Identifying Critical Infrastructure
Through the Use of Hydraulic Modeling to Support Asset Management

James P. Cooper, Prof. Engineer, Cert. Operator
ARCADIS Design & Consultancy for natural and built assets

Improving quality of life

Acknowledgements

Washington Suburban Sanitary Commission
Lisa Gresehover
Kimberly Six
Karem Carpio
Felicia James
Karen Wright

Gregg Loesch
Darren Rozenek

Andrea Kroma

Latis Associates
Vanessa Speight

ARCADIS Design & Consultancy for natural and built assets
Patrick Parault
Laura Khouvilay
Katie Sager
Kurt Smith

Agenda

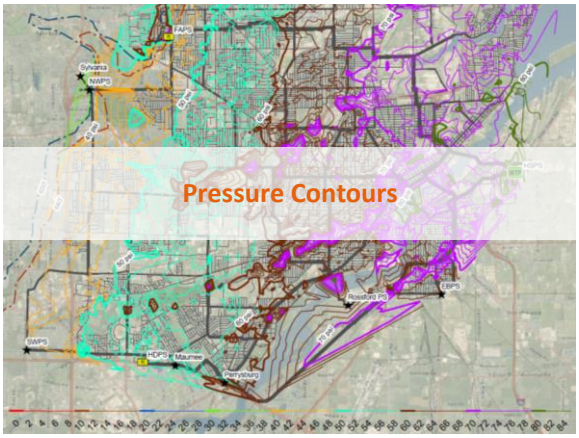
- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC (Washington Suburban Sanitary Commission)
- Ohio Case Studies: Toledo and Akron
- Remember This!

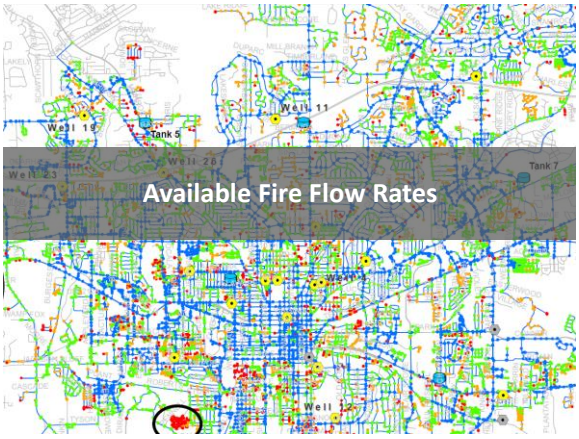
Agenda

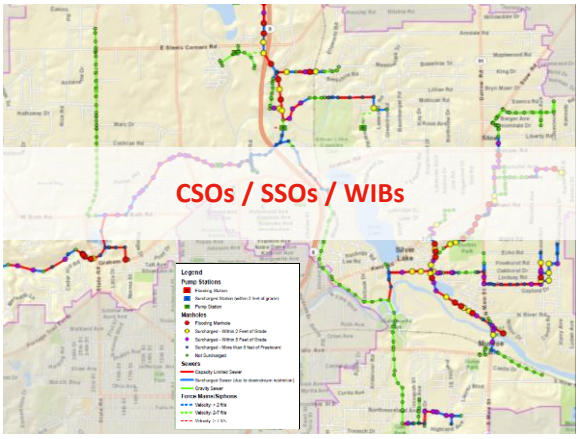
- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC (Washington Suburban Sanitary Commission)
- Ohio Case Studies: Toledo and Akron
- Remember This!

Why Model? – Traditional Applications

Evaluate Complex Hydraulics	Test Out Alternatives	Plan for Growth	Analyze Water Quality
• Seasonal demands • Fire flow analysis • Main breaks • Surge analysis	• Operational changes • Future service areas	• New demands • New supplies	• Tank cycling / mixing • Water age • Chlorine residual





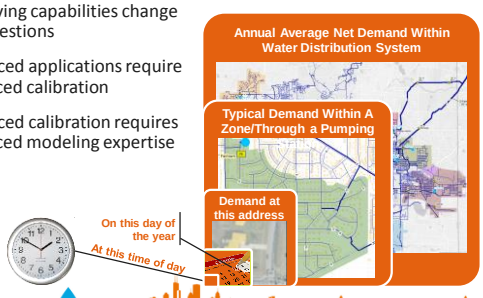


Advanced Modeling Applications

Improving capabilities change our questions

Advanced applications require advanced calibration

Advanced calibration requires advanced modeling expertise



Advanced Modeling Applications

Improving capabilities change our questions

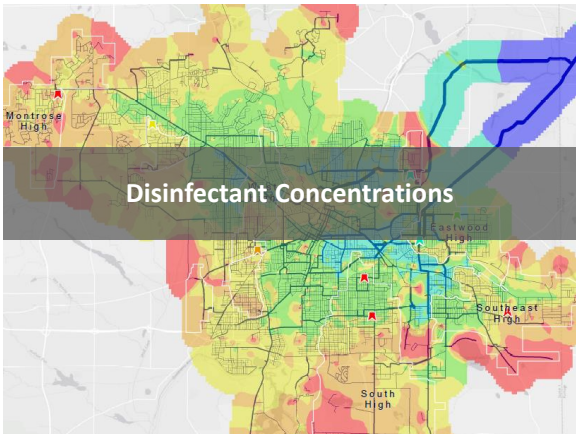
Advanced applications require advanced calibration

Advanced calibration requires advanced modeling expertise

"Big Picture" Master Planning

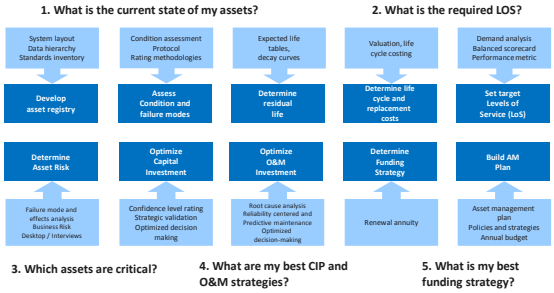
Specific, Detailed Analyses

- Optimization
- Energy
- Criticality



Hydraulic Modeling vs. Asset Management

Asset Management



Hydraulic Modeling and Asset Management

Hydraulic Models Support Asset Management!

Likelihood of Failure

- High Pressure Water Mains / Force Mains
- Wide Range of Pressures / Velocities
- Pipes With Varying Flow Direction
- Pipes with High Headloss / Excessive I/I

Hydraulic Models Support Asset Management!

Consequence of Failure

- High Flow Water Mains / Sewers
- Pipe Failure Impact
  - Minimum Pressure Requirements
  - Ability to Supply All Demands
  - Operations Concerns (Pump running off curve, etc.)
- Pipe Network Redundancy

Agenda

ARCADIS Design & Consultancy for natural and built assets

- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC — Washington Suburban Sanitary Commission
- Ohio Case Studies: Toledo and Akron
- Remember This!

Semi-Automatic Criticality Analysis

General Analytics Process:

Take a segment out of service → Run model → Evaluate LOS Requirements → Take next segment out of service

Many Hydraulic Modeling Platforms Include a Criticality Tool

Criticality Analysis Approach

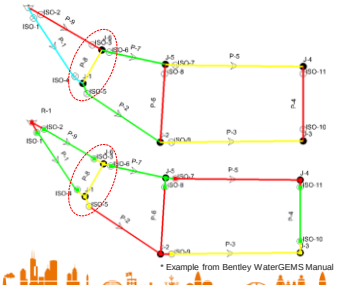
STEP 1: Define Analysis Criteria	Determine the infrastructure (i.e., mains) and criteria for the analysis
STEP 2: Perform Criticality Analysis in the Model	Set up the model and run the analysis using the criticality module
STEP 3: Review Results of the Criticality Analysis	Identify list of segments by unique identifier and rank by selected performance criteria
STEP 4: Identify Mitigation Strategies	Workshop to review results and identify potential mitigation strategies for top 5 most critical outages
STEP 5: Evaluate Mitigation Strategies	Simulate and evaluate the mitigation strategies for the top 5 most critical outages

Segmentation

Segment: Basic element of a system that can be isolated so that the effects of an outage can be evaluated

Segment can be defined by:

- Pipes
  - Each pipe is a segment
  - No information about isolation valves
- Valves
  - Segment is defined by isolation elements (more than one pipe or section of pipes)
  - Preferred method → more accurately reflects portion of the system out-of-service during an outage



* Example from Bentley WaterGEMS Manual

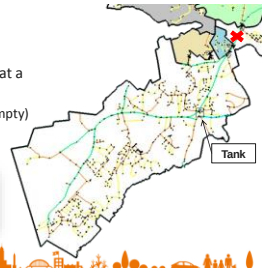
Types of Criticality Analysis

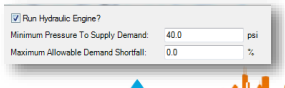
Connectivity based:

- Volume not supplied based on demand nodes disconnected from a source (reservoir or tank)

Hydraulic based:

- Volume not supplied based on the period of time during the simulation that a demand node is:
  - Disconnected from a source (e.g. tank empty)
  - Pressure is below threshold





Agenda

ARCADIS Design & Consultancy for natural and built assets

- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC (Washington Suburban Sanitary Commission)
- Ohio Case Studies: Toledo and Akron
- Remember This!

Washington Suburban Sanitary Commission

Washington Suburban Sanitary Commission

Eighth largest water/wastewater utility in the U.S.

Serves a population of nearly 1.8M people in Montgomery and Prince George's Counties, Maryland

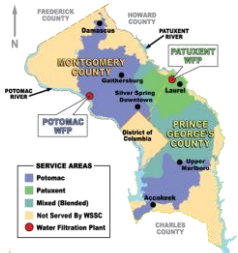
~434,000 customer accounts

Avg. day consumption = 175MGD

Max. day consumption = 220MGD

System infrastructure:

- 2 water filtration plants
- 47 water storage facilities
- 18 water pumping stations
- 86 pressure zones
- 325 PRVs
- >5,500 miles of pipe



Embracing Adaptive Resiliency

Background

2009 - WSSC developed and calibrated an all-pipes hydraulic model

2014 - WSSC model was updated with the latest infrastructure and demand projections

Current Model Applications:

- Existing System Analysis
- Future System Needs Analysis
- HGL Benchmarking
- **Criticality Analysis**

Criticality Analysis Objectives

Identify WSSC's critical buried infrastructure and quantify the impact of discrete system outages

Support asset management programs and master planning

Define Scope and Criteria

Infrastructure Scope

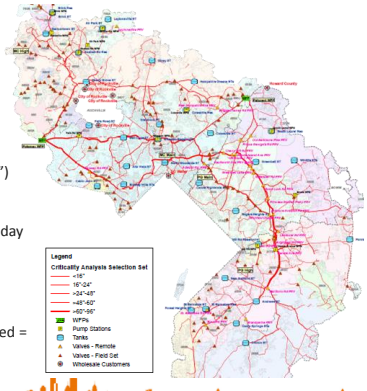
- Transmission mains (>=16")

System conditions

- Existing system maximum day
- 24 hour Extended Period simulation

Level of service

- Minimum Pressure Required = 40 psi

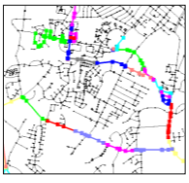


Criticality Analysis Selection Set

Segmentation Results

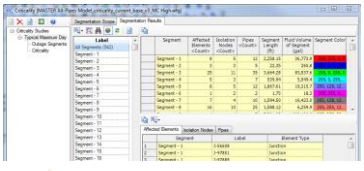
WSSC criticality analysis considered valves, including:

- Isolation valves
- Division valves
- PRVs



3,150
SEGMENTS

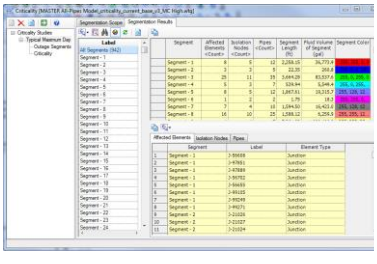
12,000
PIPES



WaterGEMS Criticality Analysis Tool

Tool to identify the most critical elements in the water transmission system (>=16"):

- Determine system performance results (e.g., demand not serviced)
- Simulation of set outages in a single run



Criticality Analysis Results Output

2,177
SEGMENTS RESULT IN DEMAND NOT BEING MET

28,572
AVG. GALLONS NOT SUPPLIED DUE TO PIPE OUTAGE

Identifying Critical Areas

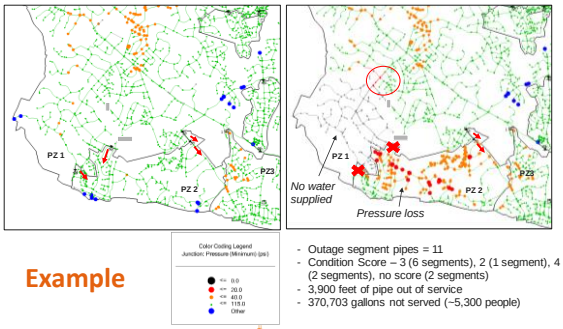
4 types of outages were identified that affect supply to:

- Facilities and large transmission mains
- Connection to a large user
- Large area disconnected from the system
- Zones fed by single PRV

WSSC identified planned CIP and operational changes to mitigate some of the critical outages

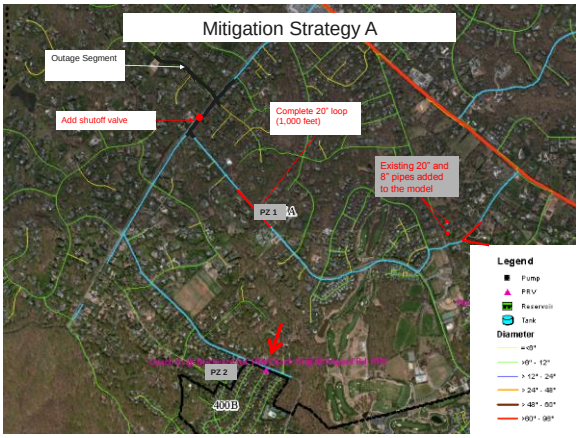
Analysis revealed new critical areas

Typical Maximum Day | **Criticality Segment Outage**



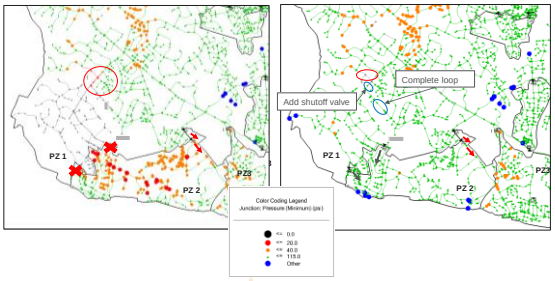
Example

- Outage segment pipes = 11
- Condition Score – 3 (6 segments), 2 (1 segment), 4 (2 segments), no score (2 segments)
- 3,900 feet of pipe out of service
- 370,703 gallons not served (~5,300 people)



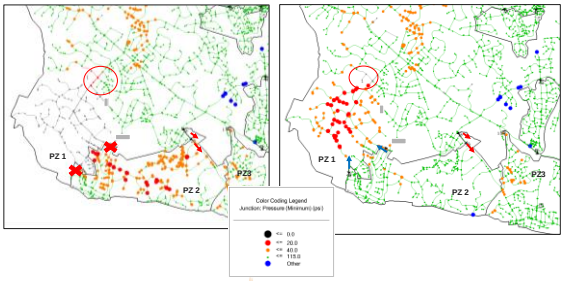
Mitigation A Evaluation

Criticality Segment Outage | **Mitigation A**



Mitigation B Evaluation

Criticality Segment Outage | **Mitigation B**



Next Steps

- WSSC to evaluate results and rankings to incorporate into their overall asset management process
- WSSC will integrate these results and mitigation strategies to evaluate potential improvements as part of their master plan

Lessons Learned

- ✓Criticality tool automates process in a single run
- ✓Both connectivity- and hydraulic-based runs can be conducted to evaluate multiple levels of service
- ✓Results are specific to simulation conditions; to be used as a comparison/ranking tool
- ✓Analysis depends on accuracy of isolation valve locations
- ✓Analysis validated planned CIP and revealed new critical areas

Agenda

ARCADIS Design & Consultancy for natural and built assets

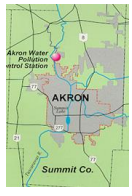
- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC — Washington Suburban Sanitary Commission
- Ohio Case Studies: Toledo and Akron
- Remember This!

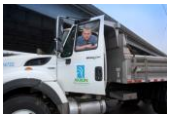
AKRON WATER DISTRIBUTION "A LANDSCAPE FOR LEARNING"

Akron Global Water Alliance

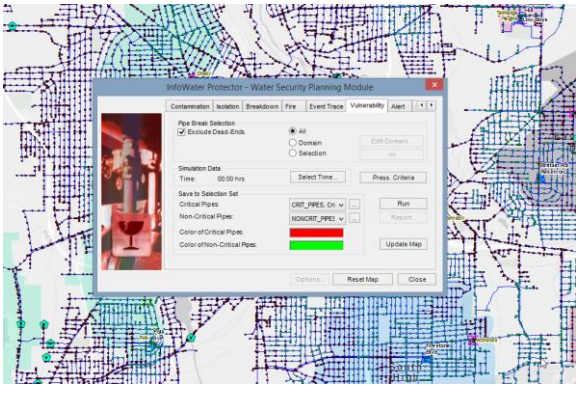
11 entities throughout Summit County Service ~300,000 consumers (90,000 Customer accounts)12 pump stations, 3 elevated tanks, 6 standpipes.

- **1,225 miles of water mains**
- **4 inch to 54 inch diameter**
- **30,000+ Valves**
- **12,000+ fire hydrants**

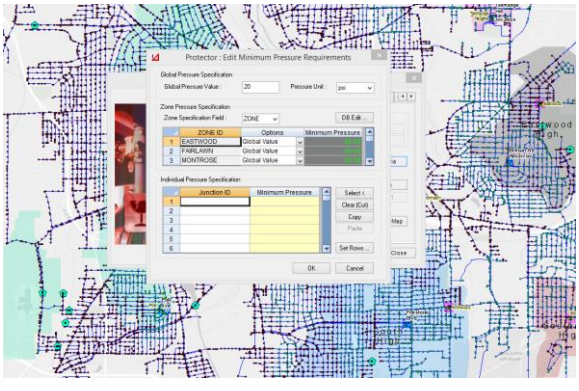




Akron Criticality Analysis

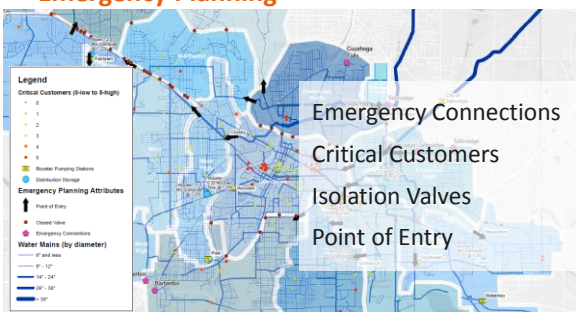


Akron Criticality Analysis

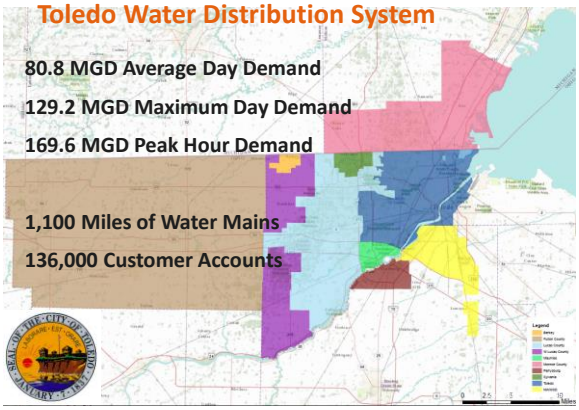


Think Outside Of The Box!

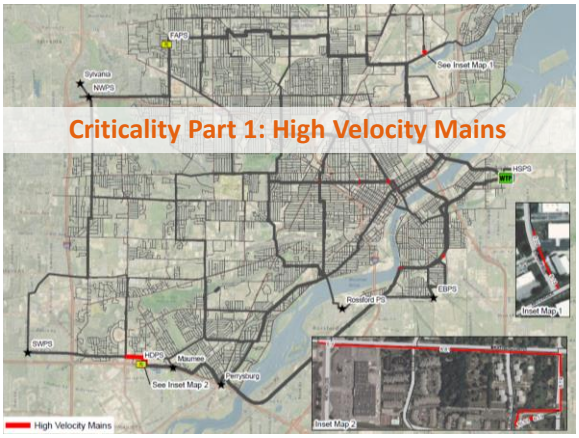
Emergency Planning



Toledo Water Distribution System



Criticality Part 1: High Velocity Mains



Criticality Part 2: Operations

City of Toledo
Water Distribution System
Hydraulic Model Results Dashboard

ARCADIS

Model Scenario: 2010 Peak Hour Demand

System Overview

169.61	mgd	Total System Demand
80.00	psi	Collin's Park Discharge Pressure

System Pressure Recorders

72.57 psi	Summit and 124th	43.39 psi	Holland Sylvania & Cook
56.3 psi	Detroit & Glendale	61.64 psi	Lewis Ave
57.77 psi	Bancroft and Goddard	66.44 psi	Flanders Area PS
		61.71 psi	Heatherdowns PS

Pumping Overview

141.32	mgd	High Service Total Flow Rate
28.29	mgd	Heatherdown's Total Flow Rate (Pump 1, Pump 2, Pump 3)
1.62	mgd	Flander's Total Flow Rate (Pump 1, Pump 2, Pump 3)

Satellite Systems

Note: PS discharge pressures reported.

8.1 mgd / 68.13 psi	East Broadway PS	16.99 mgd / 42.31 psi	SWPS
1.88 mgd / 62.62 psi	Rossford PS	6.13 mgd / 31.46 psi	NWPS
3.51 mgd / 64.97 psi	Perrysburg PS	4.71 mgd / 25.52 psi	Sylvania
4.85 mgd / 58.29 psi	Maumee	3.49 mgd / 61.64 psi	SCW Lewis
		3.49 mgd / 67.26 psi	SCW Dixie

Toledo Criticality Analysis Results

Average Day Demands
Vulnerability Assessment

Pipe ID	Status	Flow Condition	Number of Nodes in Violation	Ave.Pressure Violation (psi)	Max.Pressure Violation (psi)	Min. Residual Pressure (psi)	Critical Node ID
17072	Fail	OK	6	2.91	5.95	14.05	J32350
17076	Fail	OK	5	2.81	5.95	14.05	J32350
P4039	Fail	OK	3	3.23	5.95	14.05	J32350
P4813	Fail	OK	4	3.06	5.95	14.05	J32350
17075	Fail	OK	2	1.87	2.03	17.97	J35678
P5389	Fail	OK	1	2	2	18	J35678
125	Fail	Cannot supply demand	0	0	0	0	
1067	Fail	Cannot supply demand	0	0	0	0	
1245	Fail	Cannot supply demand	0	0	0	0	
1728	Fail	Cannot supply demand	0	0	0	0	
1914	Fail	Cannot supply demand	0	0	0	0	
2571	Fail	Cannot supply demand	0	0	0	0	
2613	Fail	Cannot supply demand	0	0	0	0	
3293	Fail	Cannot supply demand	0	0	0	0	
3296	Fail	Cannot supply demand	0	0	0	0	
3297	Fail	Cannot supply demand	0	0	0	0	
4346	Fail	Cannot supply demand	0	0	0	0	
4858	Fail	Cannot supply demand	0	0	0	0	
4446	Fail	Cannot supply demand	0	0	0	0	
4673	Fail	Cannot supply demand	0	0	0	0	
8967	Fail	Cannot supply demand	0	0	0	0	
8737	Fail	Cannot supply demand	0	0	0	0	
8739	Fail	Cannot supply demand	0	0	0	0	

Toledo Criticality Analysis Results

Maximum Day Demands
Vulnerability Assessment

Pipe ID	Status	Flow Condition	# of Nodes in Violation	Ave.Pressure Violation (psi)	Max.Pressure Violation (psi)	Min. Residual Pressure (psi)	Critical Node ID
17072	Fail	OK	11	36.98	47.81	-27.81	J32350
17076	Fail	OK	10	36.39	47.81	-27.81	J32350
P4039	Fail	OK	8	34.48	47.81	-27.81	J32350
P4813	Fail	OK	9	35.59	47.81	-27.81	J32350
17075	Fail	OK	7	32.58	43.9	-23.9	J35678
P5389	Fail	OK	5	28.47	43.83	-23.83	J35678
1015	Fail	OK	15	24.71	33	-13	J32350
16554	Fail	OK	13	24.21	33	-13	J32350
P311	Fail	OK	17	23.71	33	-13	J32350
P313	Fail	OK	19	23.86	33	-13	J32350
1305	Fail	OK	48	11.17	21.76	-1.76	J32350
2701	Fail	OK	122	4.36	12.19	7.81	J32350
P627	Fail	OK	81	3.77	11.81	8.19	J32350
2698	Fail	OK	79	3.69	11.74	8.26	J32350
11273	Fail	OK	208	2.15	9.77	10.23	J32350
16334	Fail	OK	3	5.17	7.76	12.24	J31610
16346	Fail	OK	3	5.17	7.76	12.24	J31610
16347	Fail	OK	3	5.17	7.76	12.24	J31610
16355	Fail	OK	3	5.17	7.76	12.24	J31610
16356	Fail	OK	3	5.17	7.76	12.24	J31610
16358	Fail	OK	3	5.17	7.76	12.24	J31610
16359	Fail	OK	3	5.17	7.76	12.24	J31610
P5841	Fail	OK	3	5.17	7.76	12.24	J31610

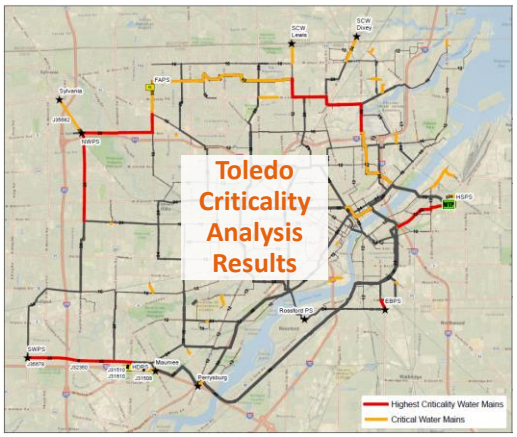
Toledo Cr

Peak Hour Demands
Vulnerability Assessment

Pipe ID	Status	Flow Condition	# of Nodes in Violation	Ave.Pressure Violation (psi)	Max.Pressure Violation (psi)	Min. Residual Pressure (psi)	Critical Node ID
17072	Fail	OK	492	4.93	39.08	-14.08	J32350
17076	Fail	OK	492	4.77	39.08	-14.08	J32350
P4039	Fail	OK	492	4.33	39.08	-14.08	J32350
P4813	Fail	OK	492	4.44	39.08	-14.08	J32350
17075	Fail	OK	384	4.58	35.33	-10.33	J35678
P5389	Fail	OK	384	3.93	35.33	-10.33	J35678
1015	Fail	OK	368	6.07	14.21	-0.21	J32350
16554	Fail	OK	368	6.07	14.21	-0.21	J32350
P311	Fail	OK	368	6.07	14.21	-0.21	J32350
P313	Fail	OK	368	6.07	14.21	-0.21	J32350
1305	Fail	OK	1,168	10.18	21.76	-1.76	J32350
11273	Fail	OK	1,168	10.18	21.76	-1.76	J32350
2701	Fail	OK	1,168	10.18	21.76	-1.76	J32350
P627	Fail	OK	1,168	10.18	21.76	-1.76	J32350
2698	Fail	OK	1,168	10.18	21.76	-1.76	J32350
P4584	Fail	OK	6	27.58	43.83	-23.83	J35678
16346	Fail	with Hydrotriage	4	27.58	43.83	-23.83	J35678
16347	Fail	with Hydrotriage	4	27.58	43.83	-23.83	J35678
16462	Fail	with Hydrotriage	4	27.58	43.83	-23.83	J35678
P5389	Fail	OK	6	27.58	43.83	-23.83	J35678
16334	Fail	OK	6	27.58	43.83	-23.83	J35678
1015	Fail	OK	7	16.68	19.68	3.32	J35669
16554	Fail	OK	7	16.68	19.68	3.32	J35669
P311	Fail	OK	7	16.68	19.68	3.32	J35669
P313	Fail	OK	7	16.68	19.68	3.32	J35669
1305	Fail	OK	712	4.58	17.27	2.63	J35671
11273	Fail	OK	712	4.58	17.27	2.63	J35671
2701	Fail	OK	712	4.58	17.27	2.63	J35671
P627	Fail	OK	712	4.58	17.27	2.63	J35671
2698	Fail	OK	712	4.58	17.27	2.63	J35671
P4584	Fail	OK	23	3.45	14.79	5.33	J35662
16346	Fail	OK	23	3.45	14.79	5.33	J35662
16347	Fail	OK	23	3.45	14.79	5.33	J35662
16462	Fail	with Hydrotriage	23	3.45	14.79	5.33	J35662
P5389	Fail	with Hydrotriage	23	3.45	14.79	5.33	J35662
16334	Fail	OK	23	3.45	14.79	5.33	J35662
P4584	Fail	OK	2	4.87	12.31	6.33	J35662
16346	Fail	OK	2	4.87	12.31	6.33	J35662
16347	Fail	OK	2	4.87	12.31	6.33	J35662
16462	Fail	OK	2	4.87	12.31	6.33	J35662
P5389	Fail	OK	2	4.87	12.31	6.33	J35662
16334	Fail	OK	2	4.87	12.31	6.33	J35662
1015	Fail	OK	108	1.34	13.1	6.9	J35662
16554	Fail	OK	108	1.34	13.1	6.9	J35662
P311	Fail	OK	108	1.34	13.1	6.9	J35662
P313	Fail	OK	108	1.34	13.1	6.9	J35662
1305	Fail	OK	13	3.31	12.49	6.59	J35662
11273	Fail	OK	13	3.31	12.49	6.59	J35662
2701	Fail	OK	13	3.31	12.49	6.59	J35662
P627	Fail	OK	13	3.31	12.49	6.59	J35662
2698	Fail	OK	13	3.31	12.49	6.59	J35662
P2589	Fail	OK	19	3.31	12.49	6.59	J35662
P2585	Fail	OK	19	3.31	12.49	6.59	J35662
1015	Fail	OK	19	3.31	12.49	6.59	J35662
16554	Fail	OK	19	3.31	12.49	6.59	J35662
16398	Fail	OK	19	3.31	12.49	6.59	J35662
18573	Fail	OK	19	3.31	12.49	6.59	J35662
16401	Fail	OK	19	3.31	12.49	6.59	J35662
16402	Fail	OK	19	3.31	12.49	6.59	J35662
16407	Fail	with Hydrotriage	19	3.31	12.49	6.59	J35662
P5683	Fail	with Hydrotriage	19	3.31	12.49	6.59	J35662
1015	Fail	OK	11	1.59	7.76	12.24	J31508
16554	Fail	OK	11	1.59	7.76	12.24	J31508
P311	Fail	OK	11	1.59	7.76	12.24	J31508
P313	Fail	OK	11	1.59	7.76	12.24	J31508
16407	Fail	with Hydrotriage	39	1.1	4.3	15.7	J31510
P5683	Fail	with Hydrotriage	39	1.1	4.3	15.7	J31510
1015	Fail	OK	4	0.87	6.33	13.67	J32652
16554	Fail	OK	4	0.87	6.33	13.67	J32652
P311	Fail	OK	4	0.87	6.33	13.67	J32652
P313	Fail	OK	4	0.87	6.33	13.67	J32652
16355	Fail	OK	37	1.58	8.33	11.67	J32652
16356	Fail	OK	37	1.58	8.33	11.67	J32652
16358	Fail	OK	37	1.58	8.33	11.67	J32652
16359	Fail	OK	37	1.58	8.33	11.67	J32652
16407	Fail	OK	4	0.87	6.33	13.67	J32652
16462	Fail	OK	4	0.87	6.33	13.67	J32652
16407	Fail	with Hydrotriage	40	0.9	6.33	13.67	J32652

Extreme-22psi

Page 1 of 8



Agenda

ARCADIS Design & Consultancy for natural and built assets

- Purpose: Hydraulic Models vs. Asset Mgmt.
- Basics of an Operational-Based Criticality Analysis
- Case Study: WSSC — Washington Suburban Sanitary Commission
- Ohio Case Studies: Toledo and Akron
- Remember This!

Hydraulic Models Support Asset Management!

Likelihood of Failure

- High Pressure Water Mains / Force Mains
- Wide Range of Pressures / Velocities
- Pipes With Varying Flow Direction
- Pipes with High Headloss / Excessive I/I

Hydraulic Models Support Asset Management!

Consequence of Failure

- High Flow Water Mains / Sewers
- Pipe Failure Impact
  - Minimum Pressure Requirements
  - Ability to Supply All Demands
  - Operations Concerns (Pump running off curve, etc.)
- Pipe Network Redundancy

Hydraulic Modeling and Asset Management

ARCADIS Design & Consultancy for natural and built assets

Improving quality of life.

James P. Cooper, PE

jim.cooper@arcadis.com
+1 330 283 1652

© Arcadis 2016