

Lessons Learned in Deploying Machine Learning for Predicting Tunnel Inflows

Derek Sutton, Citizens Energy Group

Chris Ranck, PE, BCEE, D.WRE, ENV SP, Black & Veatch

2023

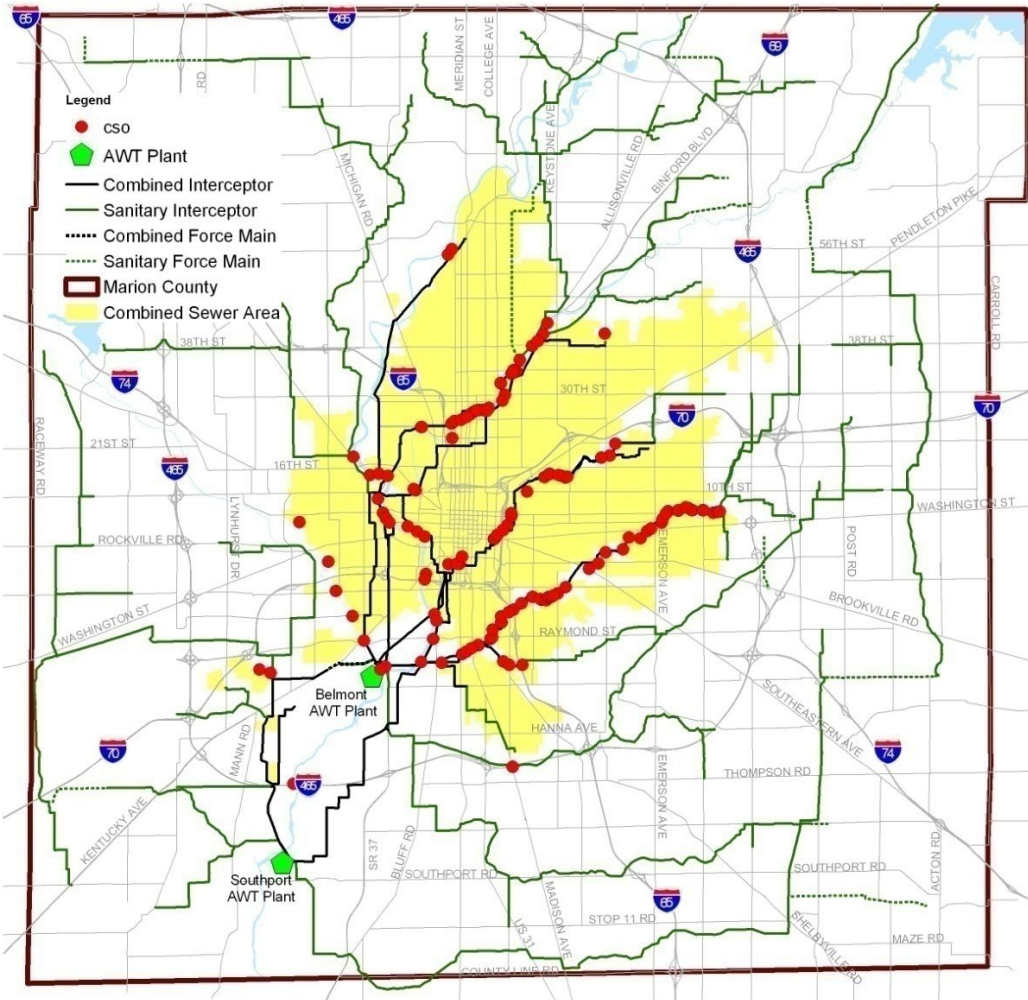
INDIANAPOLIS

FIVE CITIES PLUS

Agenda

- Background: Citizens Energy Group
- Background: Citizens' Machine Learning (ML) Tool
- How is it Working?
- Tool Enhancements & Maintenance
- Summary & Next Steps
- Discussion

Background: Citizens Energy Group

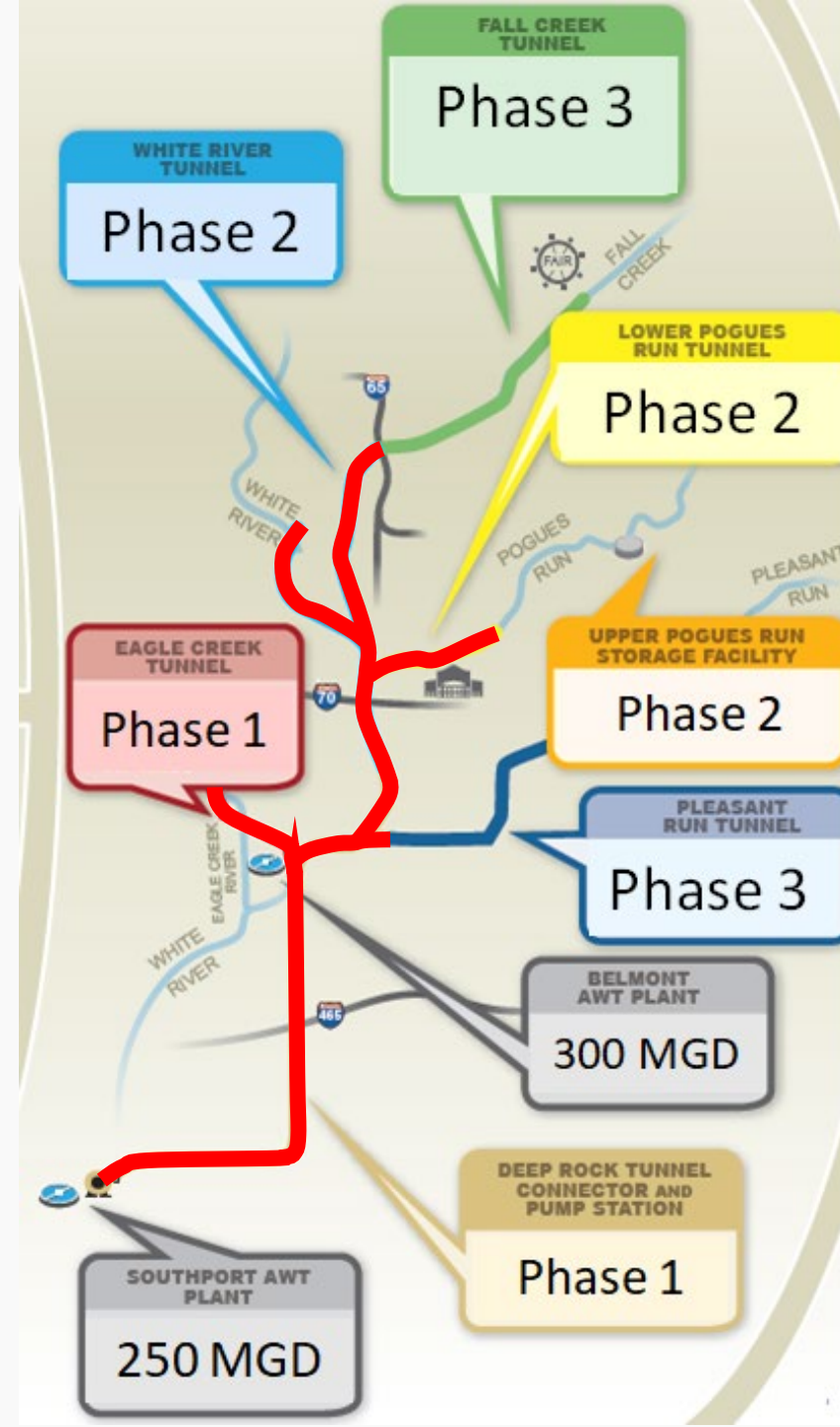


- Two Advanced Wastewater (AWT) Plants
- Combined Sewer Area with ~ 34 square miles, 131 outfalls
- Service area population of ~ 800,000
- 20-year Combined Sewer Overflow Long-Term Control Plan (CSO LTCP) approved December 2006
- Amended Three Times
- Completion 2025

Background: Citizens Energy Group

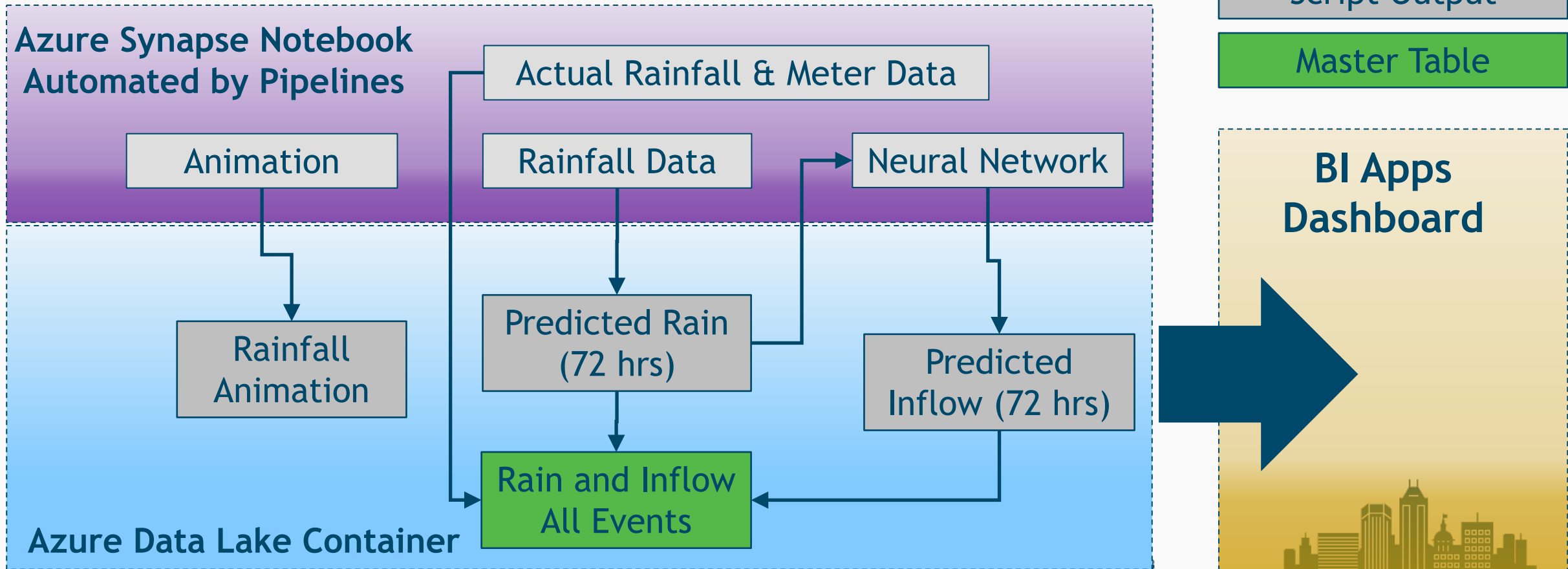
Consent Decree Projects

- Phase 1: DigIndy Tunnel ~ 9 Miles, 80 MG
- Phase 2: DigIndy Tunnel ~ 17 Miles, 170 MG



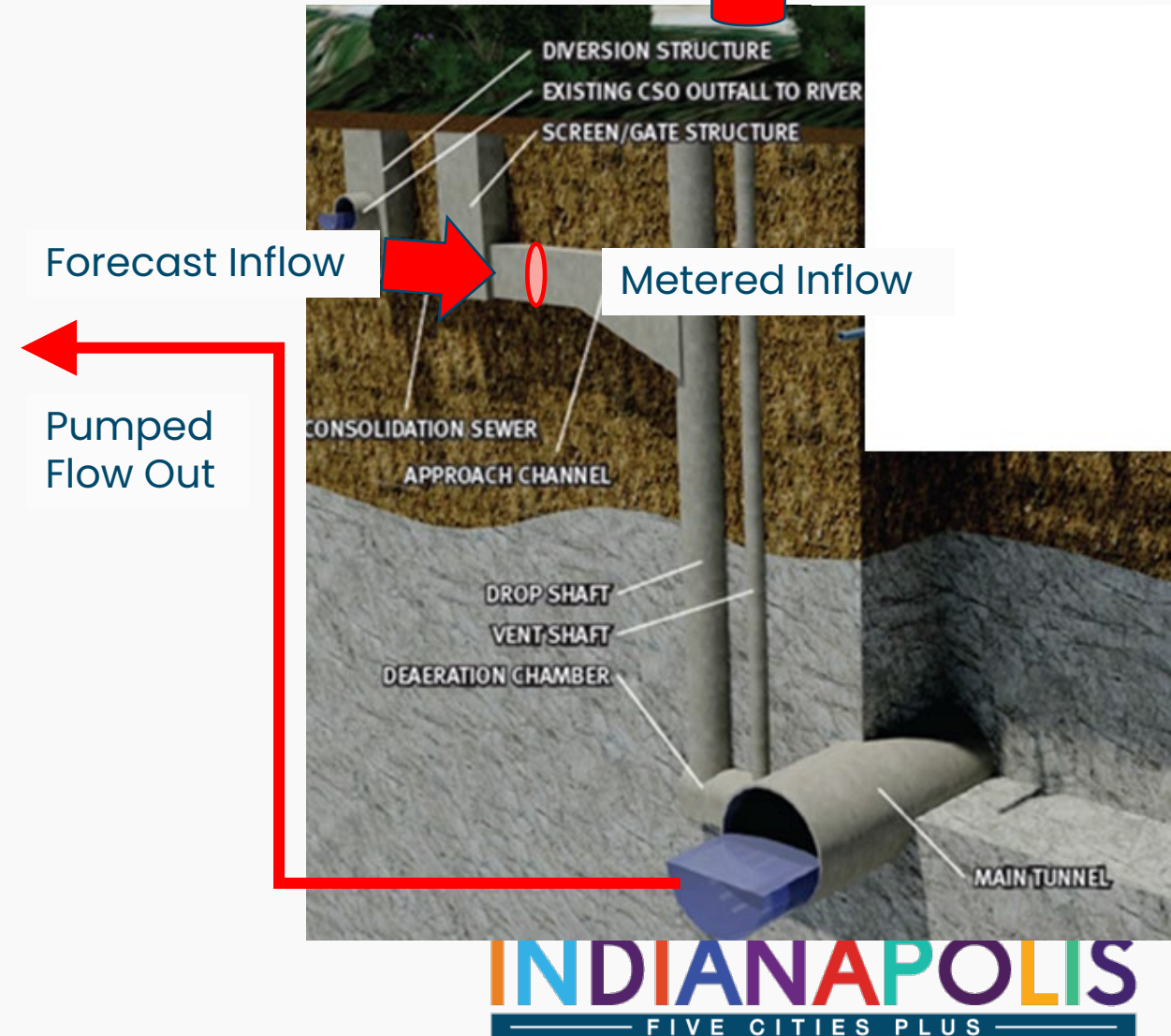
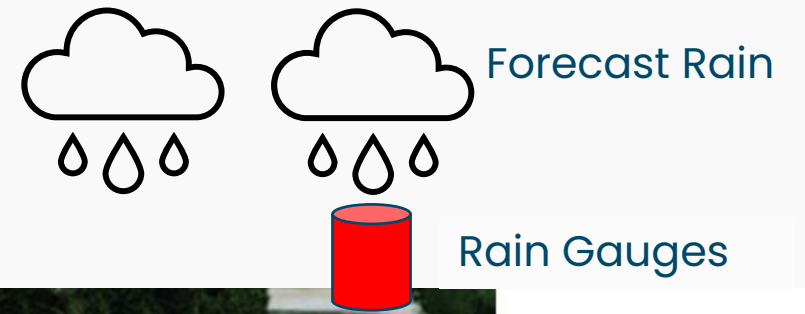
Background: Citizens' ML Tool

- Architecture



Background: Citizens' ML Tool

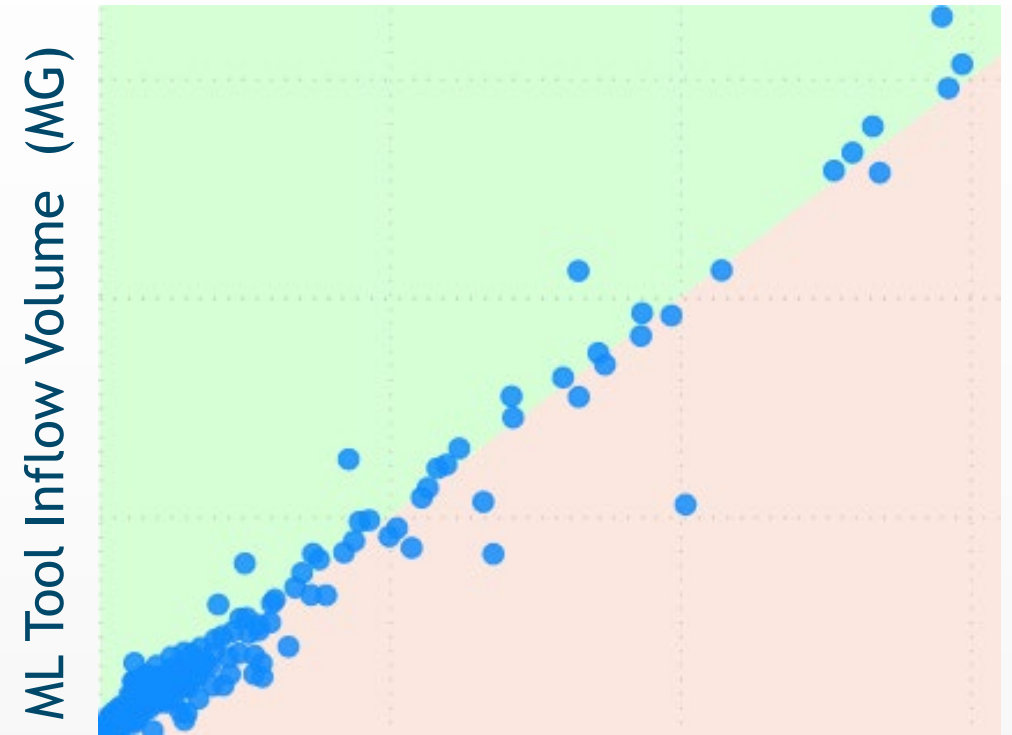
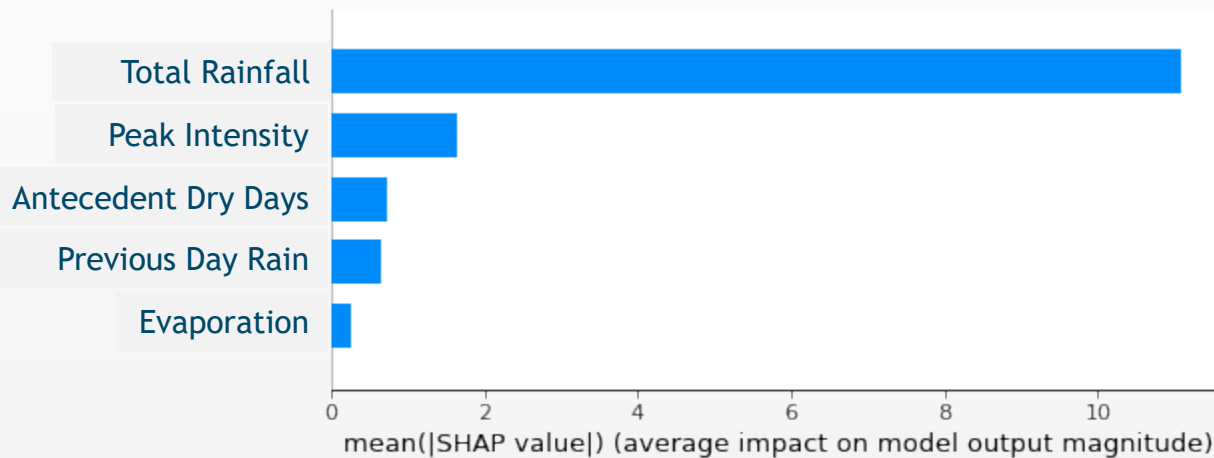
- Digital Elements
- Physical Elements
- Checks
 - Forecast v. Meters
 - Meters v. Pumping



Background: Citizens' ML Tool

- Basis: 2016-2019 Modeled Tunnel Inflow
 - Input: Rainfall
 - Input: Evaporation

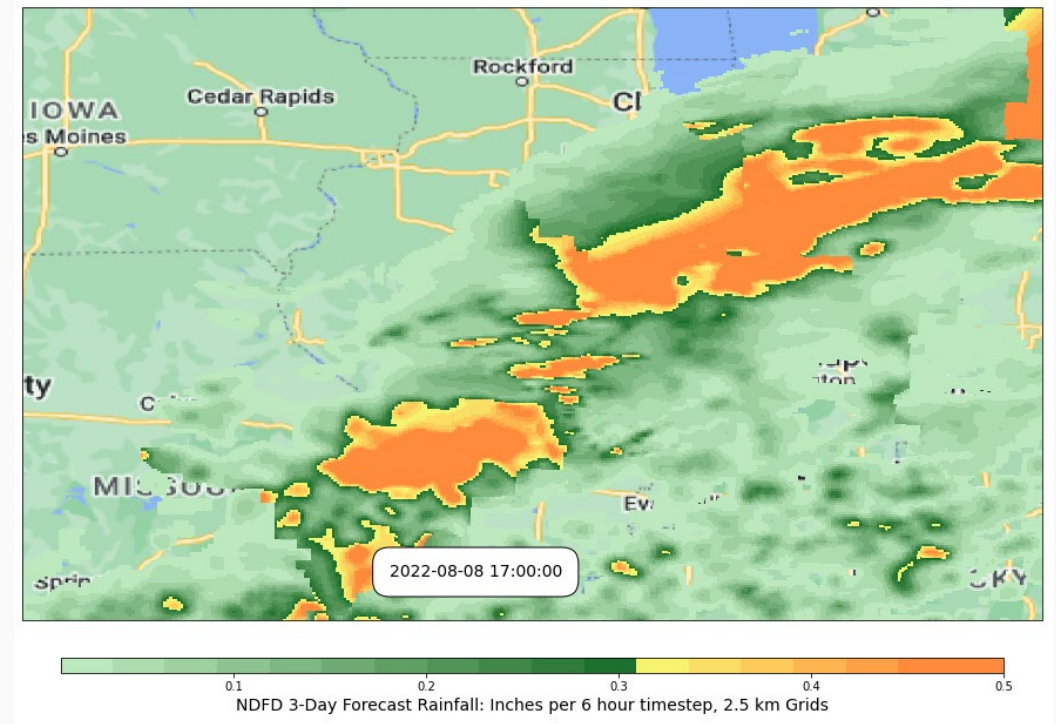
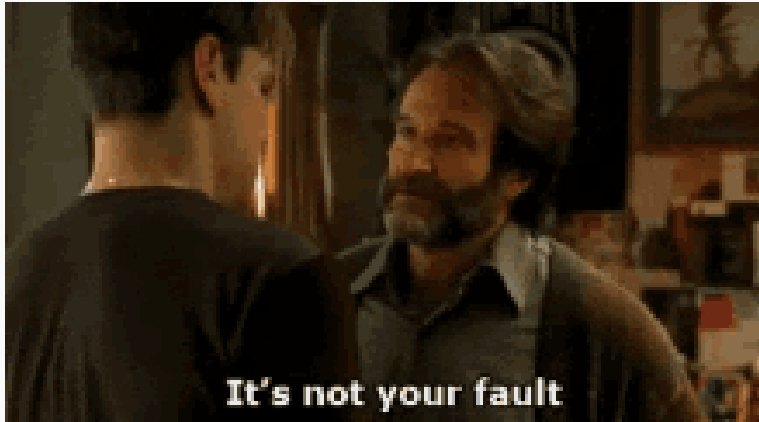
Parameter Sensitivity Evaluation



InfoWorks Modeled Inflow Volume (MG)

Sutton et. al, 2022

How is it Working?



Dates	Forecast Rain (in)	Gauged Rain (in)	Forecast Inflow (MG)	Metered Inflow (MG)
8/9/2022	1.48	1.54	80	95
2/8/2023 - 2/9/2023	1.81	1.25	55	55
3/3/2023	2.92	2.24	120	188

How is it Working?

Dates	Metered Inflow (MG)	Estimated Infiltration (MG)	Total Pumped (MG)	% Difference
8/9/2022	95	6	105	- 4%
2/8/2023 – 2/9/2023	55	10	55	+ 18%
3/3/2023 – 3/6/2023	219	13	194	+ 20%
8/29/2022 – 8/30/2022	122	8	144	- 9%

- Range of Meters v. Pumping: +29% to -23%
- Overall Average: +7%

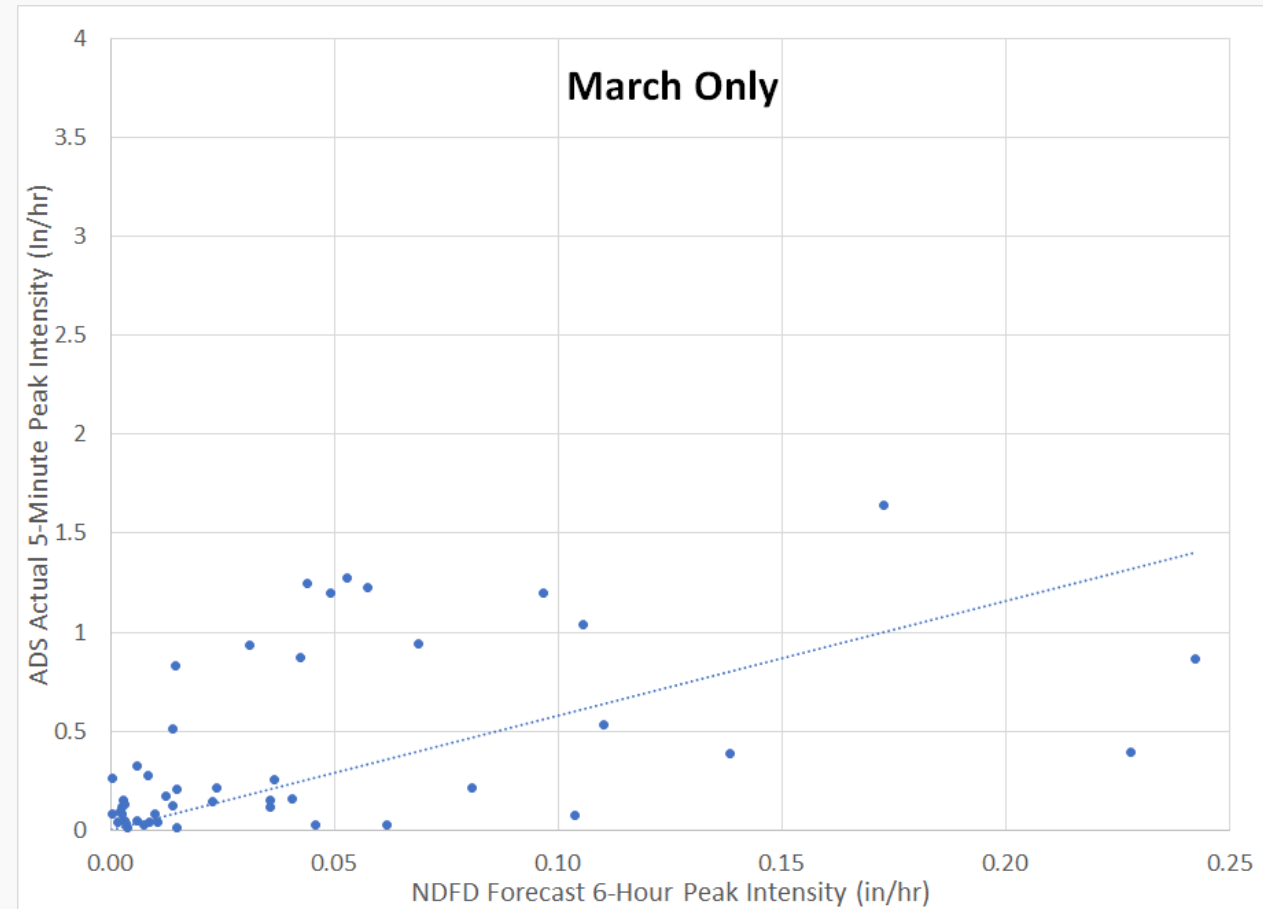
Tool Enhancements & Maintenance

- Peak Intensity Correction
- Integration of High Resolution Rapid Refresh (HRRR) Forecast with National Digital Forecast Database (NDFD) Forecast
- Drop Shaft Meter Data Review
- NOAA Backend Changes August 2022



Tool Enhancements & Maintenance

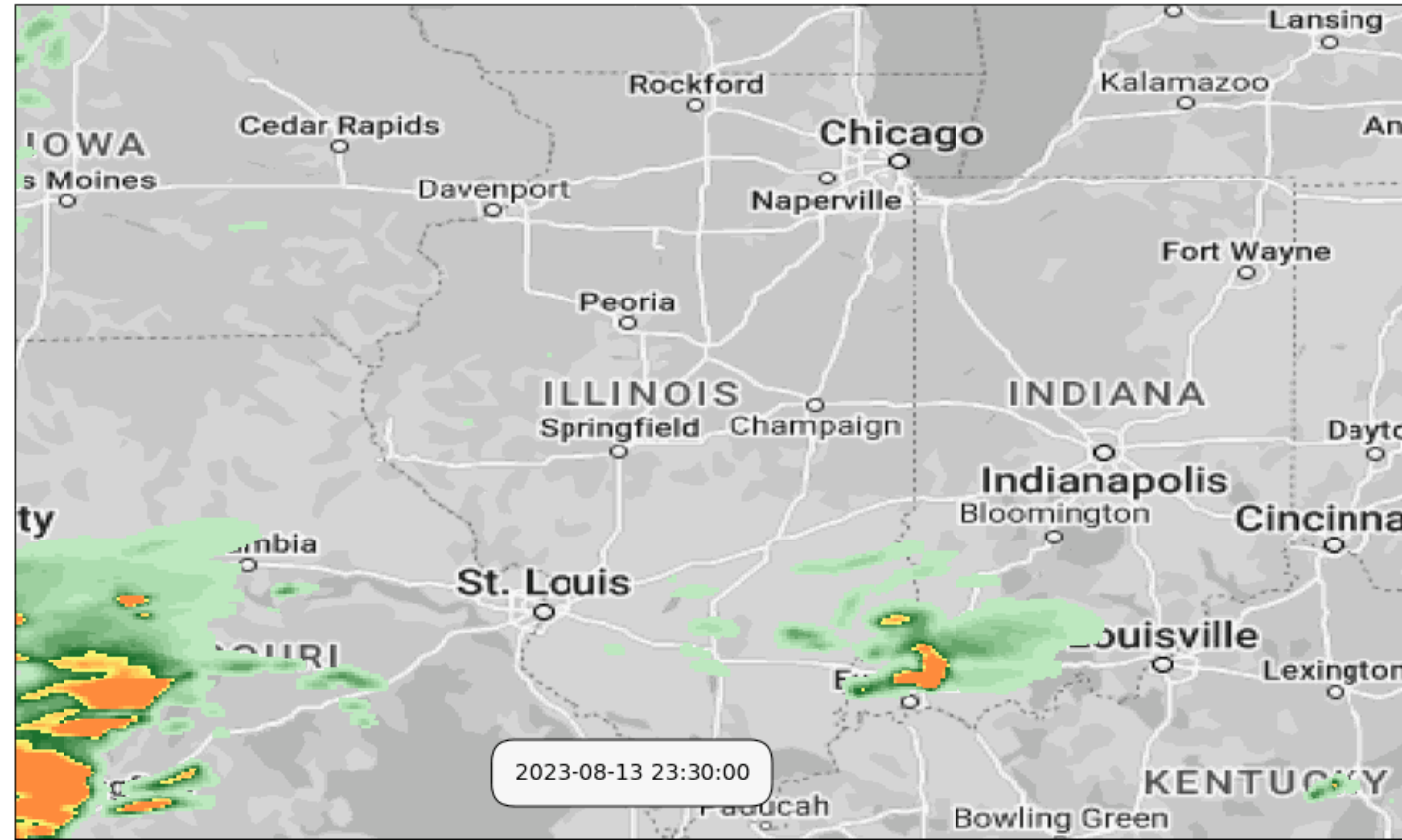
- Peak Intensity Correction
 - Neural Network: 5-minute data
 - NDFD Forecast: 6-hour data
 - Compare March 2021 - March 2023
 - Correction
 - October - March based on intensity
 - April - September based on intensity and evaporation



Tool Enhancements & Maintenance

- Integration of High Resolution Rapid Refresh Forecast

Parameter	NOAA HRRR	NOAA NDFD
Duration	18 Hours	72 Hours
Spatial Resolution	2.5 km	2.5 km
Temporal Resolution	1 Hour	6 Hours



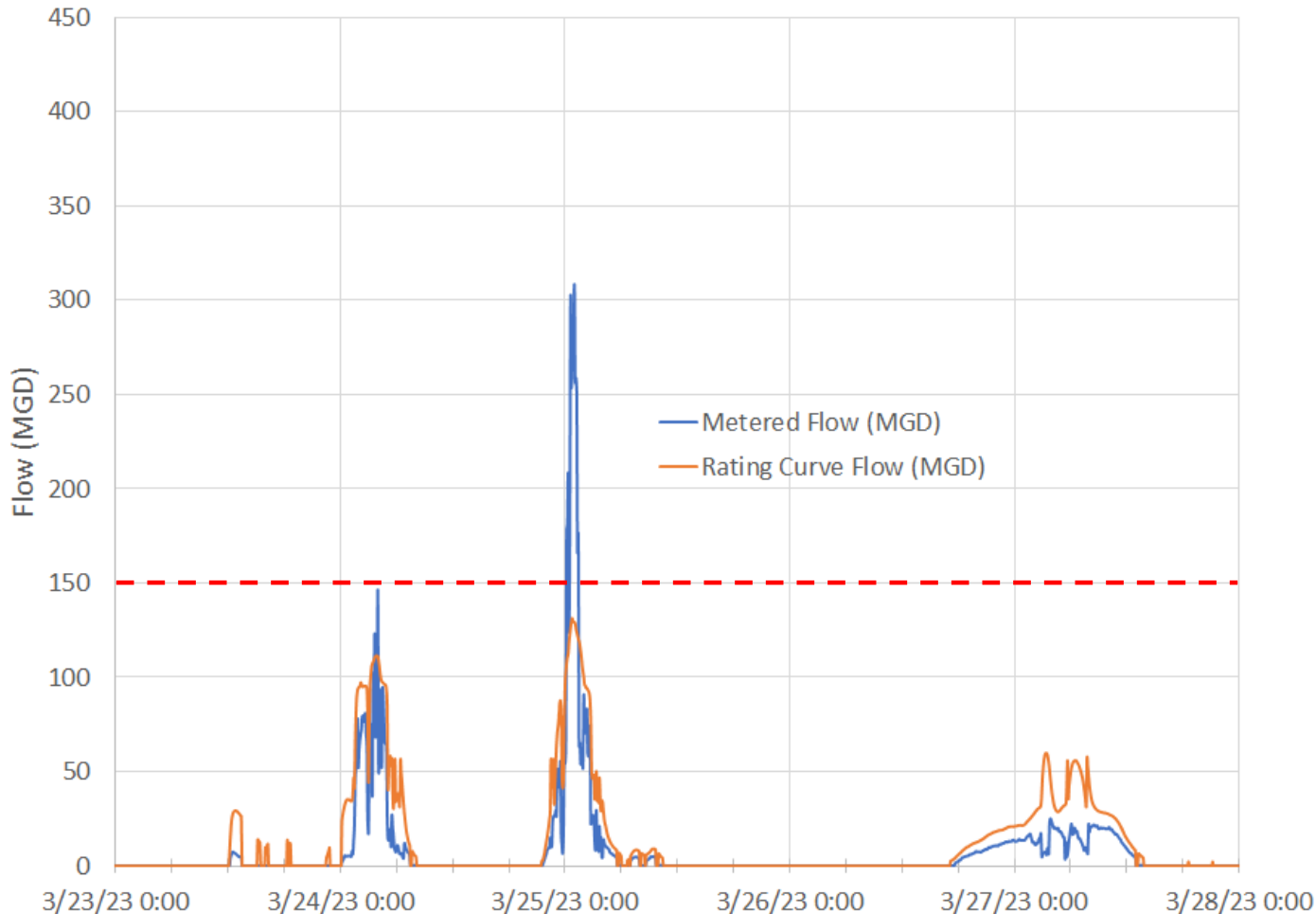
Tool Enhancements & Maintenance

- Integration of High Resolution Rapid Refresh Forecast

Dates	Forecast Rain (in)	Gauged Rain (in)	Forecast Inflow (MG)	Metered Inflow (MG)
7/28/2023	0.34	0.41	< 5	11
7/29/2023	0.82	0.34	25	3
8/5/2023	1.40	0.11	50	0
8/6/2023	0.22	0.11	< 5	1
8/7/2023	0.57	0.49	15	2
8/8/2023	0.01	0.24	0	4
8/9/2023	1.45	1.71	55	88

Tool Enhancements & Maintenance

CSO 118 Tunnel Inflow - Metered v. Drop Shaft Rating Curve



Drop Shaft Meter Data Review

- CSO 117 - 100 MGD Shaft
- CSO 118 - 150 MGD Shaft
- Peak flows adjusted based on design Rating Curve
- Reviewing lingering inflow and river stage

Summary

• Lessons Learned

- Maintenance is a **daily** activity
- Be prepared to make updates
- Review meter data before criticizing the ML tool

• Potential Next Steps

- Incorporate current meter or SCADA data to “correct on the fly”
- Re-train and re-test ML tool following next collection system model update
- Re-train and re-test ML tool to volume pumped

Discussion

- Questions?

Derek Sutton dsutton@citizensenergygroup.com

Chris Ranck ranckcj@bv.com

