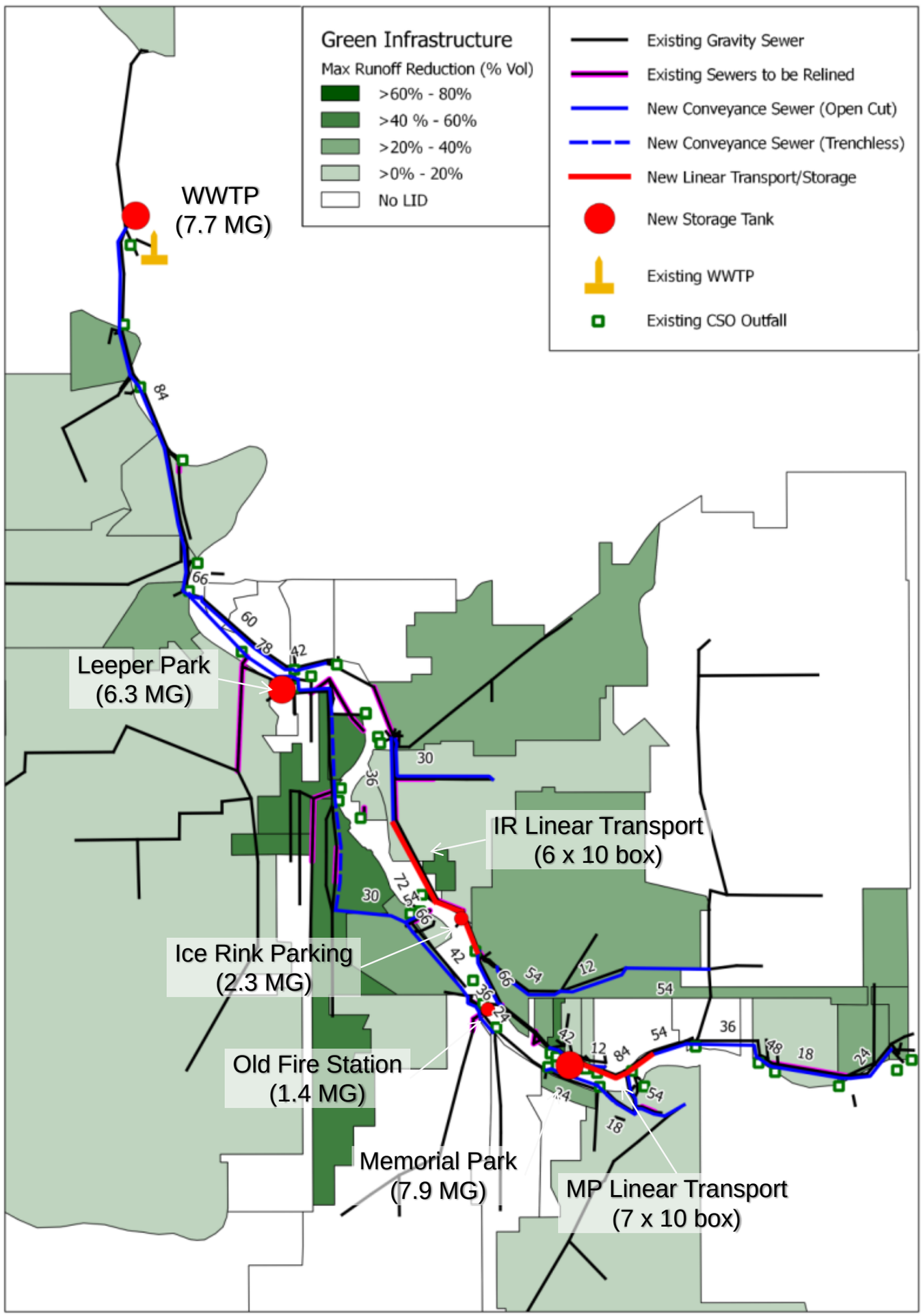



# Generation 5

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 165.77 | 4.37 | 170.14 |
| Storage (Tanks & Linear T/S) | 147.91 | 34.46 | 182.37 |
| Green Infrastructure | 8.58 | 0.76 | 9.34 |
| **Total Project Cost** | **322.27** | **39.60** | **361.86** |
| Performance Violation Penalty Cost | - | - | 45.89 |
| **Total Solution Fitness** | - | - | **407.75** |

- Best solution in 5th generation
- Total of 1,000 trial solutions evaluated
- Actual processing time: 1:38 hours (104 cores)

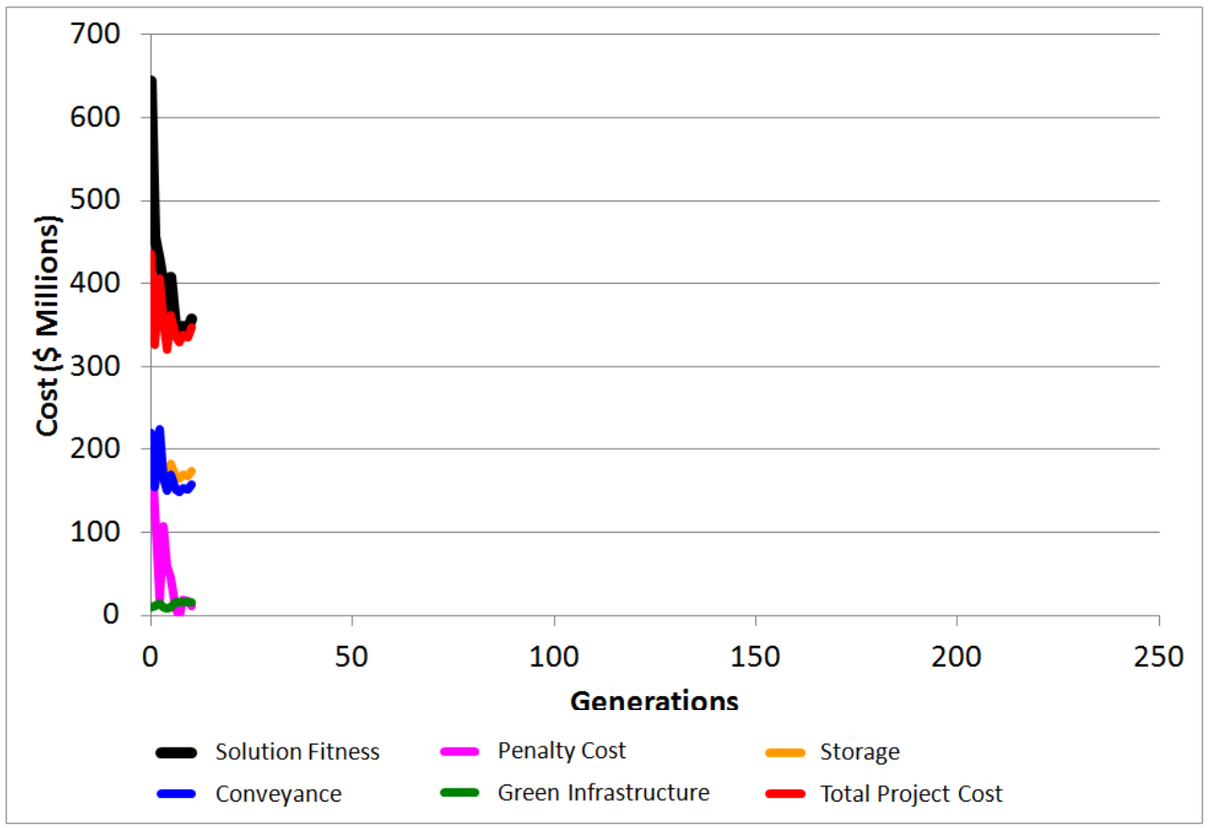


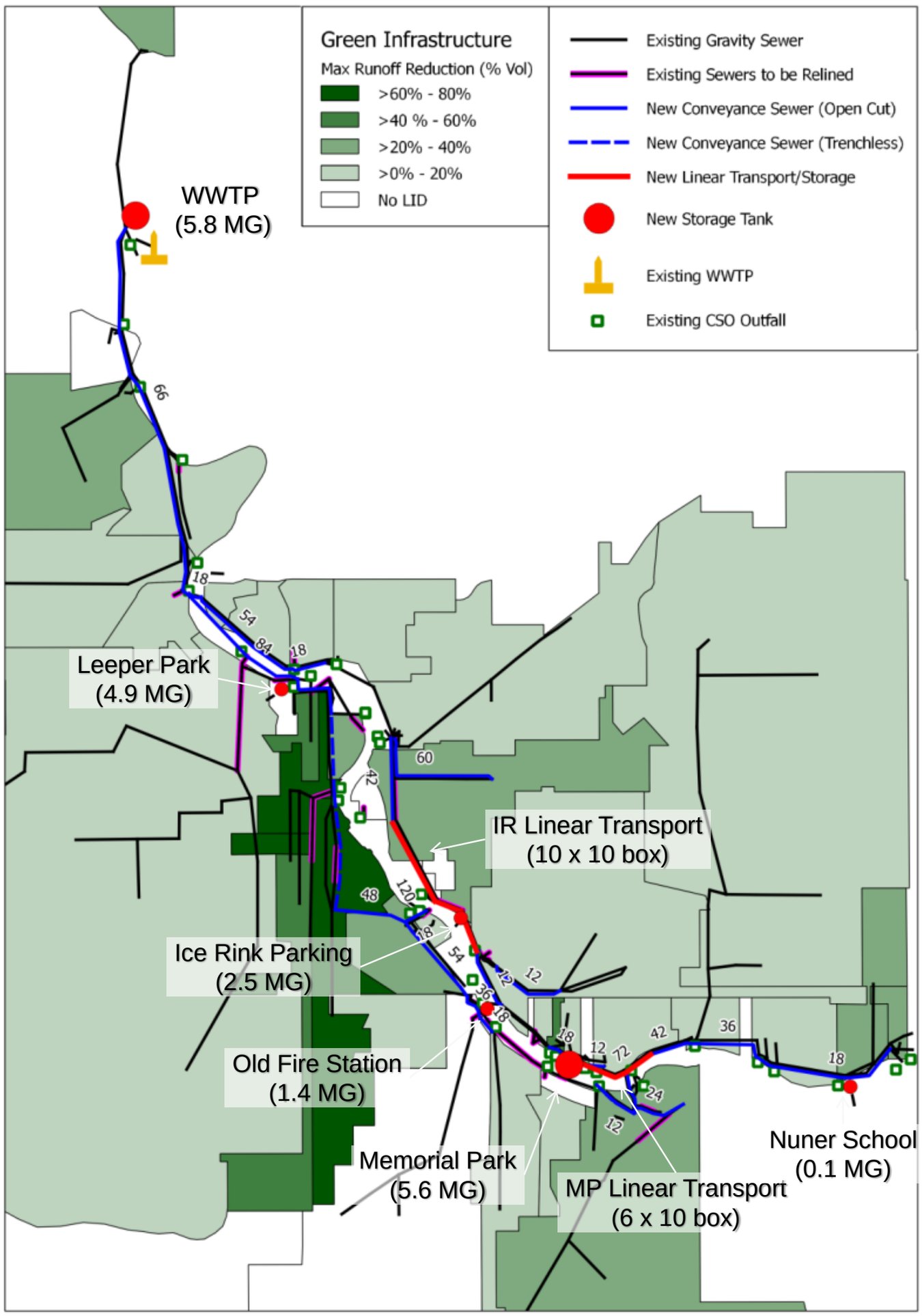



# Generation 10

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 153.15 | 4.02 | 157.17 |
| Storage (Tanks & Linear T/S) | 139.10 | 34.84 | 173.94 |
| Green Infrastructure | 14.82 | 1.26 | 16.07 |
| **Total Project Cost** | **307.06** | **40.12** | **347.18** |
| Performance Violation Penalty Cost | - | - | 10.89 |
| **Total Solution Fitness** | - | - | **358.07** |

- Best solution in 10th generation
- Total of 2,000 trial solutions evaluated
- Actual processing time: 2:57 hours (104 cores)

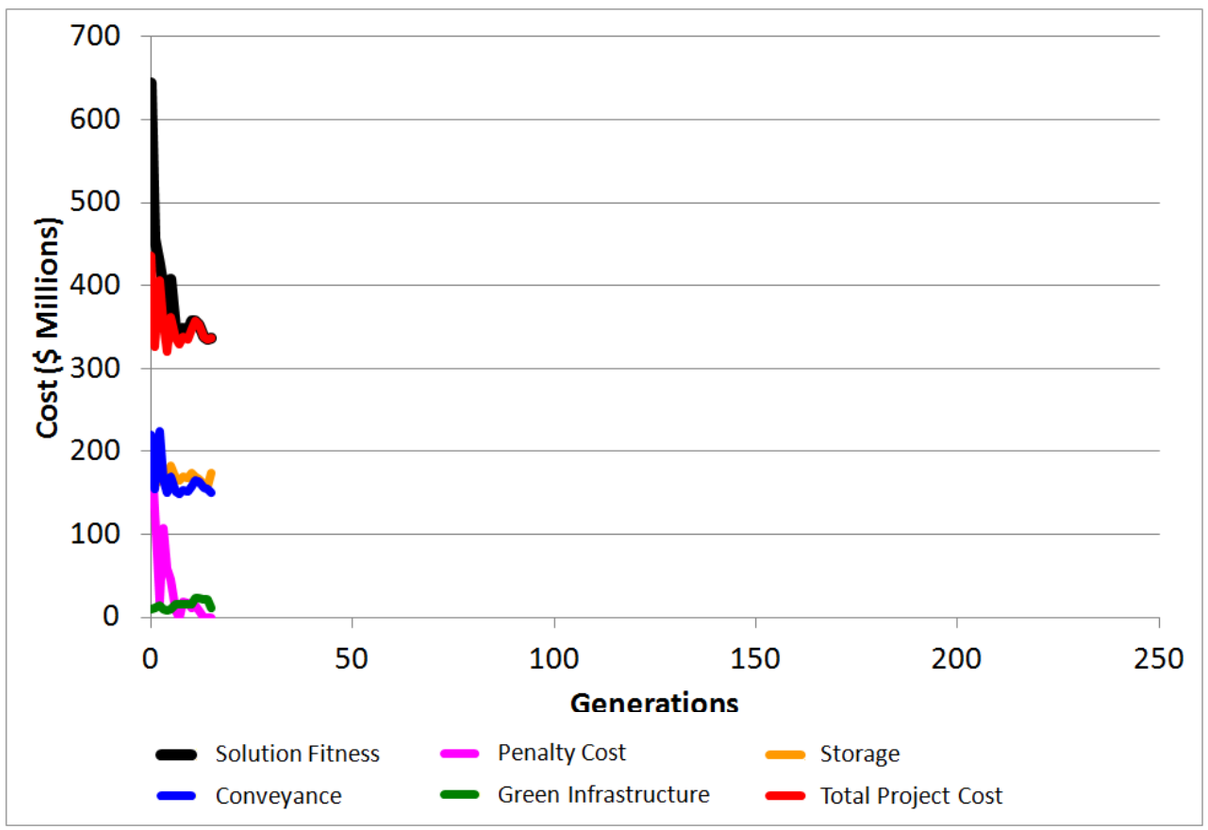


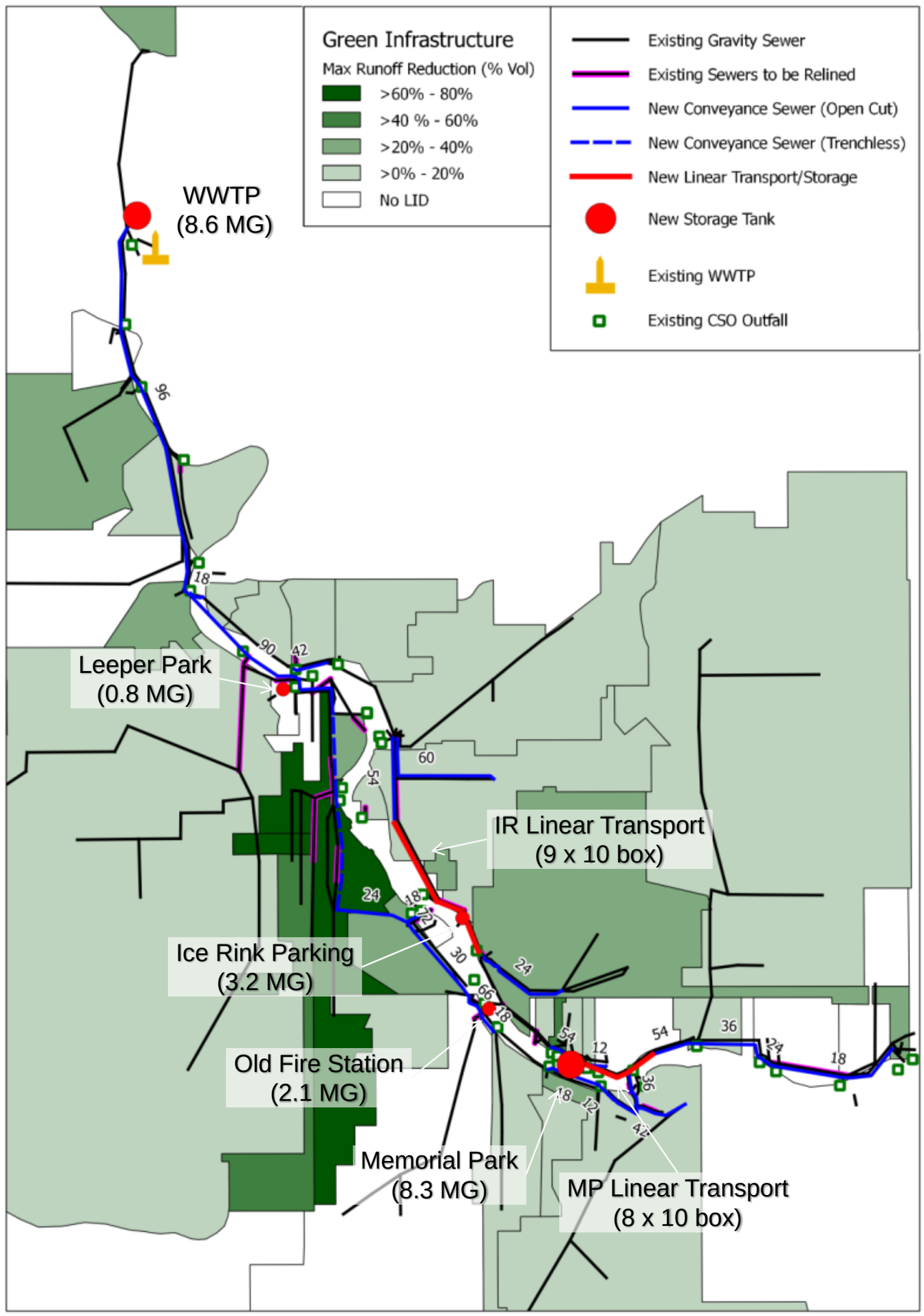



# Generation 15

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 147.36 | 3.36 | 150.72 |
| Storage (Tanks & Linear T/S) | 142.39 | 32.11 | 174.51 |
| Green Infrastructure | 10.43 | 0.91 | 11.35 |
| **Total Project Cost** | **300.18** | **36.39** | **336.57** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **336.57** |

- Best solution in 15th generation
- Total of 3,000 trial solutions evaluated
- Actual processing time: 4:15 hours (104 cores)

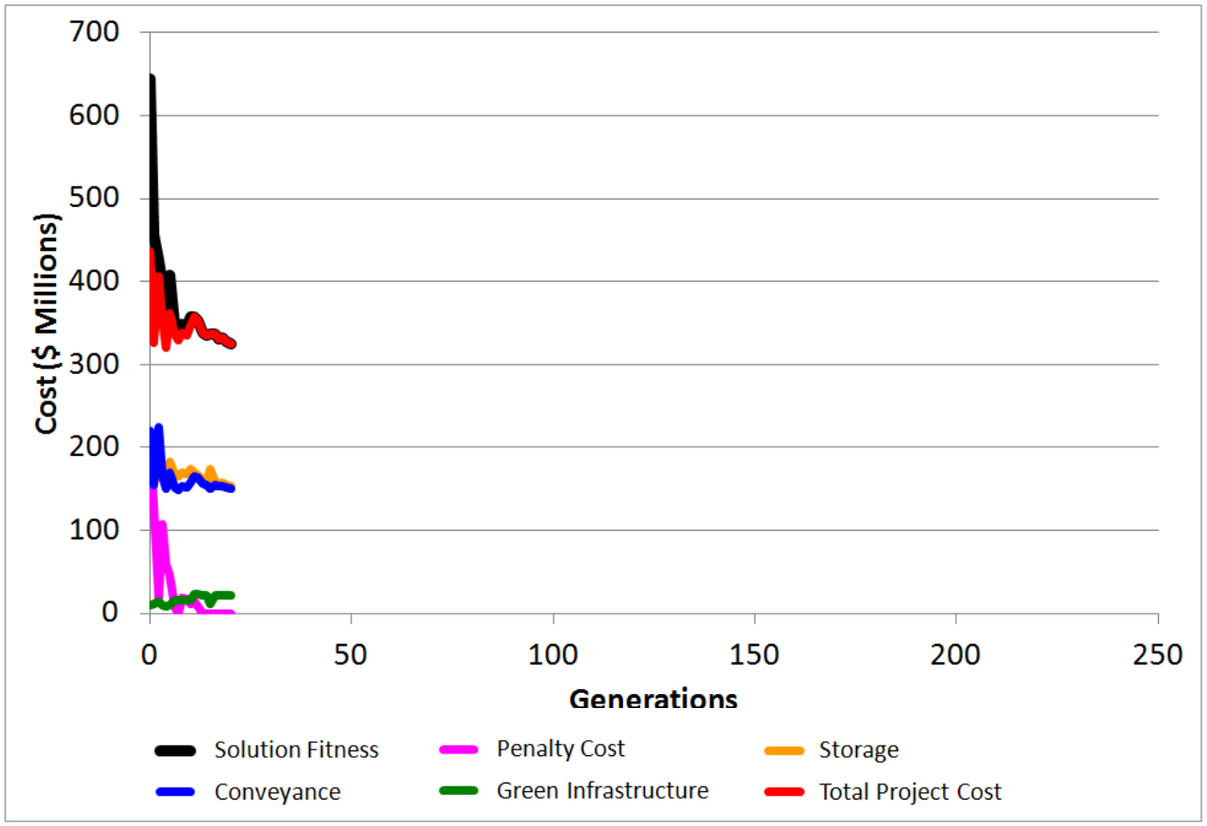


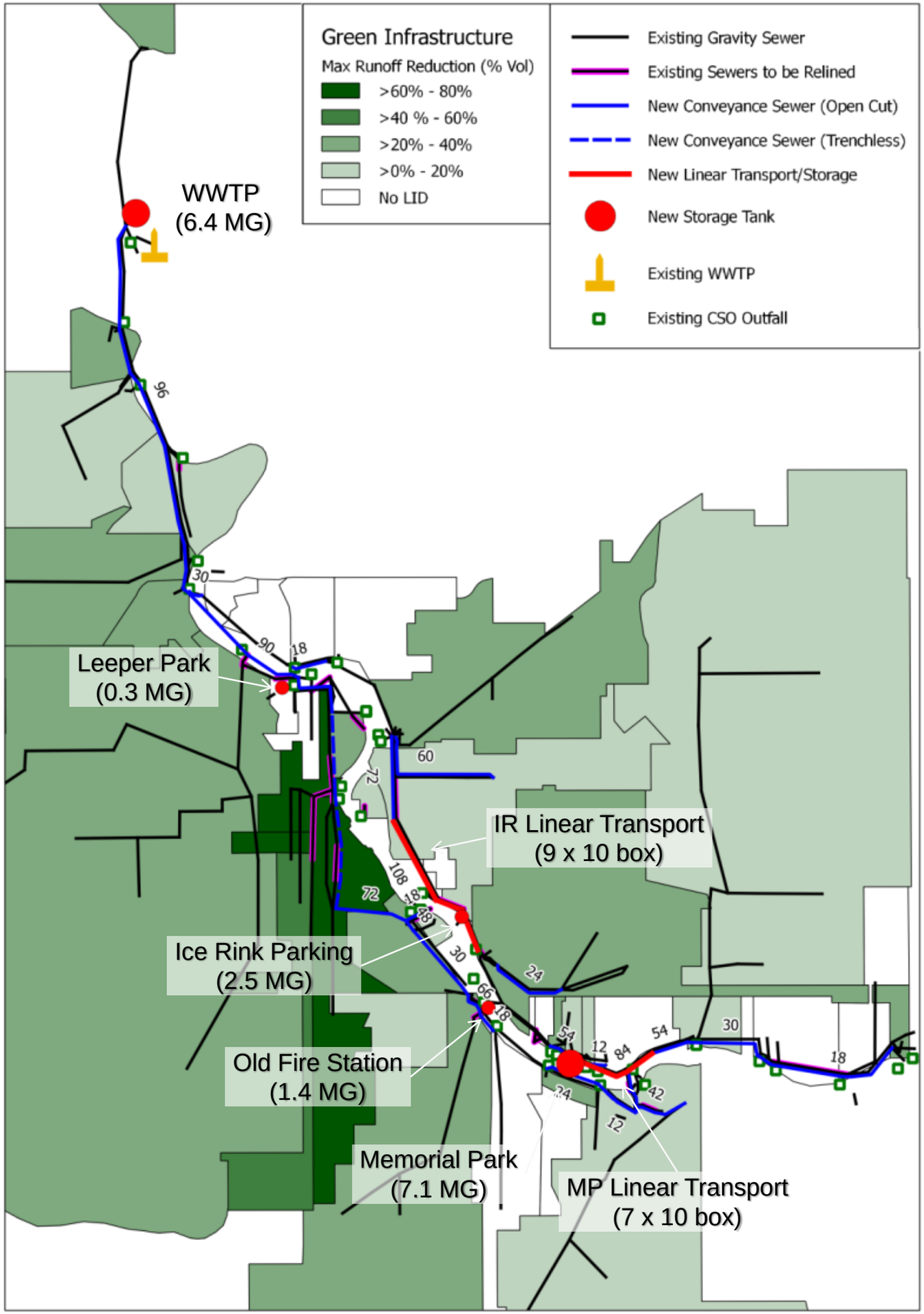



# Generation 20

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 146.43 | 3.42 | 149.85 |
| Storage (Tanks & Linear T/S) | 124.94 | 28.61 | 153.55 |
| Green Infrastructure | 19.34 | 1.69 | 21.04 |
| **Total Project Cost** | **290.72** | **33.72** | **324.44** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **324.44** |

- Best solution in 20th generation
- Total of 4,000 trial solutions evaluated
- Actual processing time: 5:30 hours (104 cores)

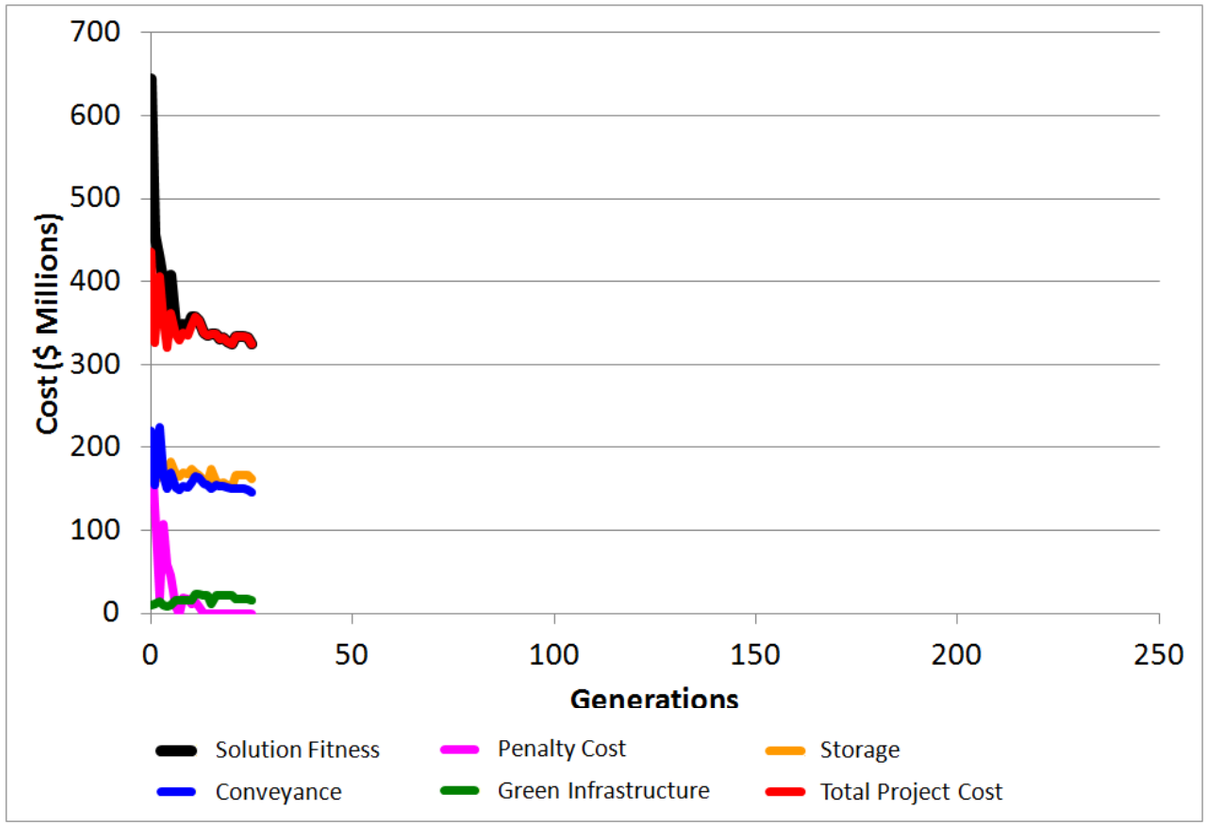


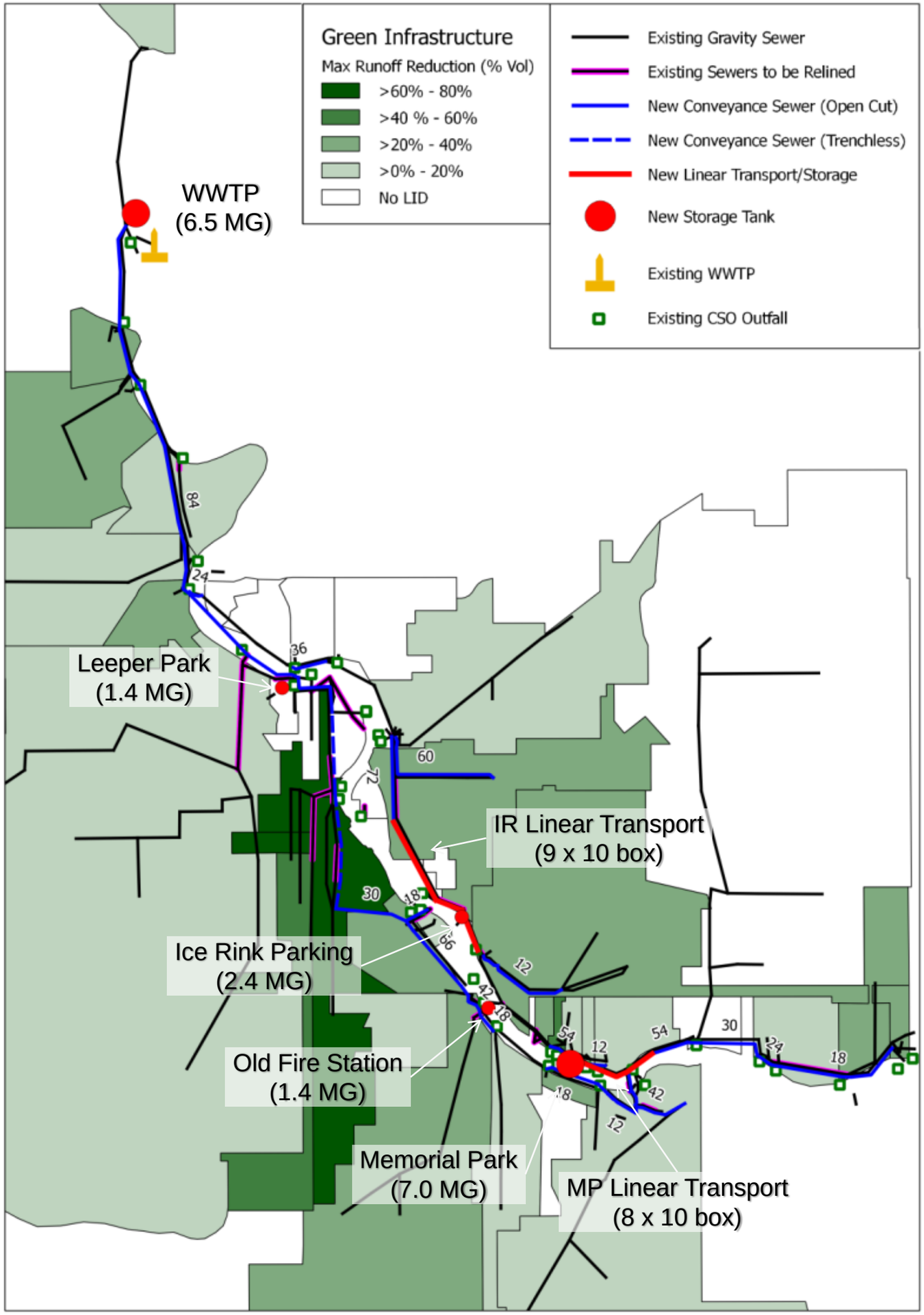



# Generation 25

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 142.84 | 3.28 | 146.12 |
| Storage (Tanks & Linear T/S) | 132.41 | 30.00 | 162.41 |
| Green Infrastructure | 14.92 | 1.30 | 16.23 |
| **Total Project Cost** | **290.17** | **34.59** | **324.76** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **324.76** |

- Best solution in 25th generation
- Total of 5,000 trial solutions evaluated
- Actual processing time: 6:27 hours (104 cores)

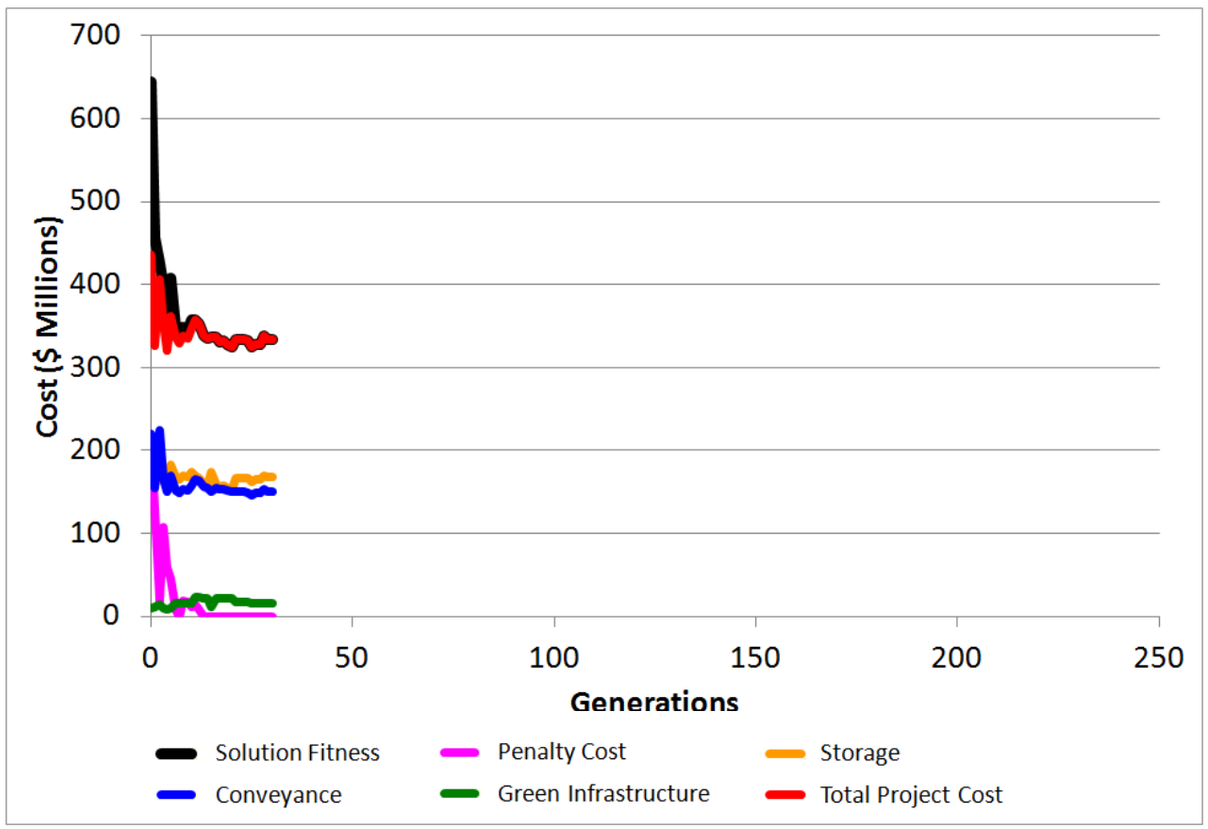


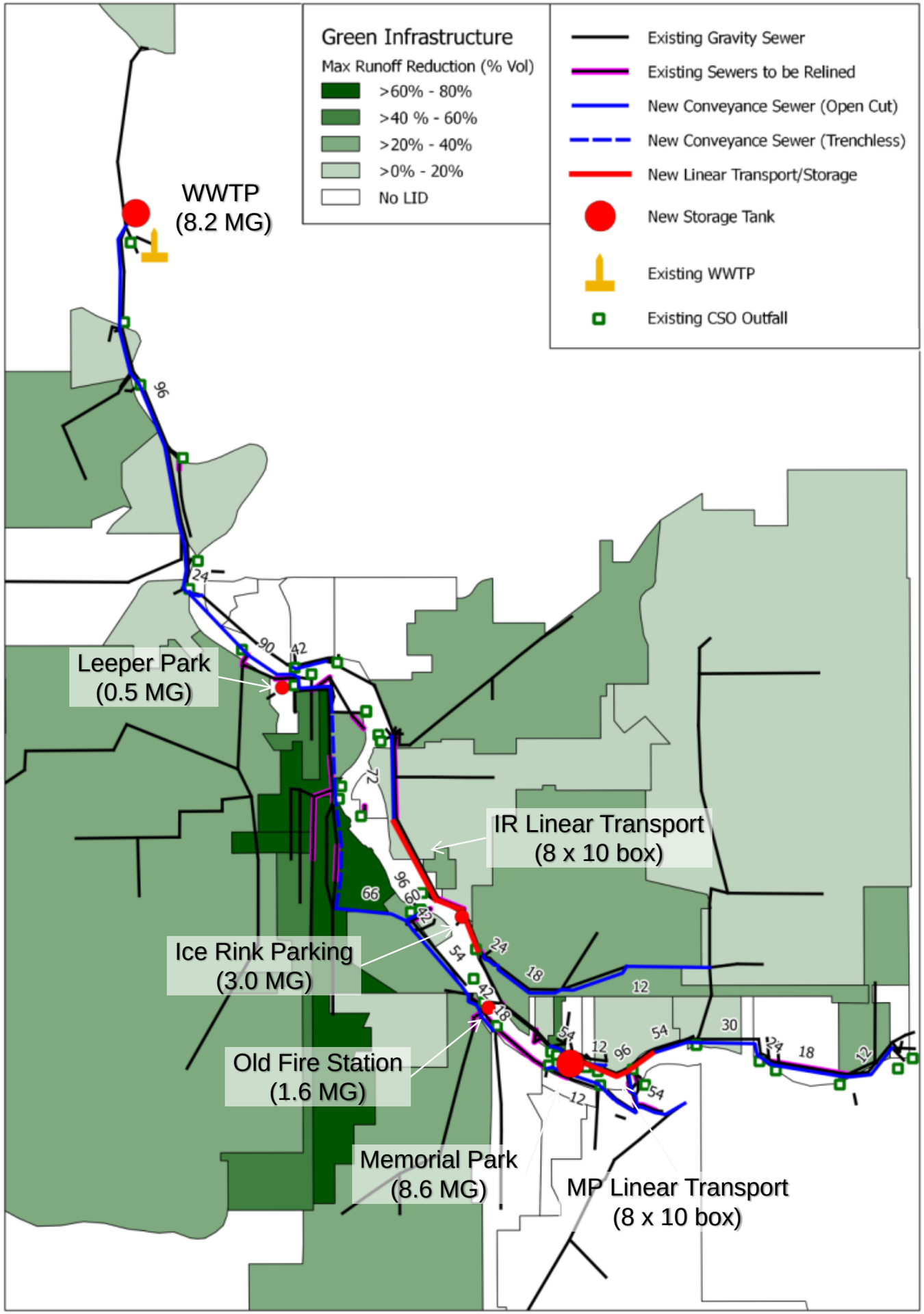



# Generation 30

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 147.49 | 3.48 | 150.97 |
| Storage (Tanks & Linear T/S) | 136.44 | 31.20 | 167.63 |
| Green Infrastructure | 14.40 | 1.21 | 15.62 |
| **Total Project Cost** | **298.33** | **35.89** | **334.22** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **334.22** |

- Best solution in 30th generation
- Total of 6,000 trial solutions evaluated
- Actual processing time: 7:27 hours (104 cores)

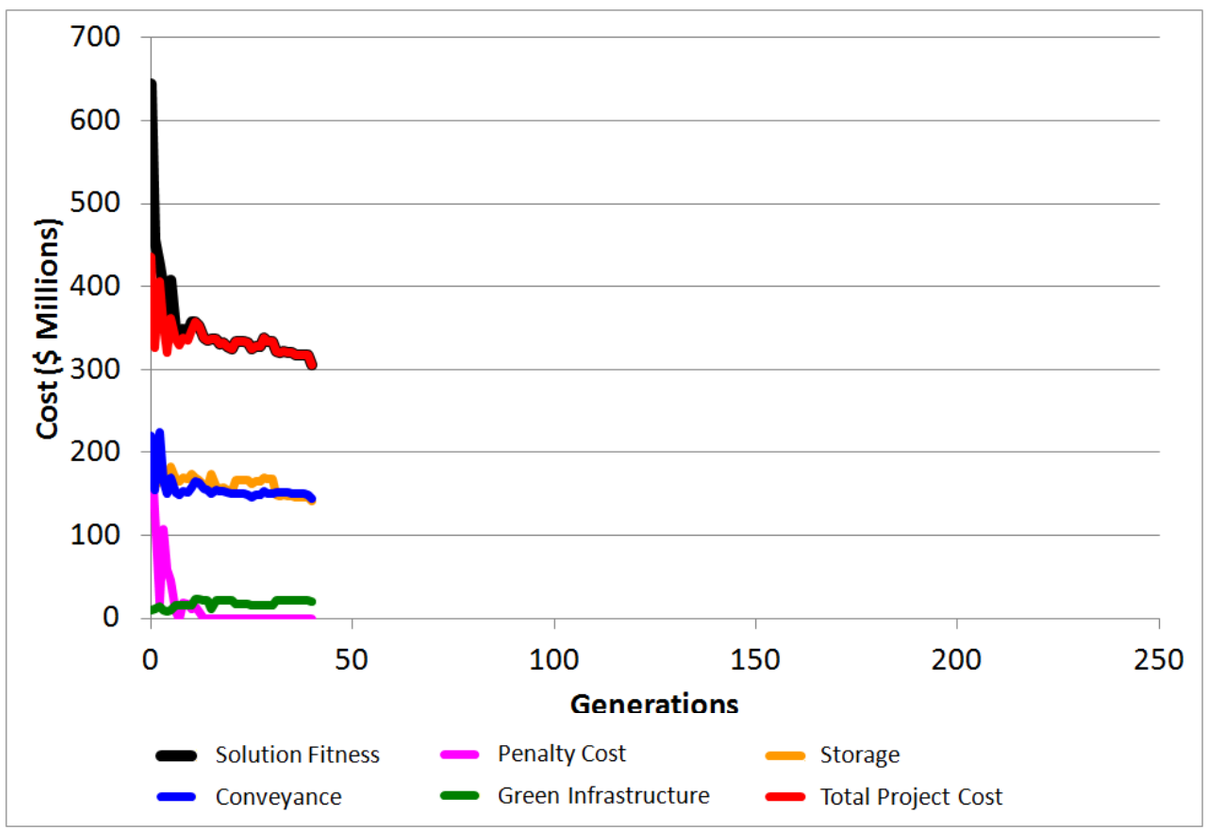


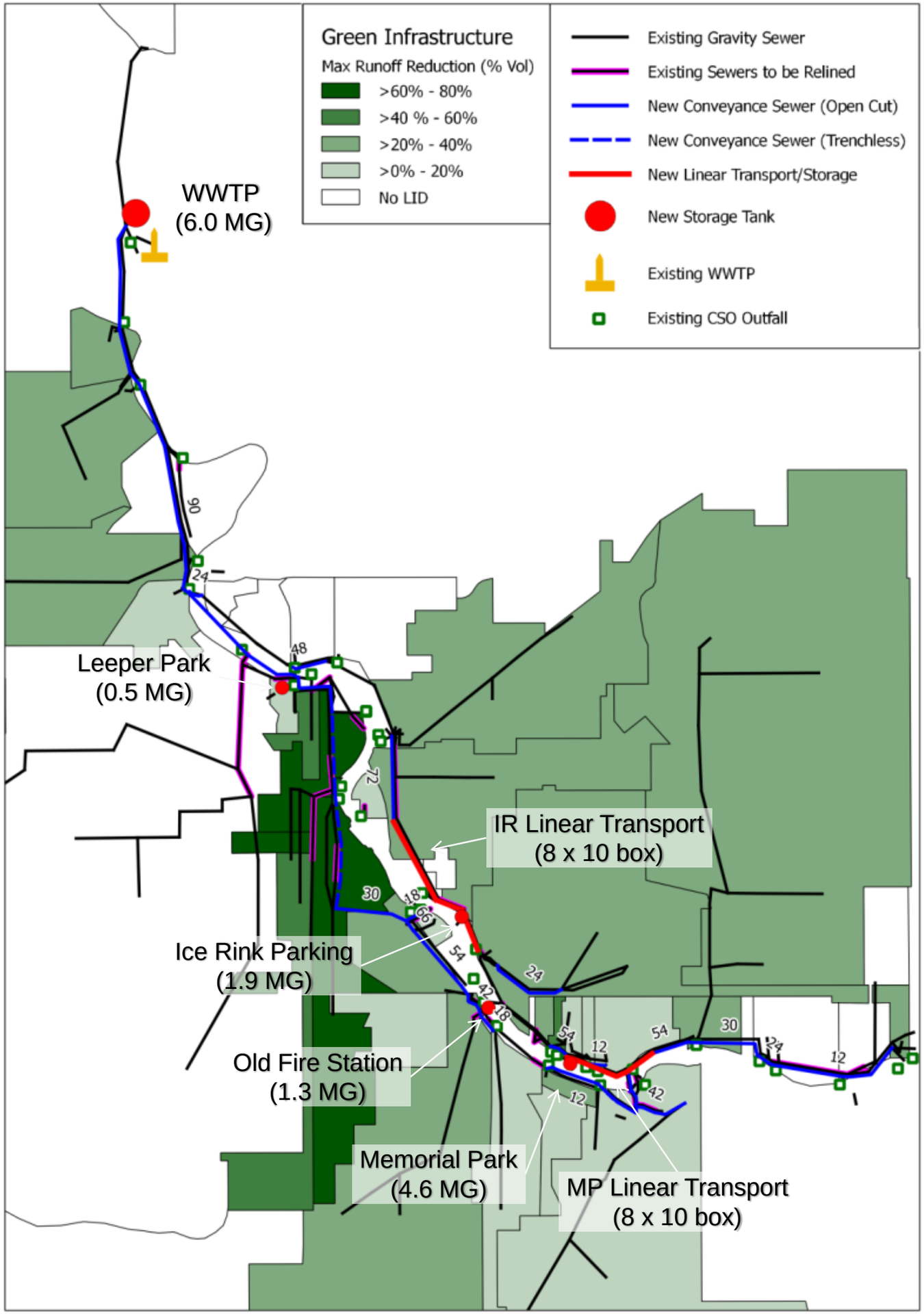



# Generation 40

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 141.26 | 3.22 | 144.48 |
| Storage (Tanks & Linear T/S) | 114.79 | 26.60 | 141.39 |
| Green Infrastructure | 18.74 | 1.63 | 20.37 |
| **Total Project Cost** | **274.79** | **31.45** | **306.24** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **306.24** |

- Best solution in 40th generation
- Total of 8,000 trial solutions evaluated
- Actual processing time: 9:23 hours (104 cores)

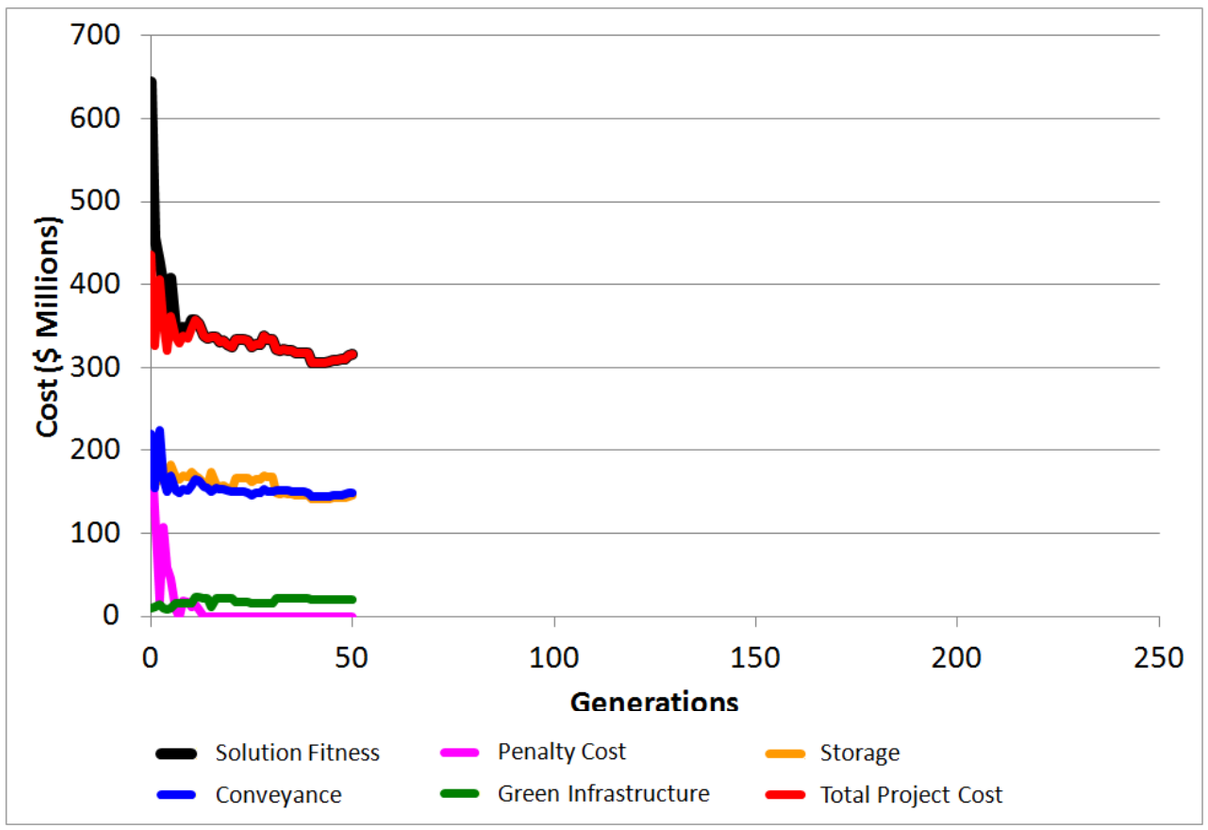


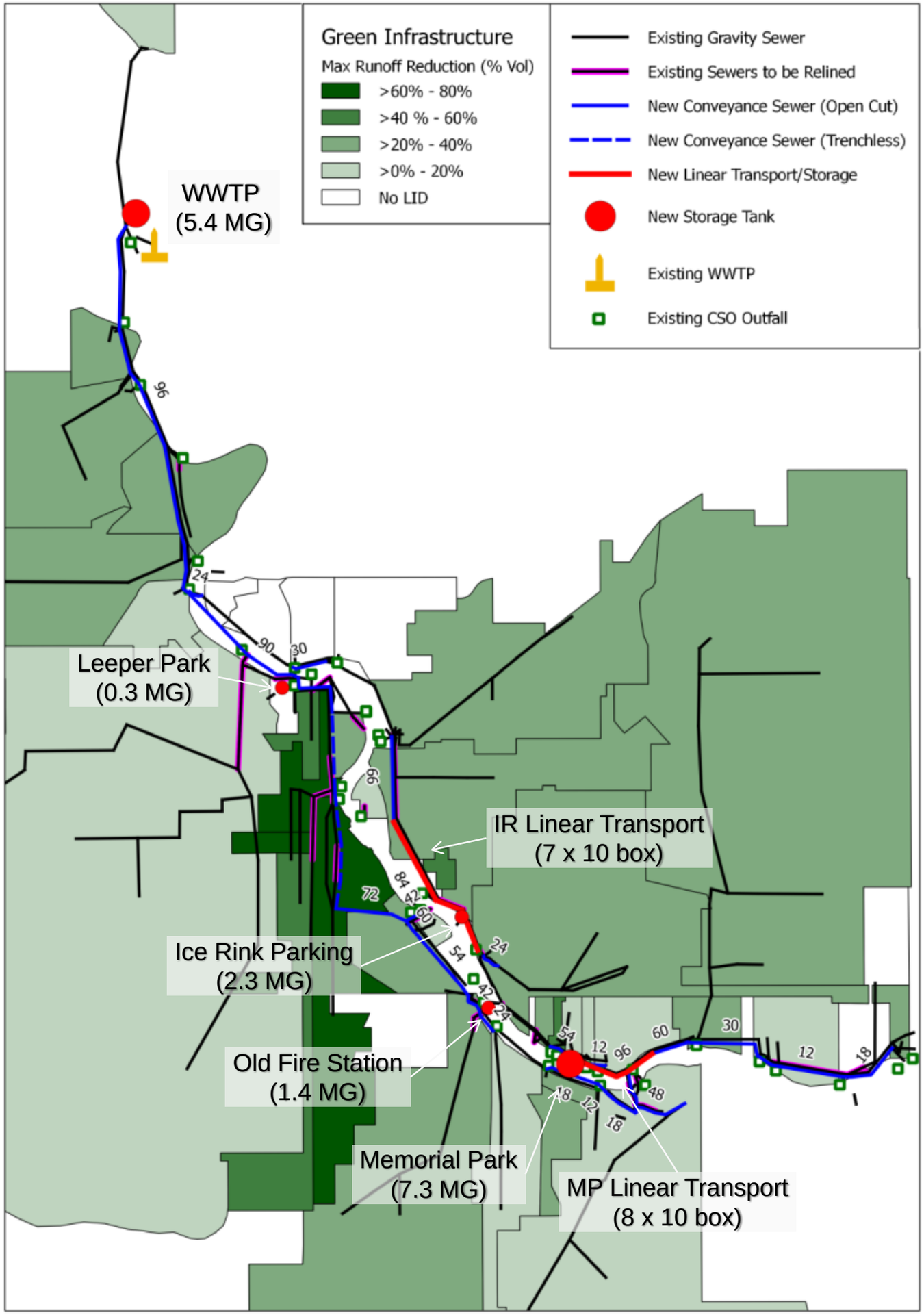



# Generation 50

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 145.68 | 3.37 | 149.05 |
| Storage (Tanks & Linear T/S) | 118.16 | 27.65 | 145.81 |
| Green Infrastructure | 19.11 | 1.68 | 20.78 |
| **Total Project Cost** | **282.94** | **32.70** | **315.64** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **315.64** |

- Best solution in 50th generation
- Total of 10,000 trial solutions evaluated
- Actual processing time: 11:18 hours (104 cores)

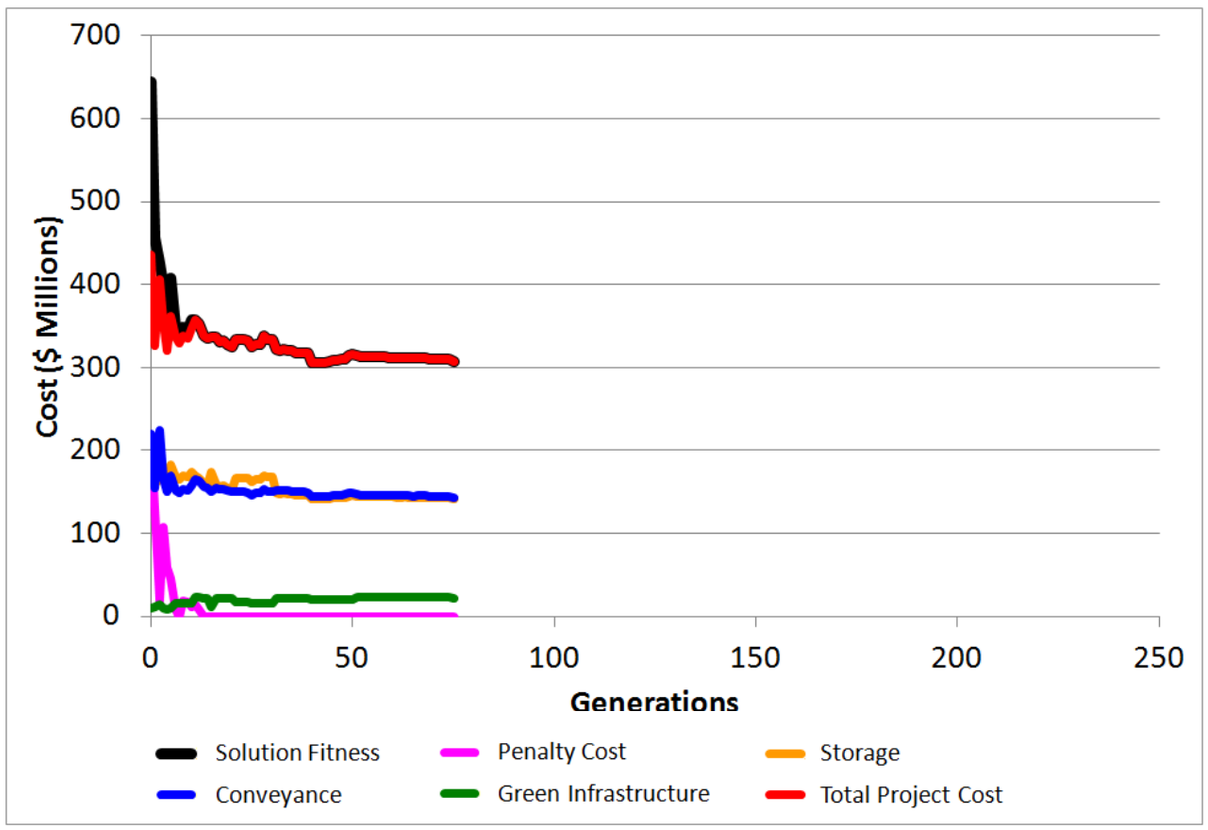


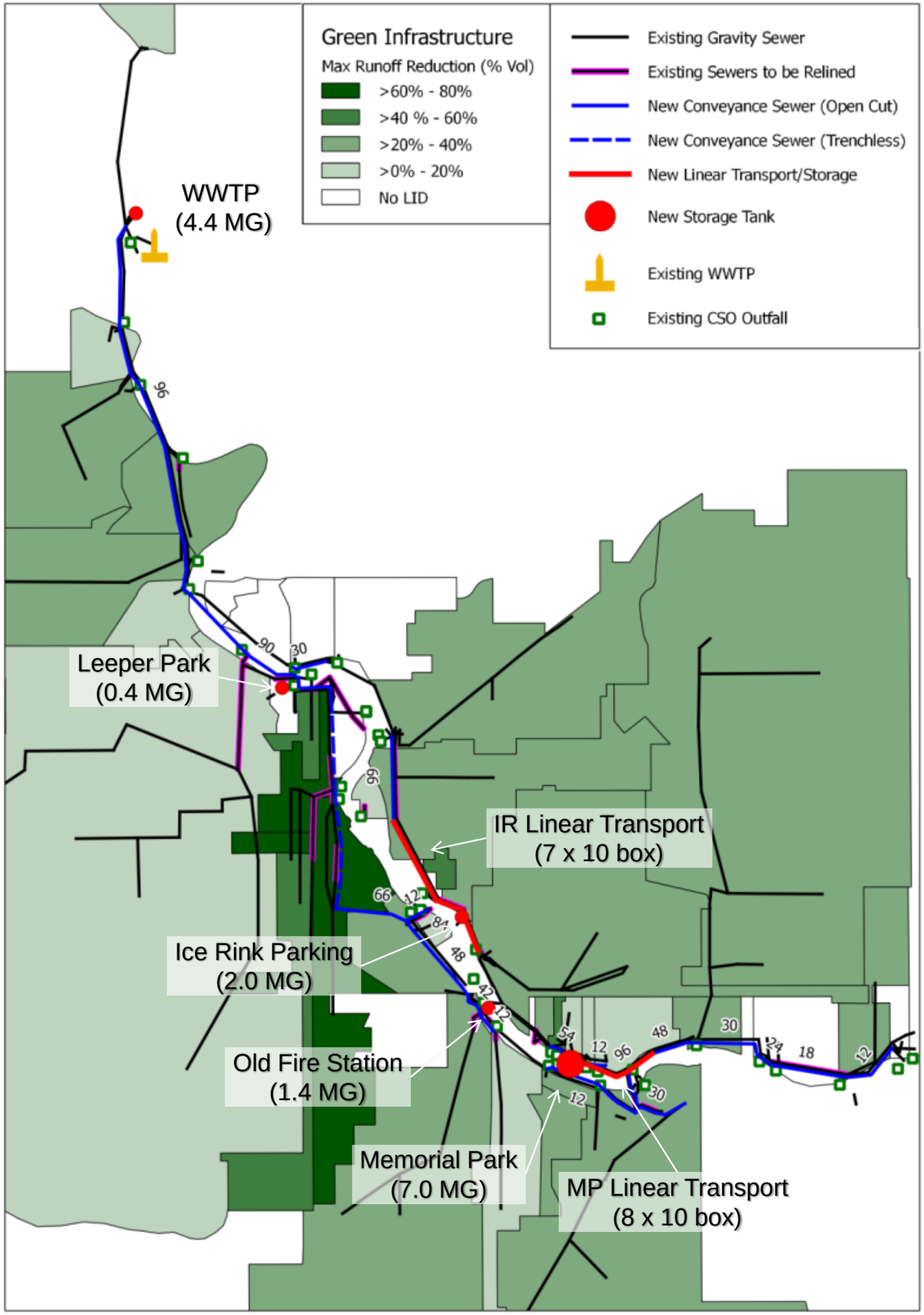



# Generation 75

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 140.32 | 3.20 | 143.52 |
| Storage (Tanks & Linear T/S) | 114.77 | 26.92 | 141.70 |
| Green Infrastructure | 20.55 | 1.76 | 22.31 |
| **Total Project Cost** | **275.64** | **31.89** | **307.53** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **307.53** |

- Best solution in 75th generation
- Total of 15,000 trial solutions evaluated
- Actual processing time: 16:17 hours (104 cores)

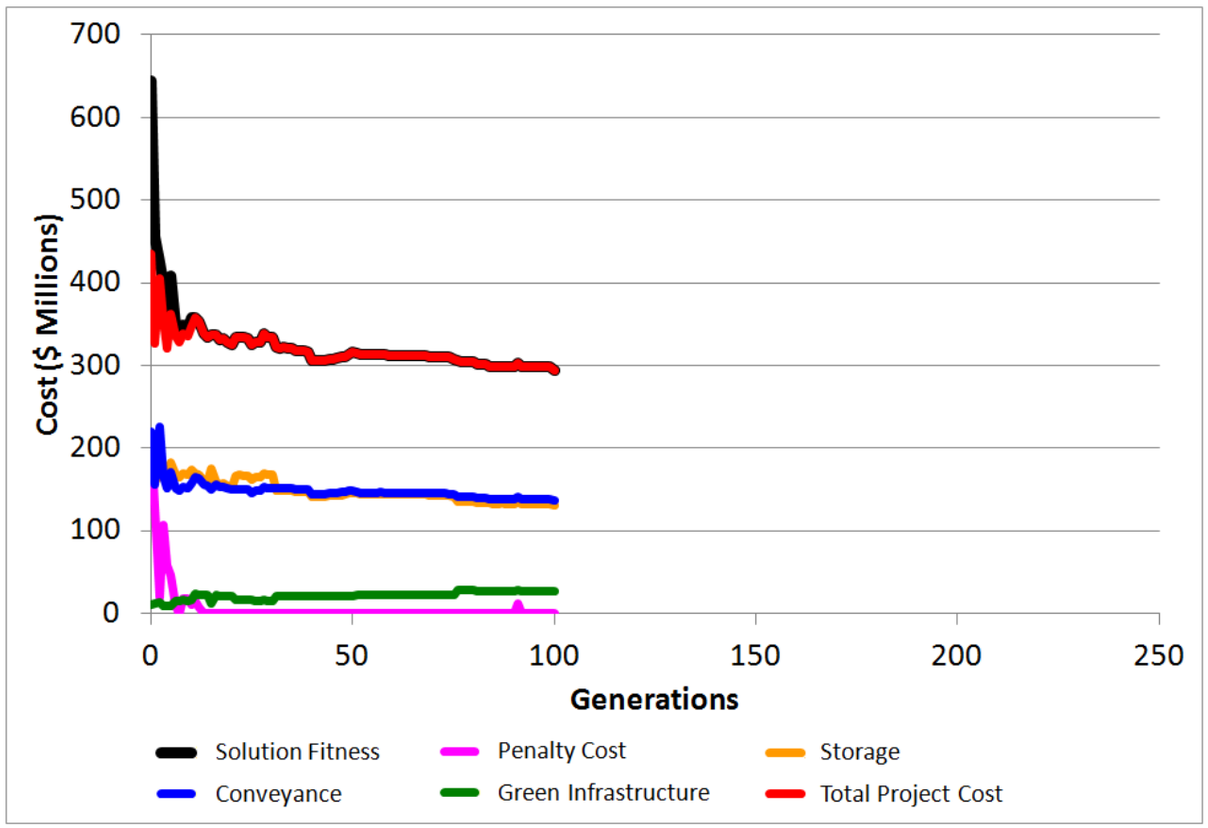


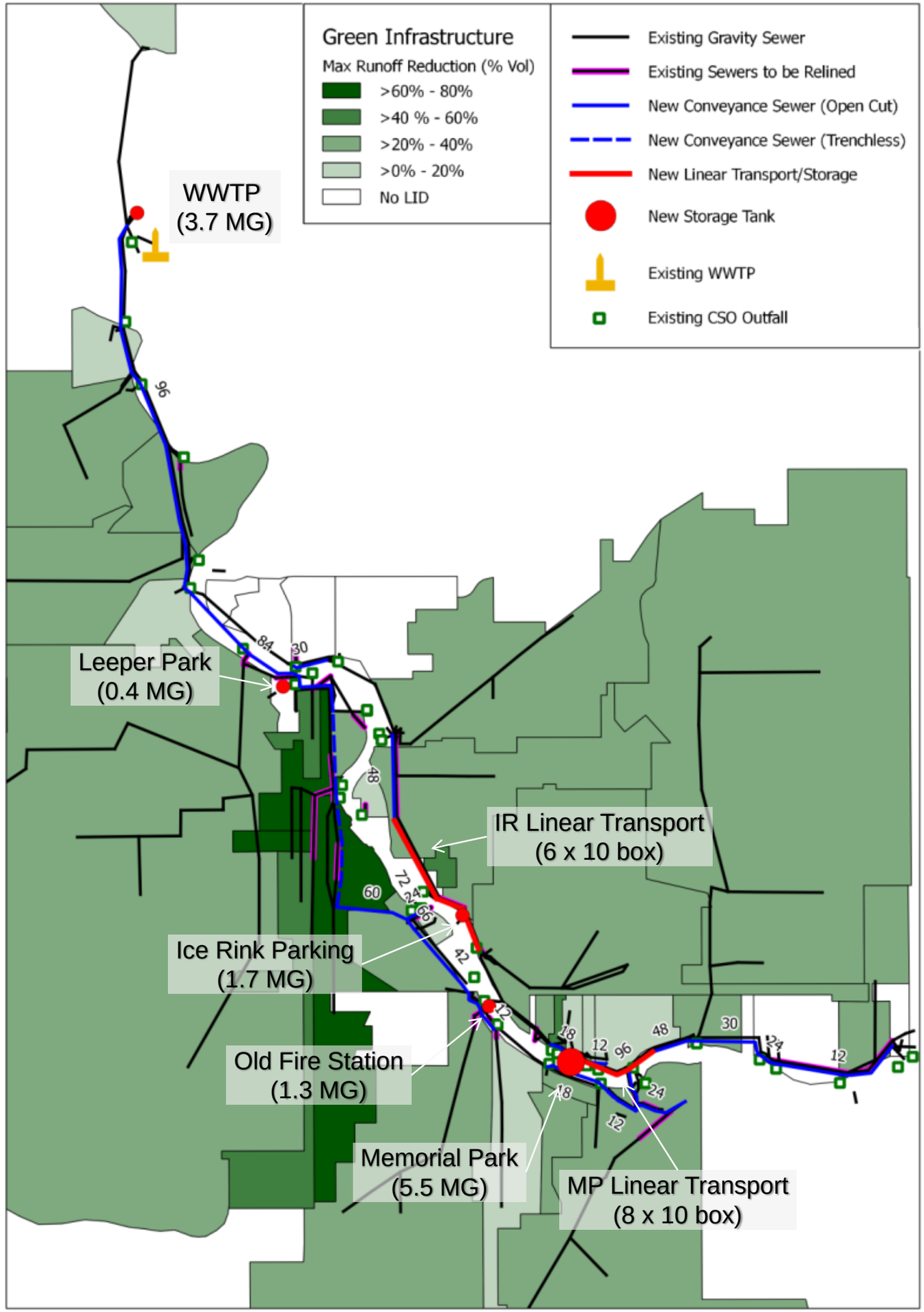



# Generation 100

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 133.60 | 3.09 | 136.69 |
| Storage (Tanks & Linear T/S) | 105.72 | 25.34 | 131.06 |
| Green Infrastructure | 24.77 | 2.13 | 26.90 |
| **Total Project Cost** | **264.10** | **30.56** | **294.66** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **294.66** |

- Best solution in 100th generation
- Total of 20,000 trial solutions evaluated
- Actual processing time: 21:25 hours (104 cores)

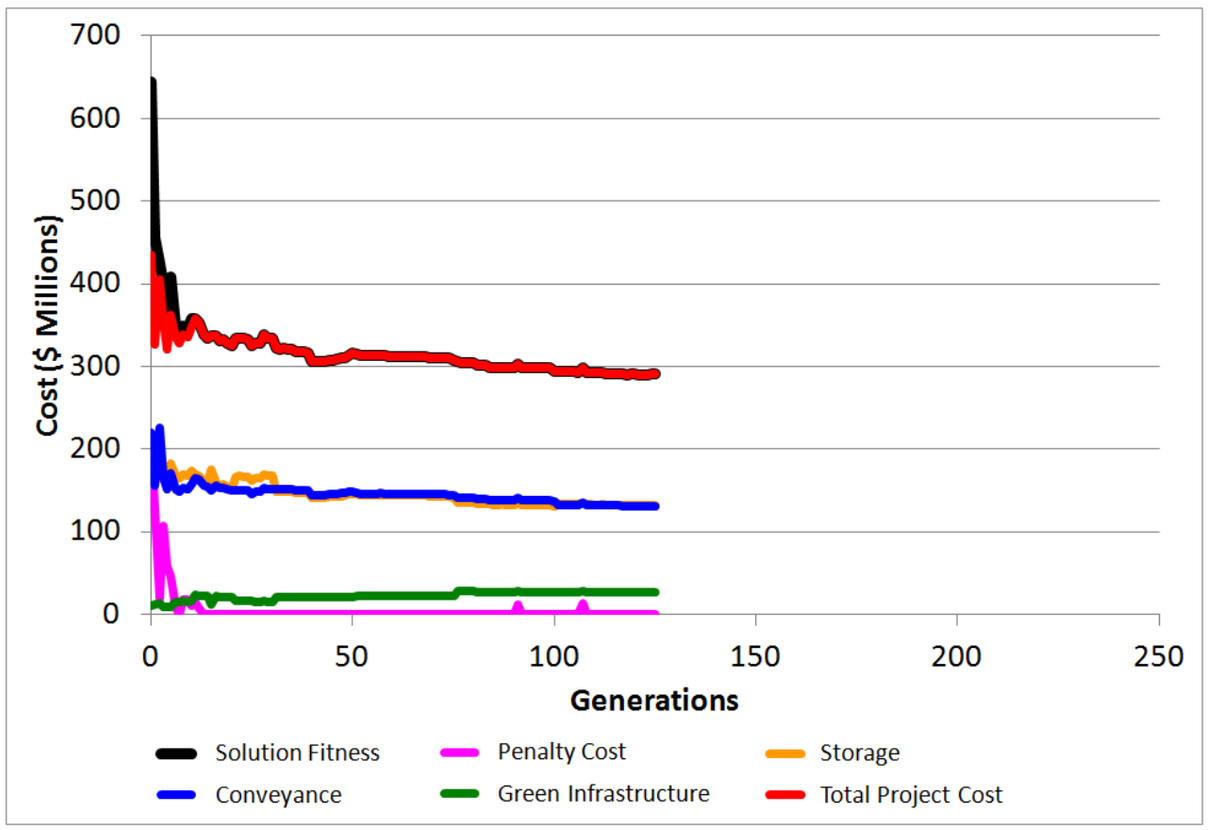


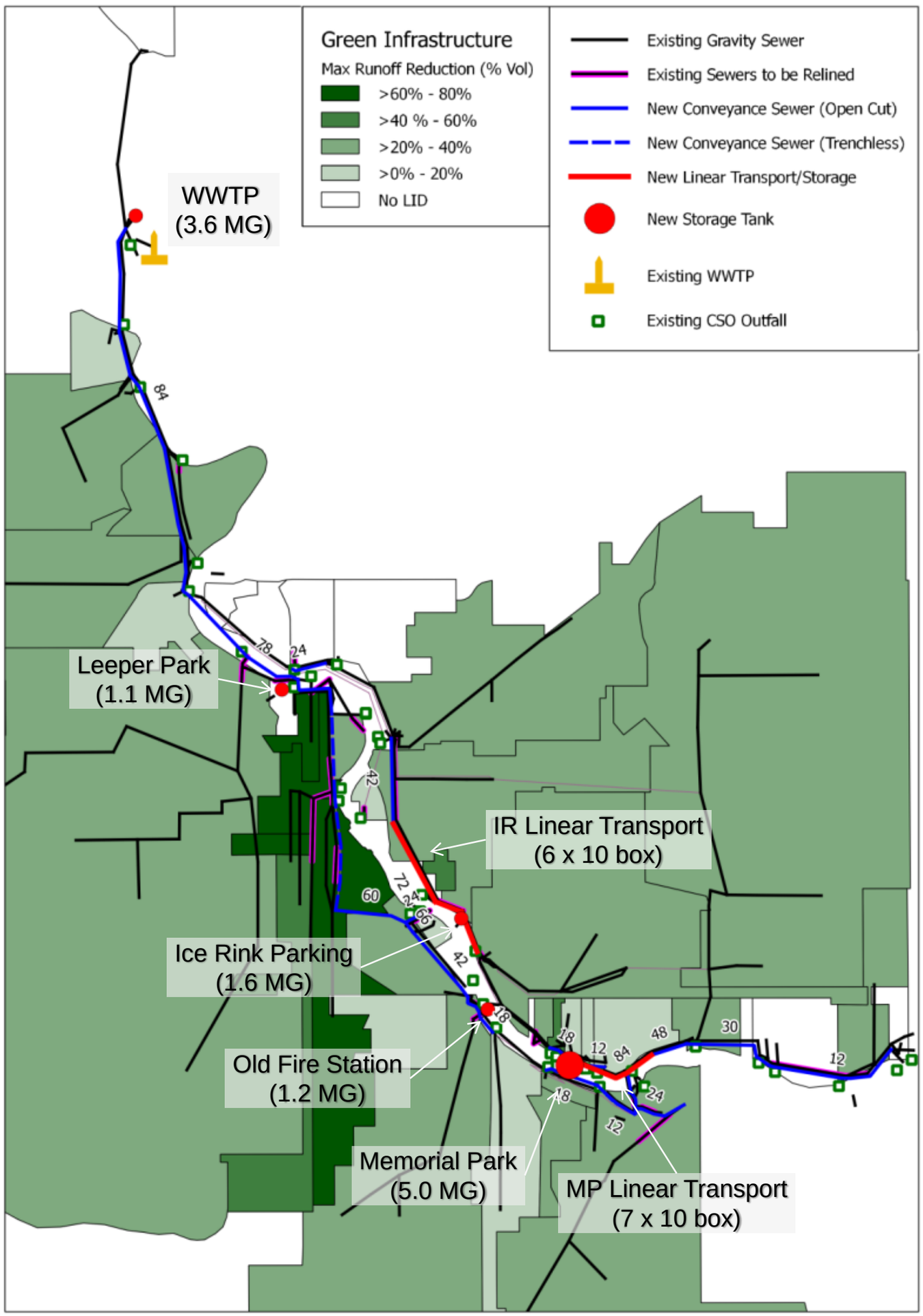



# Generation 125

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 128.11 | 2.95 | 131.06 |
| Storage (Tanks & Linear T/S) | 106.47 | 25.68 | 132.16 |
| Green Infrastructure | 24.92 | 2.14 | 27.07 |
| **Total Project Cost** | **259.51** | **30.78** | **290.28** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **290.28** |

- Best solution in 125th generation
- Total of 25,000 trial solutions evaluated
- Actual processing time: 26:35 hours (104 cores)

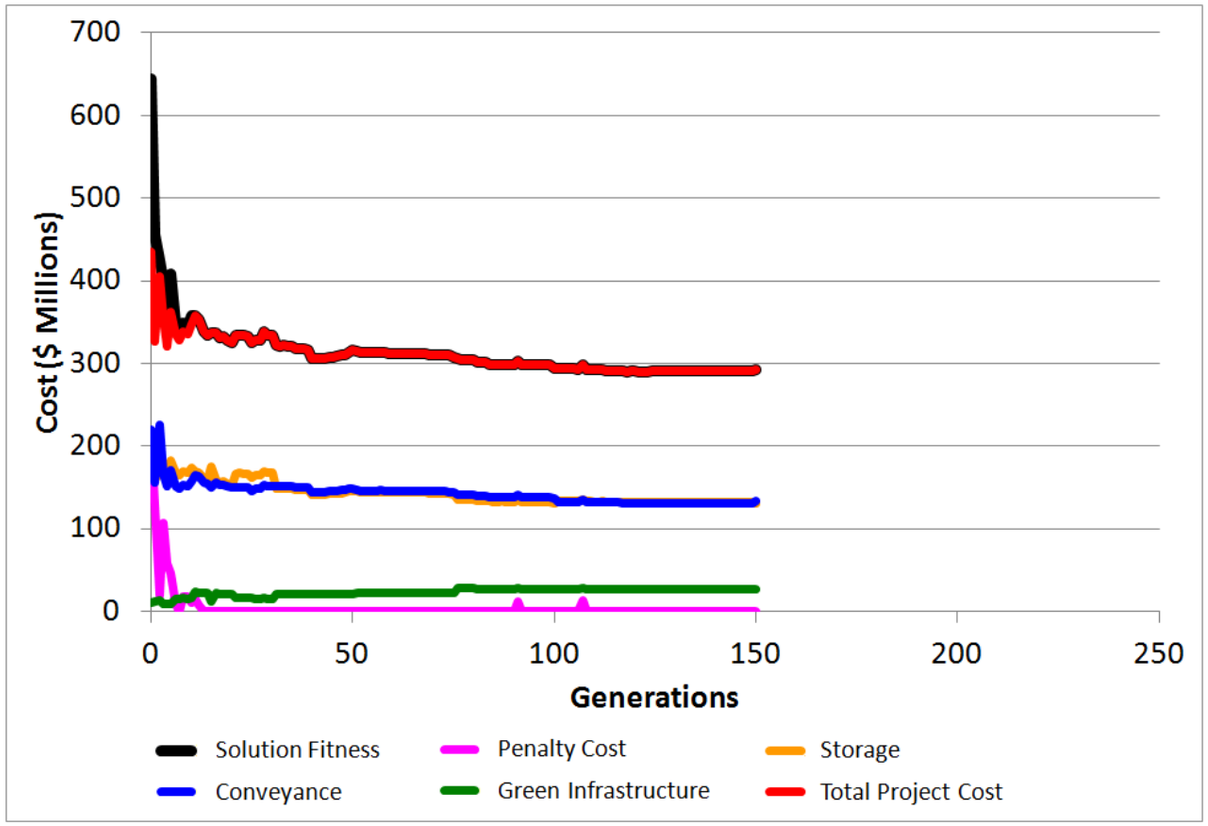


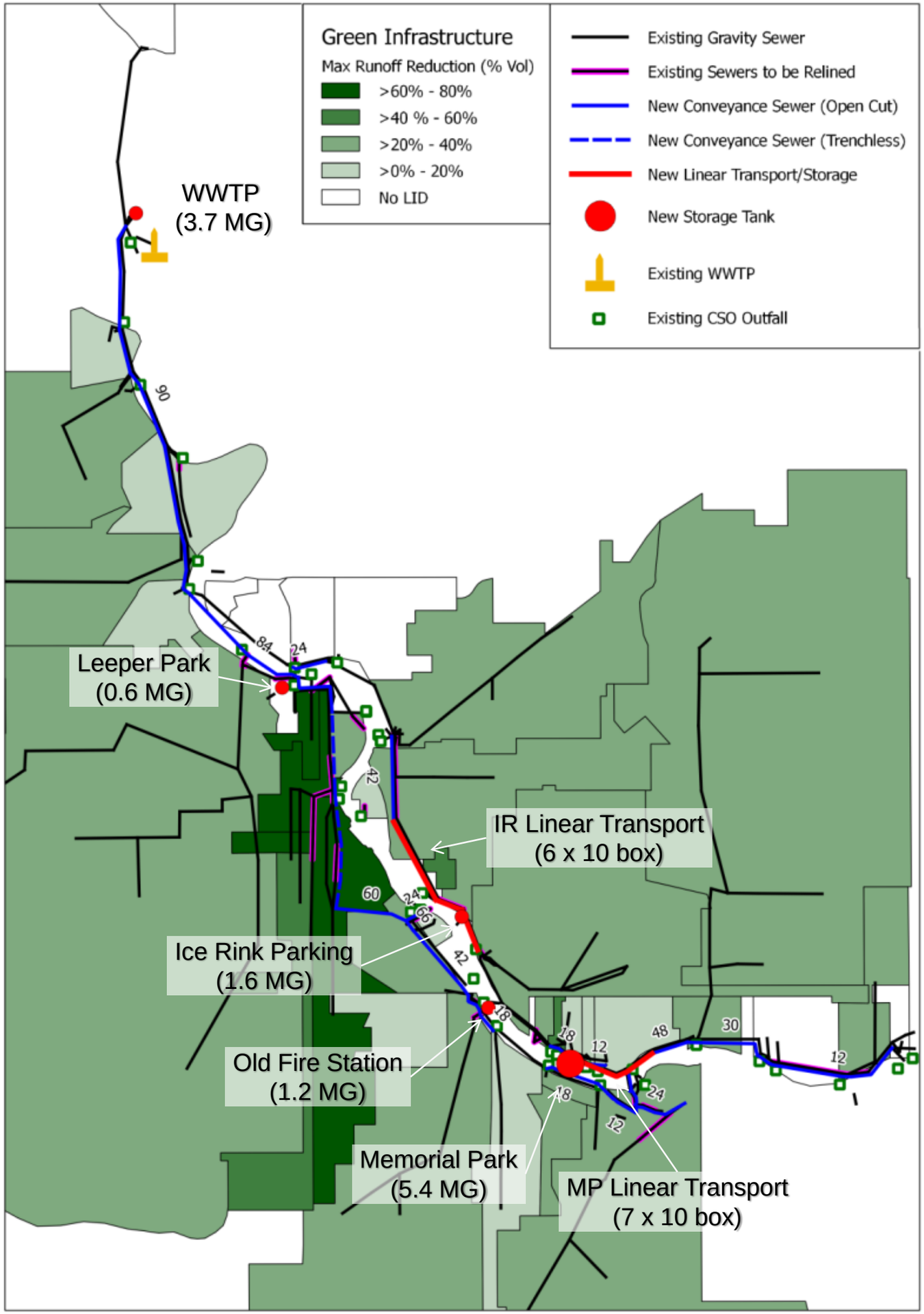



# Generation 150

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 130.93 | 3.03 | 133.96 |
| Storage (Tanks & Linear T/S) | 105.37 | 25.46 | 130.83 |
| Green Infrastructure | 24.83 | 2.13 | 26.96 |
| **Total Project Cost** | **261.13** | **30.63** | **291.76** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **291.76** |

- Best solution in 150th generation
- Total of 30,000 trial solutions evaluated
- Actual processing time: 31:48 hours (104 cores)

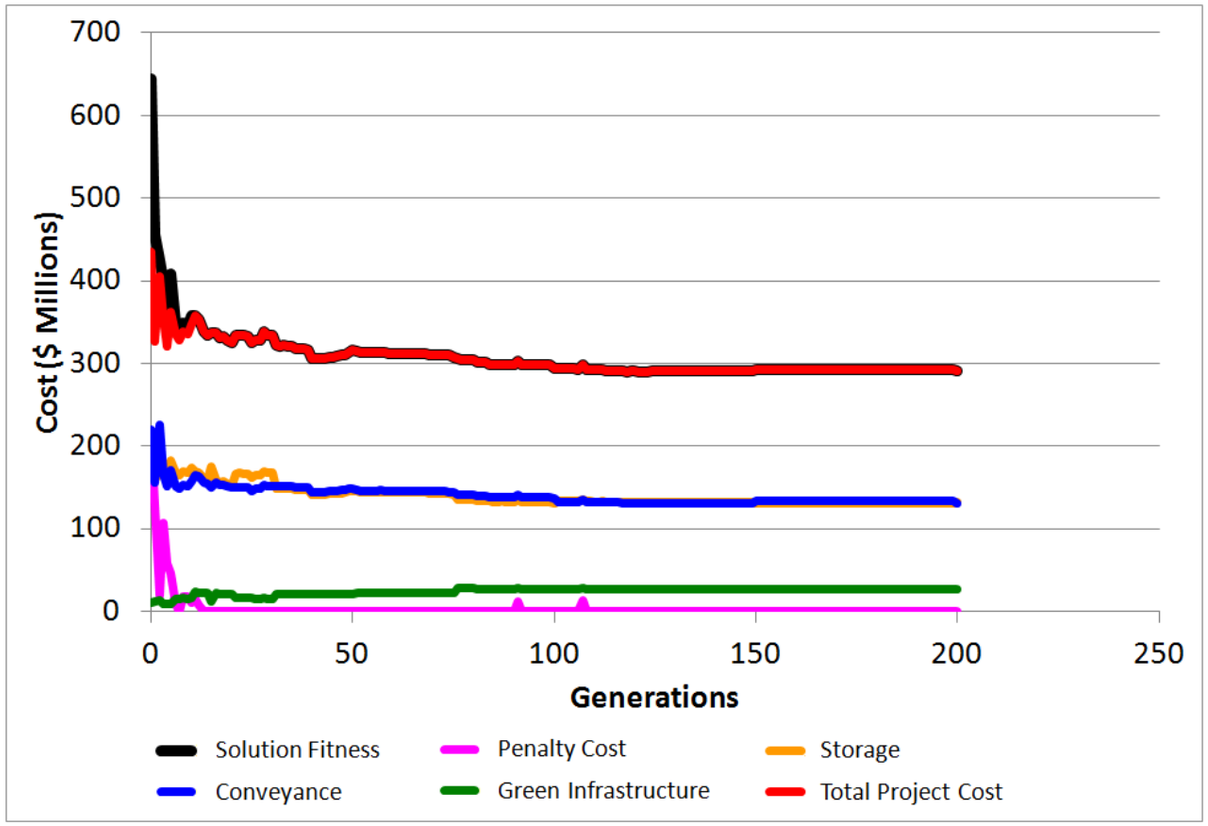


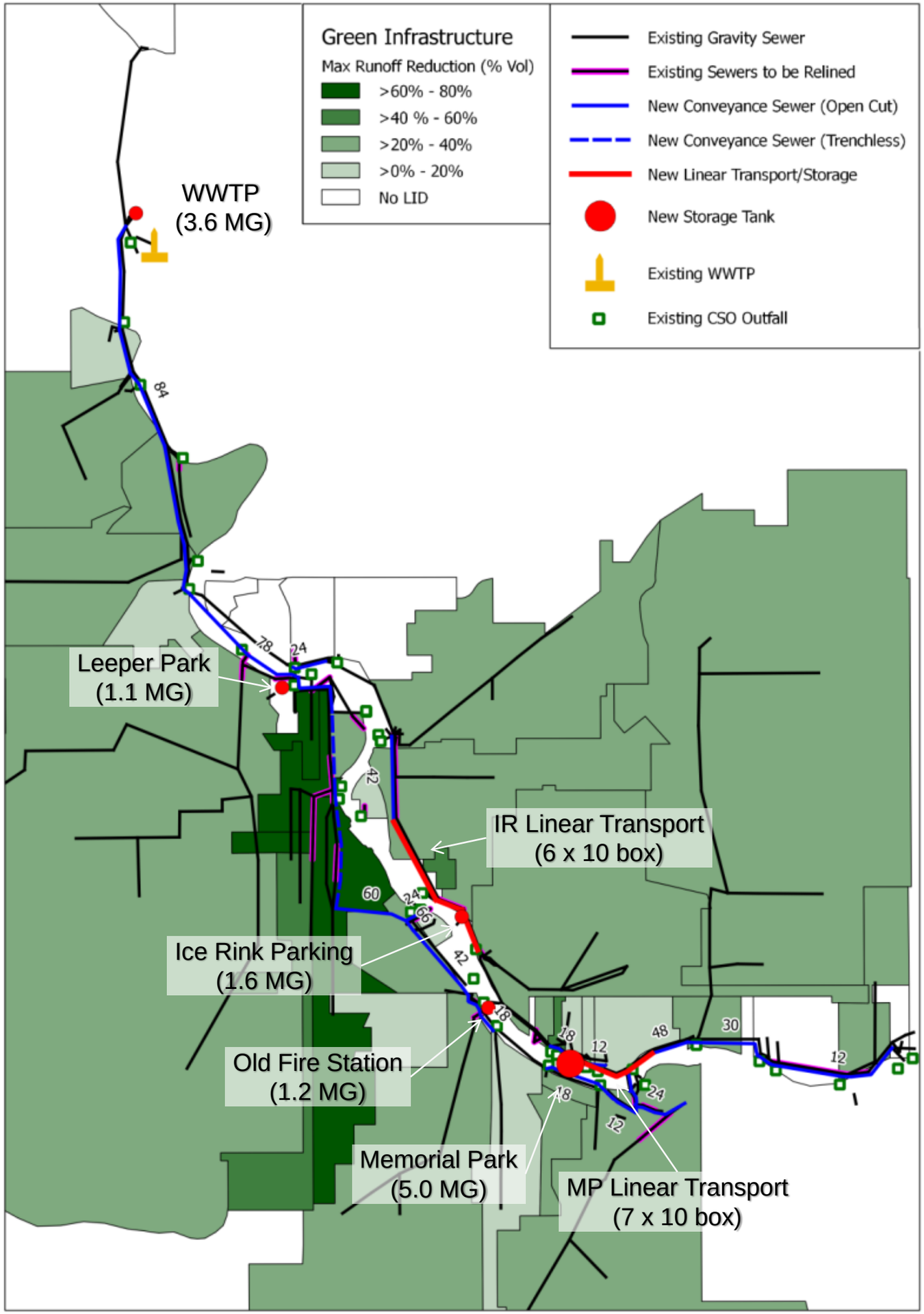



# Generation 200

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 128.11 | 2.95 | 131.06 |
| Storage (Tanks & Linear T/S) | 106.47 | 25.68 | 132.16 |
| Green Infrastructure | 24.92 | 2.14 | 27.07 |
| **Total Project Cost** | **259.51** | **30.78** | **290.28** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **290.28** |

- Best solution in 200th generation
- Total of 40,000 trial solutions evaluated
- Actual processing time: 42:18 hours (104 cores)

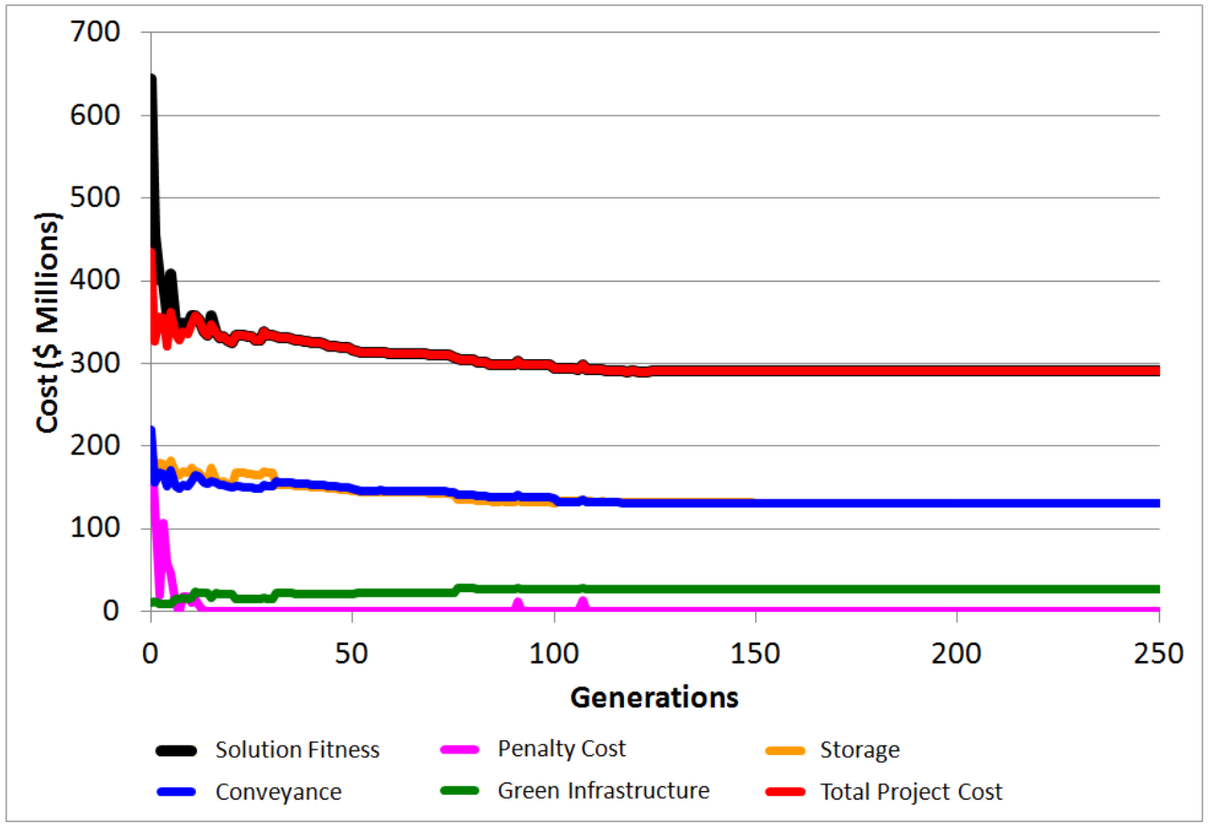


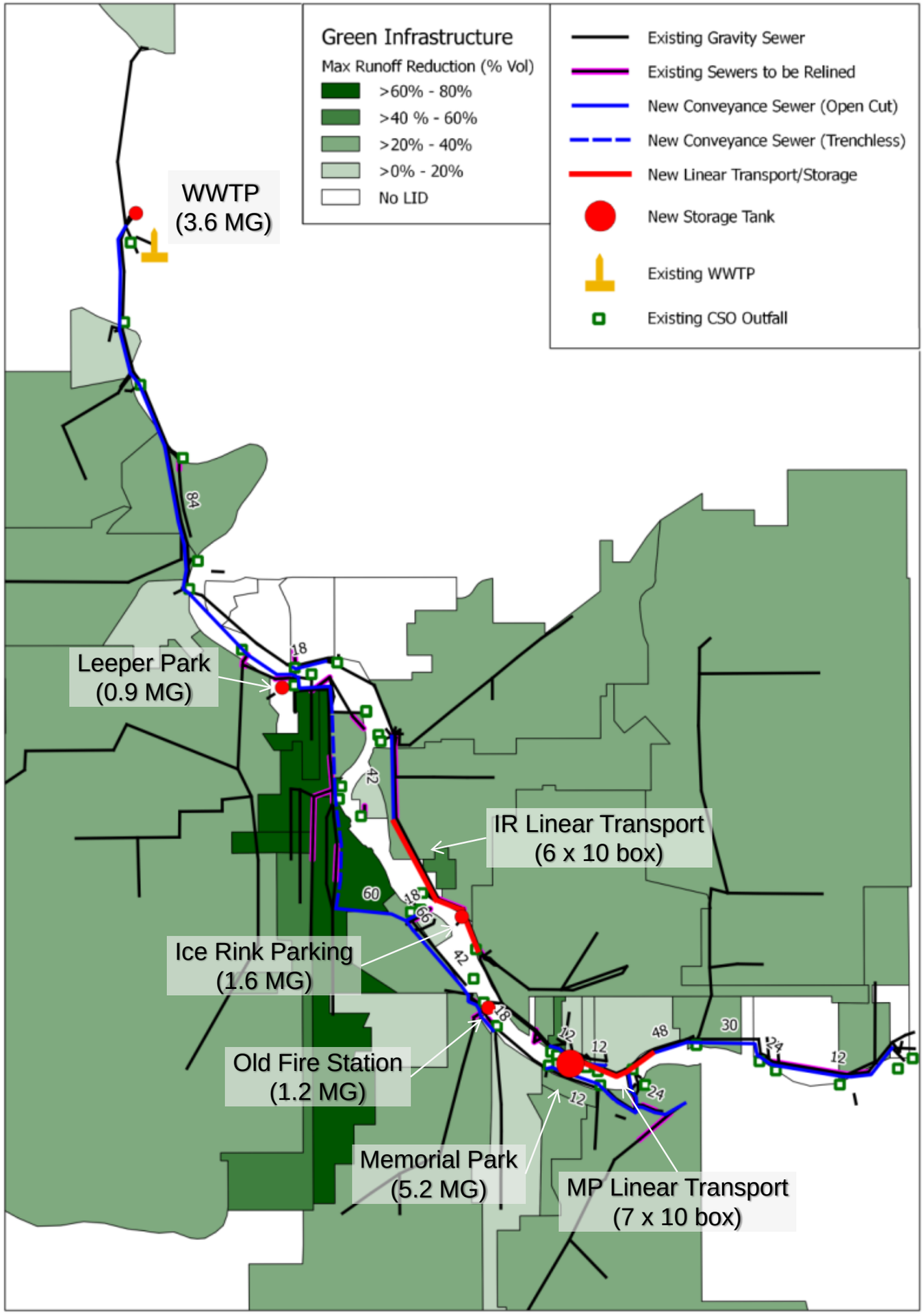



# Generation 250

| Cost Item | Capital Cost ($M) | O&M Cost ($M) | Total Cost ($M) |
|---|---|---|---|
| Conveyance (incl RTC, Lift Stations &Relining) | 128.40 | 2.99 | 131.39 |
| Storage (Tanks & Linear T/S) | 105.96 | 25.58 | 131.54 |
| Green Infrastructure | 24.95 | 2.15 | 27.10 |
| **Total Project Cost** | **259.31** | **30.72** | **290.03** |
| Performance Violation Penalty Cost | - | - | 0.00 |
| **Total Solution Fitness** | - | - | **290.03** |

- Best solution in 250th generation
- Total of 50,000 trial solutions evaluated
- Actual processing time: 52:50 hours (104 cores)

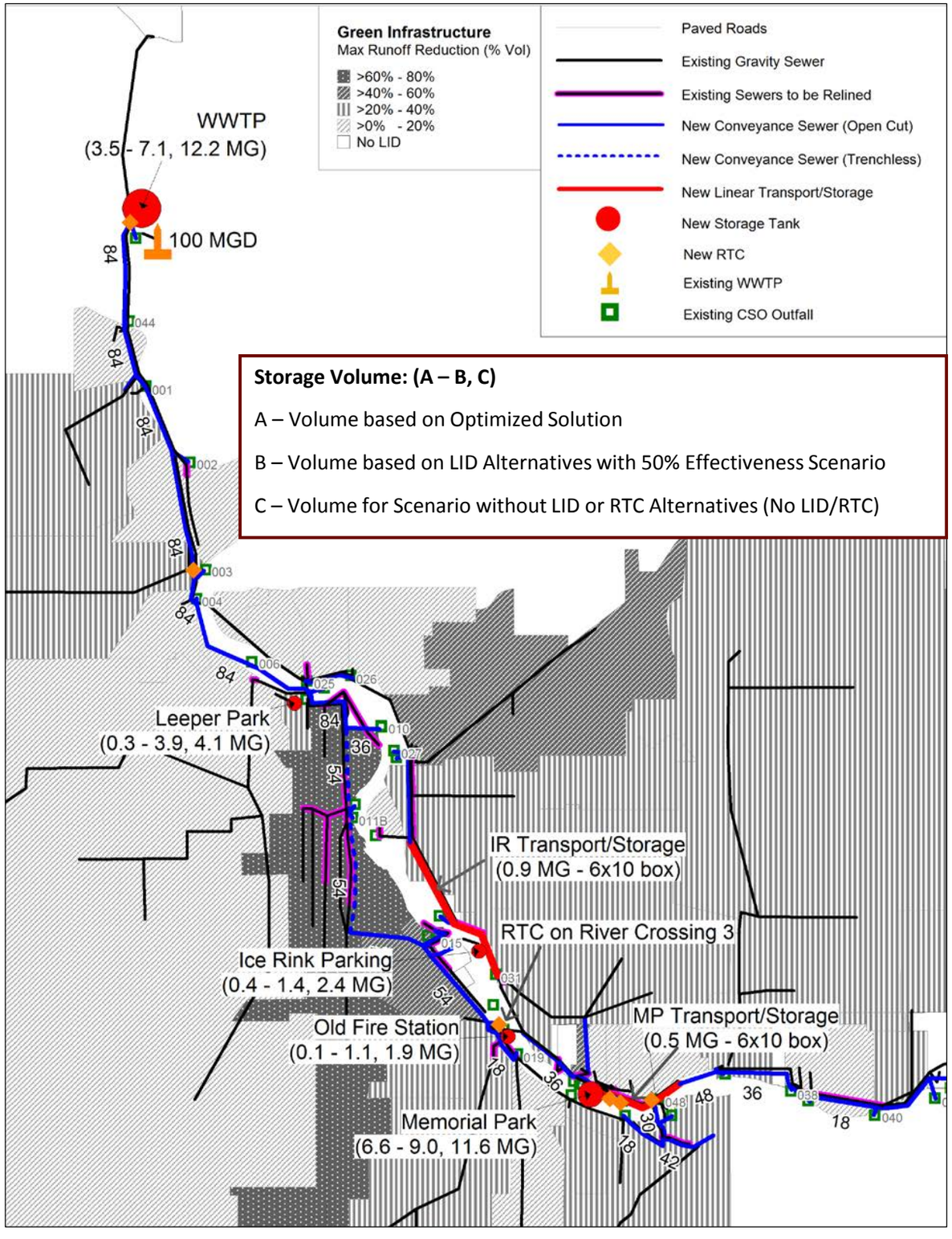


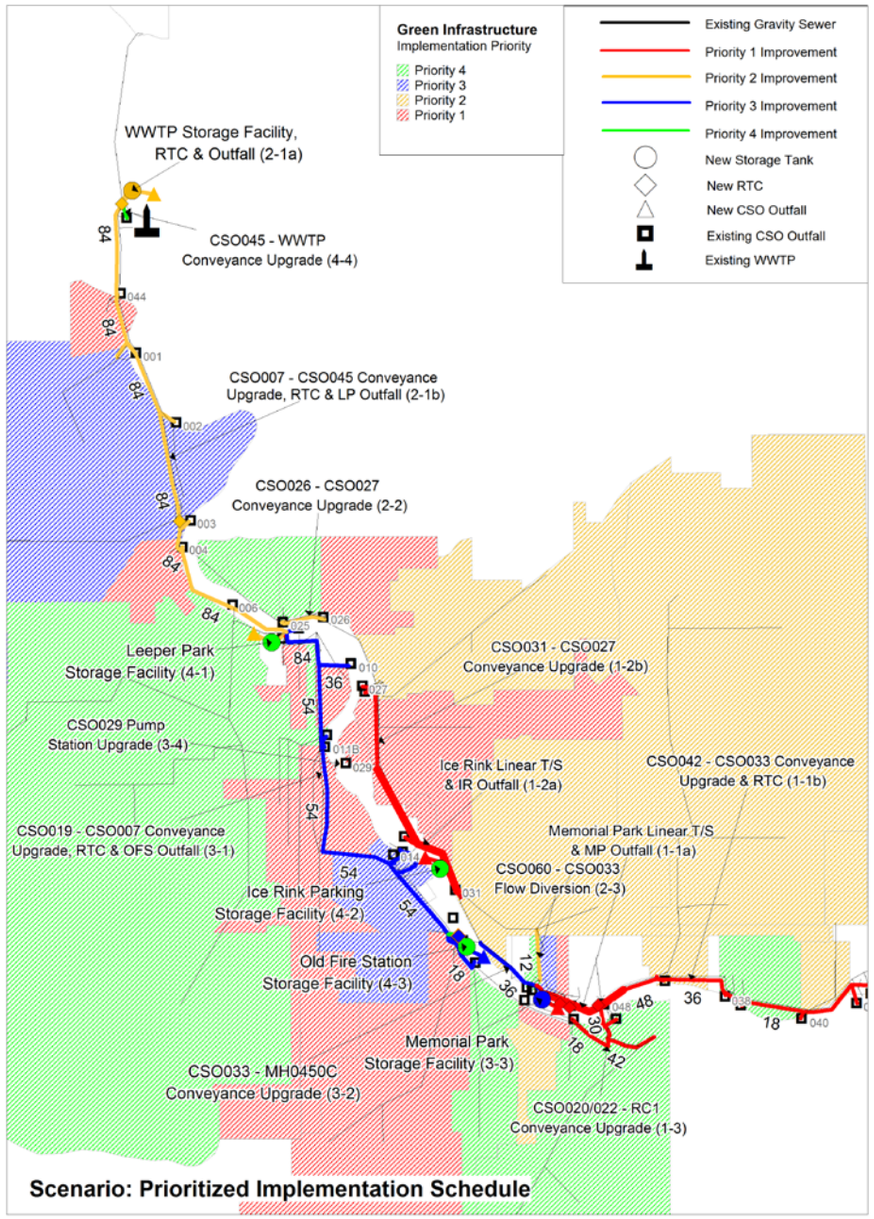
# Comparison of Total Project Costs

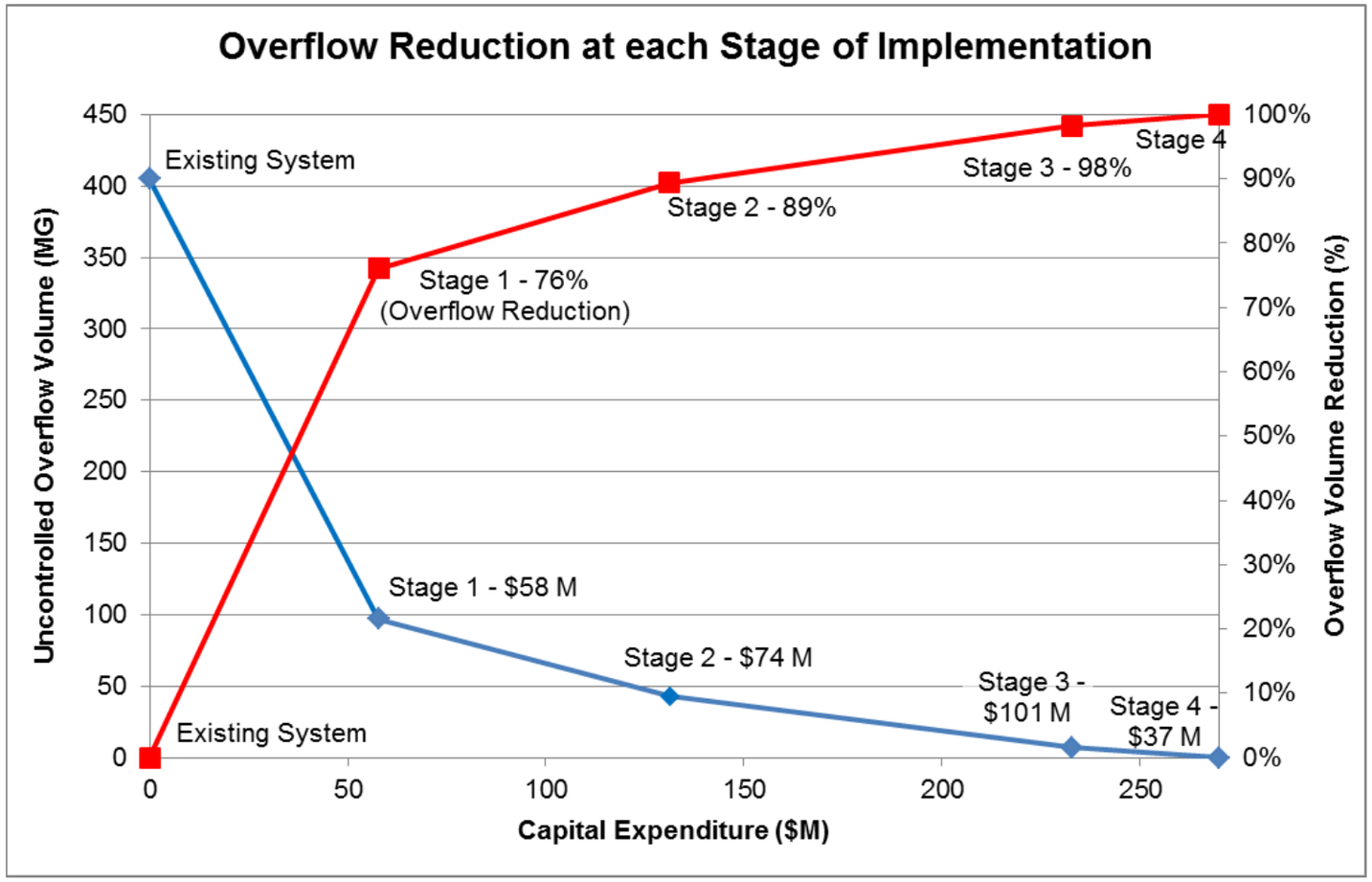
| Cost Item | Baseline Solution ($M) | Optimized Solutions | | | | |
|---|---|---|---|---|---|---|
| | | No LID/RTC ($M) | No LID ($M) | Optimized Solution ($M) | LID 50% Effective ($M) | No RGBO[3] ($M) |
| **Conveyance** | 149.83 | 114.40 | 114.40 | 114.40 | 114.40 | 114.40 |
| **Pump Station[1]** | - | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| **Linear Storage** | 42.66 | 13.96 | 13.96 | 13.96 | 13.96 | 13.96 |
| **Storage Tank** | 99.80 | 123.62 | 116.82 | 63.28 | 95.81 | 96.68 |
| **Relining** | 13.04 | 3.51 | 3.51 | 2.18 | 2.67 | 2.56 |
| **RTC** | - | - | 2.67 | 2.67 | 2.67 | 2.67 |
| **Green Technology/LID[2]** | - | - | - | 27.39 | 19.04 | 15.06 |
| **Total Construction Cost** | 305.34 | 256.75 | 252.62 | 225.13 | 249.80 | 246.58 |
| **Eng'g/Legal/Admin (20%)** | 61.07 | 51.35 | 50.52 | 45.03 | 49.96 | 49.32 |
| **Total Capital Cost** | 366.40 | 308.10 | 303.14 | 270.16 | 299.76 | 295.90 |
| **Present Worth O&M** | 45.61 | 42.02 | 40.84 | 29.40 | 37.45 | 35.92 |
| **TOTAL PROJECT COST** | 412.01 | 350.11 | 343.98 | 299.56 | 337.21 | 331.82 |
| **Savings on Baseline Cost** | ($M) | 61.90 | 68.04 | 112.46 | 74.80 | 80.19 |
| | (%) | 15% | 17% | 27% | 18% | 19% |

# Layout of Optimized Solutions showing Storage Volumes for Three Scenarios



# Prioritization of Projects for Maximum Impact



# Next Steps

- Develop CSO communications dashboard
- Increase logic aggressiveness to further reduce CSOs
- Fine tune and evaluate RT-DSS effectiveness
- Compare RT-DSS, Model, and DMR CSO volume reporting
- Review entire LTCP to realize more savings

# Questions?