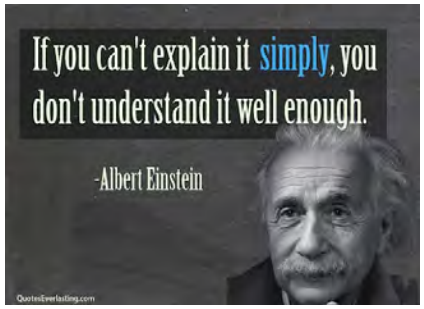
# KLINE'S ISLAND SEWER SYSTEM (KISS) 2021 MODEL

August 8, 2022

Calibration Overview – LCA Board

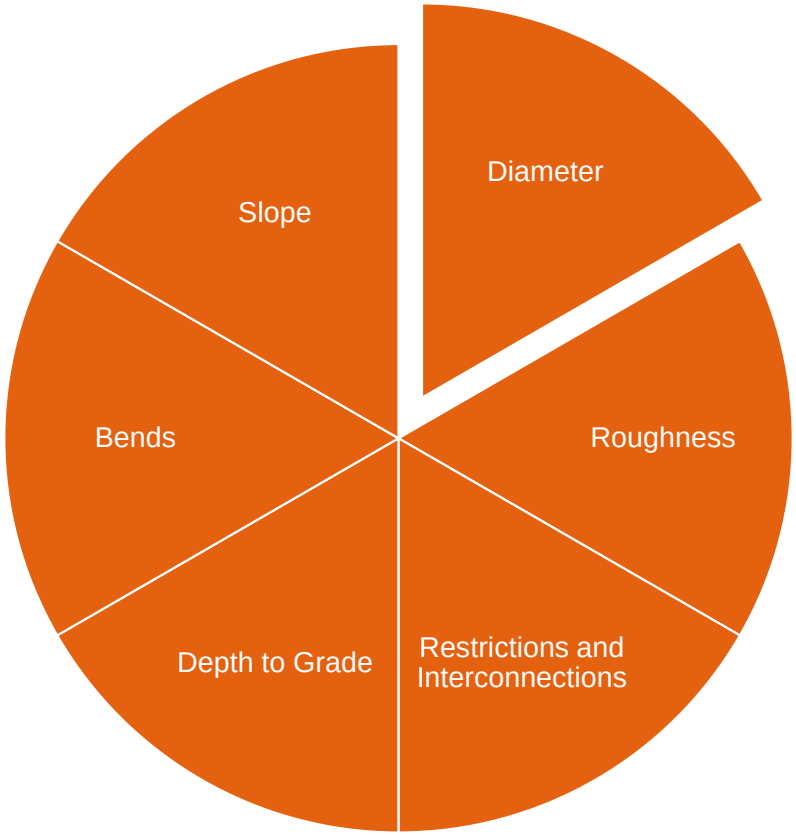
ARCADIS Design & Consultancy for natural and built assets

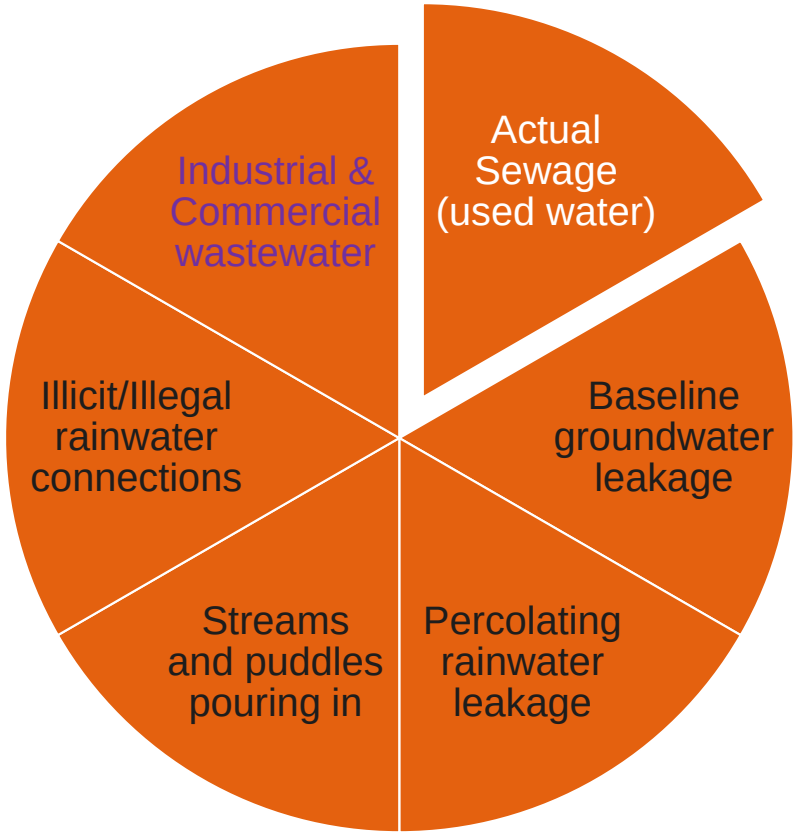

- What is a dynamic hydraulic sewer model?
- What is a model used for?
- What are steps to modeling?
- Where is model strong and weak?
- What are the things we are doing now with the calibrated model?
- What are future modeling efforts?

# What is a dynamic hydraulic sewer model?

# A sewer model is a digital twin of sewer system




Physical Attributes of Pipes




What's in the Pipe

# What is a model used for?

# Current Performance

- Blockages
- Flow restrictions
- Undersized pipes
- Available capacity
- Pump station demand
- Basement backups
- Dry weather backups
- Wet weather overflow locations, volumes, and durations
- Inflow locations
- Reliability

**What is response to large rain events?**

**How does it handle extended wet periods?**

**How good is its Level of Protection?**

**Current performance is function of base load and rainfall frequency/intensity**

# Future Performance

- Converting farms to houses and warehouses
- Revelopment
- Expanding service area
- Adding more hauled waste
- Losing industry
- Adding industry
- Aging (leaking) pipes
- Weather changes
- Water conservation

# Future infrastructure needs

- Estimating reductions from sewer collection system rehab
- Estimating reductions from private property leakage reductions
- What and where are conveyance capacity improvements needed
- When to install capacity improvements
- Replacement vs parallel
- Correctly sizing interceptors, pump station, tanks
- Determining impact on treatment plants
- Determining impact on downstream signatories

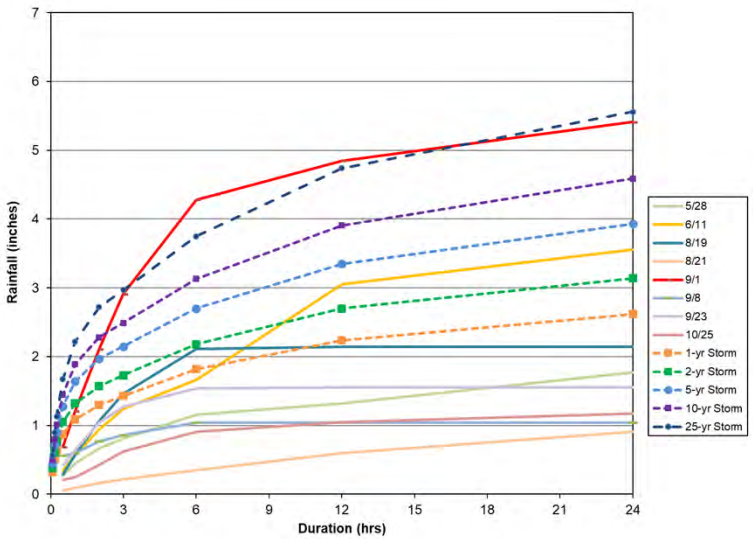

**Alternative analyses are like experimenting to find best formula**

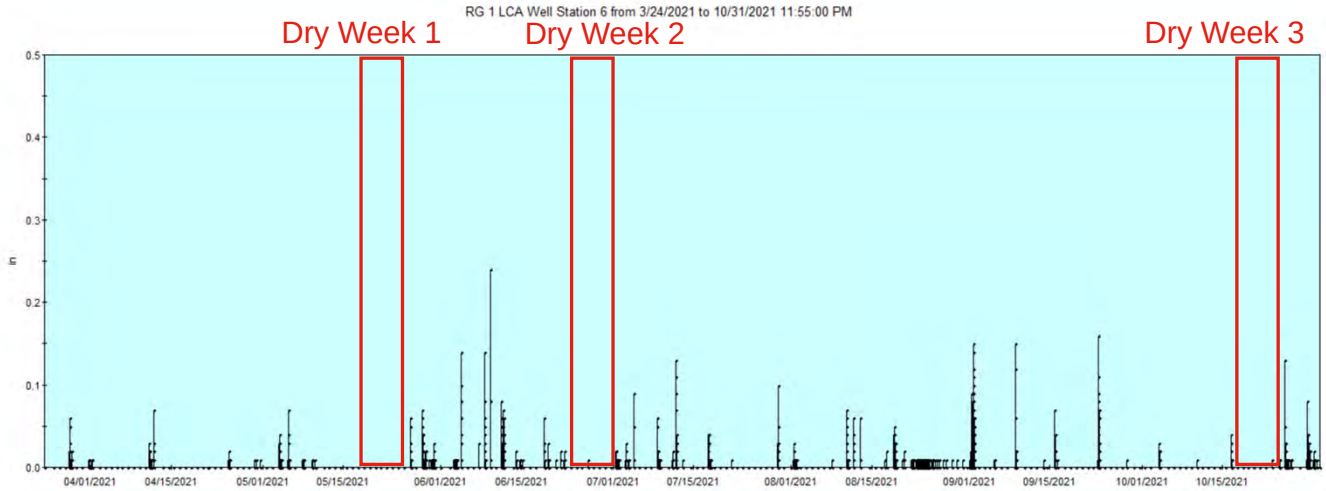
# Where are KISS model's strengths and weaknesses?


# ENTIRE KISS MODEL

# Strengths – Great Dry and Wet Weather Periods

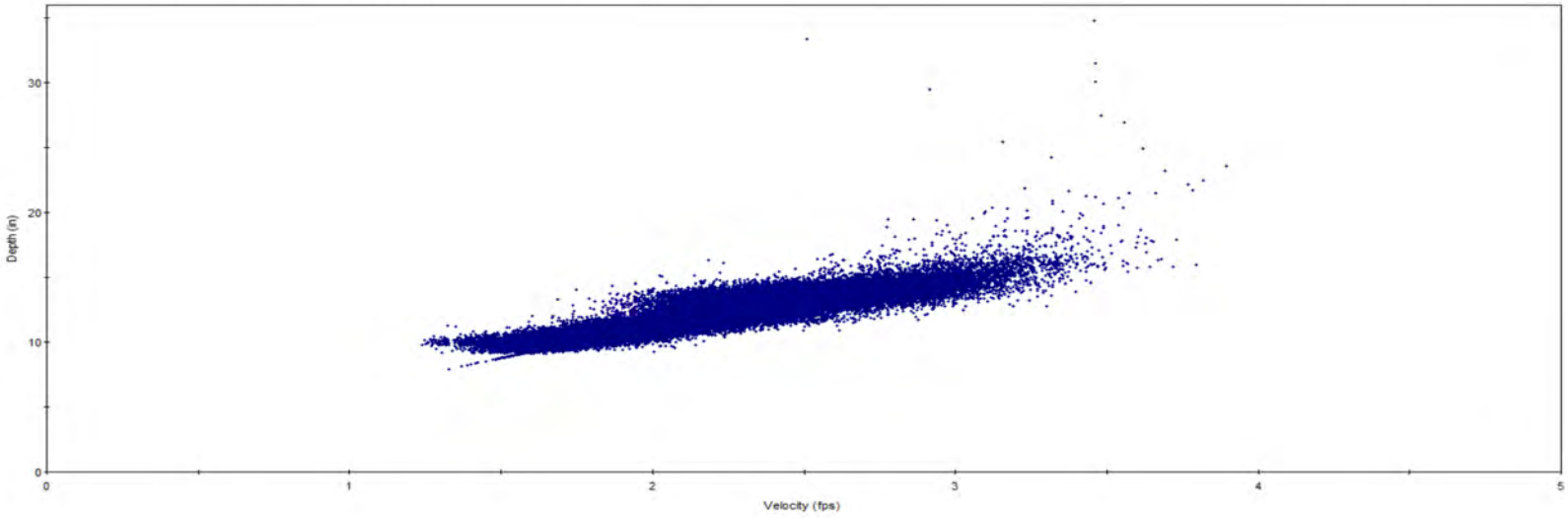
- Multiple significant storms for calibration during metering period
- Due to large groundwater fluctuation throughout the year, able to use several periods for dry weather calibration to calibrate groundwater module well



# Strengths – Flow Meter Data Validation

- Very high quality flow data
  - Independent meter installation checks led to ~15% of meters being replaced or reset, adding of meters, and abandoning of meters
  - 4 rounds of data validation led to high data confidence
  - Majority of data (temporary and permanent) collected in 5-minute increments for very good data resolution



# Strengths – Strong Knowledge of System

- Strong hydraulic knowledge of KISS systems incorporated into model
  - Interceptors are typically watertight, so bottomland catchments were delineated separately
  - Calibration upstream of WTP finally sound - knowledge of downstream siphons and system hydraulics
  - Industrial flow data used extensively
  - Operations of FEB and pump stations during calibration well documented

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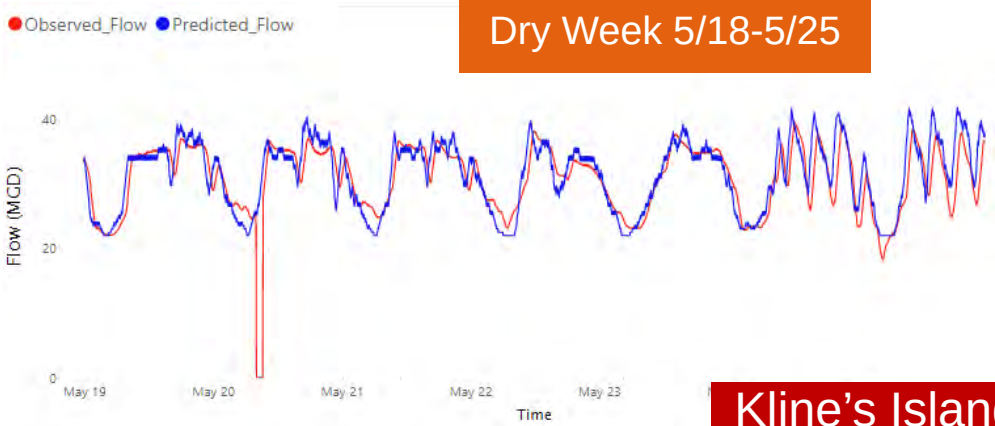
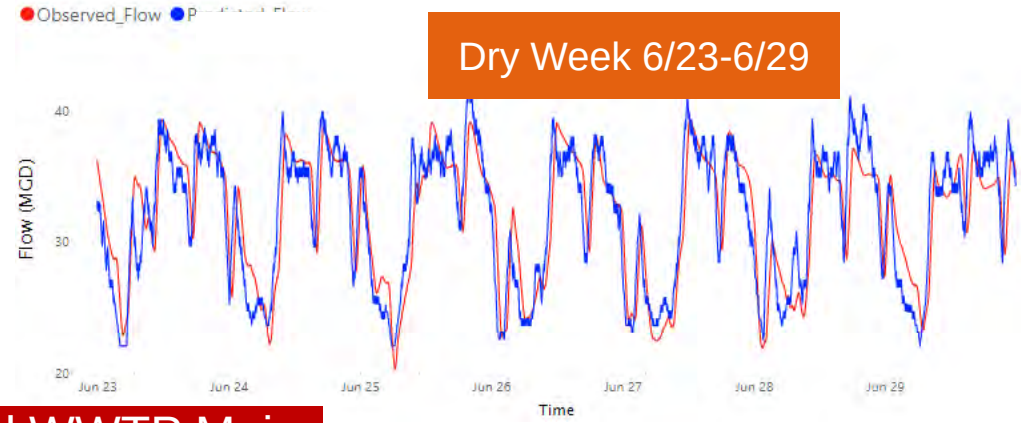
# Strengths – Strong Dry Weather Calibration

Dry Week 5/18-5/25

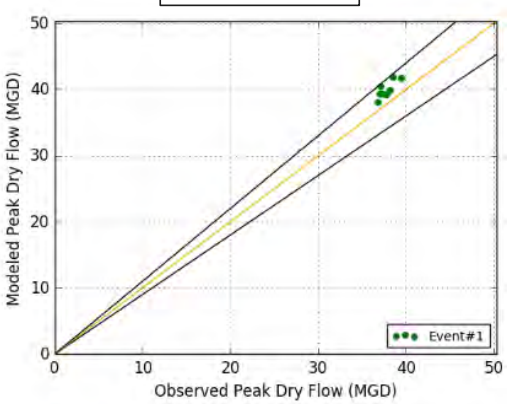



Dry Week 6/23-6/29

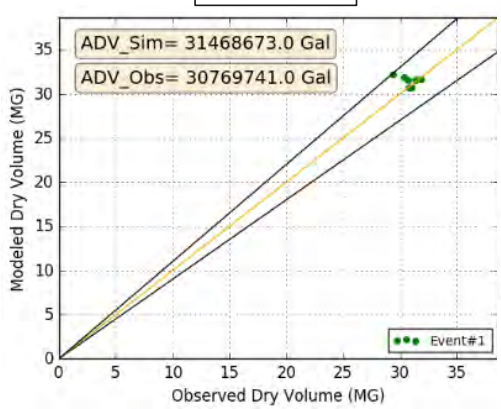



Kline's Island WWTP Main Influent- Excellent Match

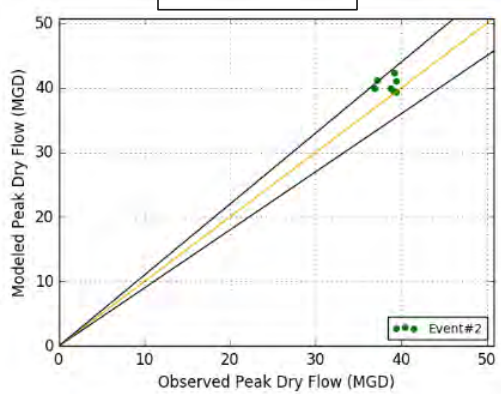
Peak Flow



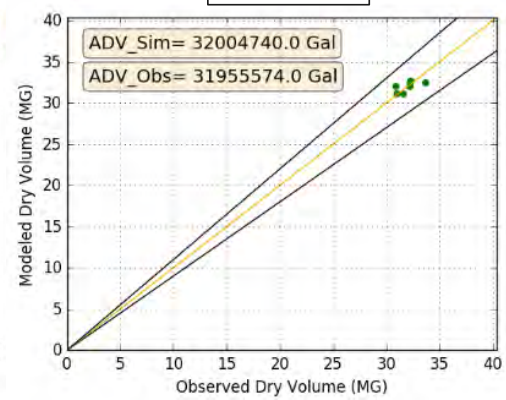

Volume




Peak Flow

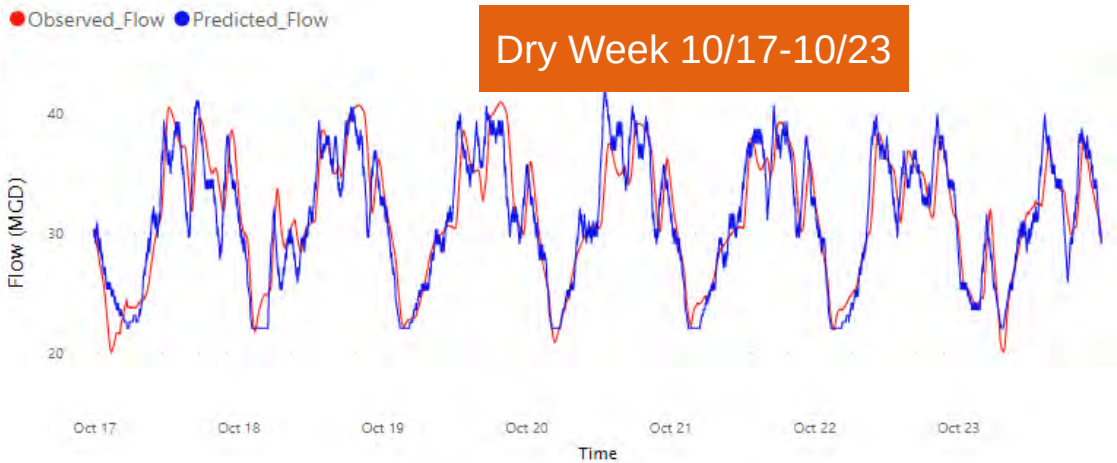



Volume



# Strengths – Strong Dry Weather Calibration

Dry Week 10/17-10/23

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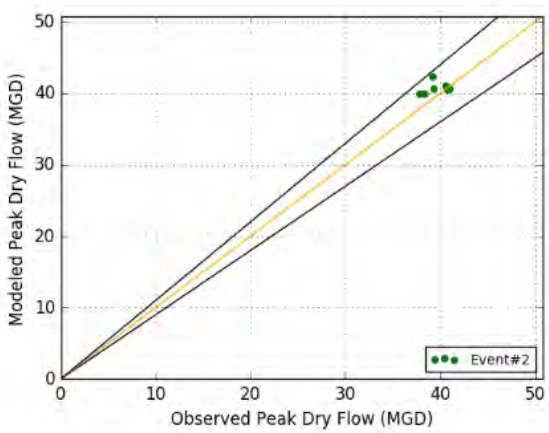
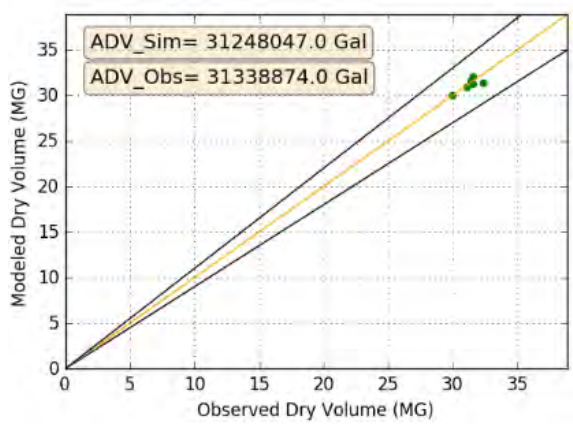


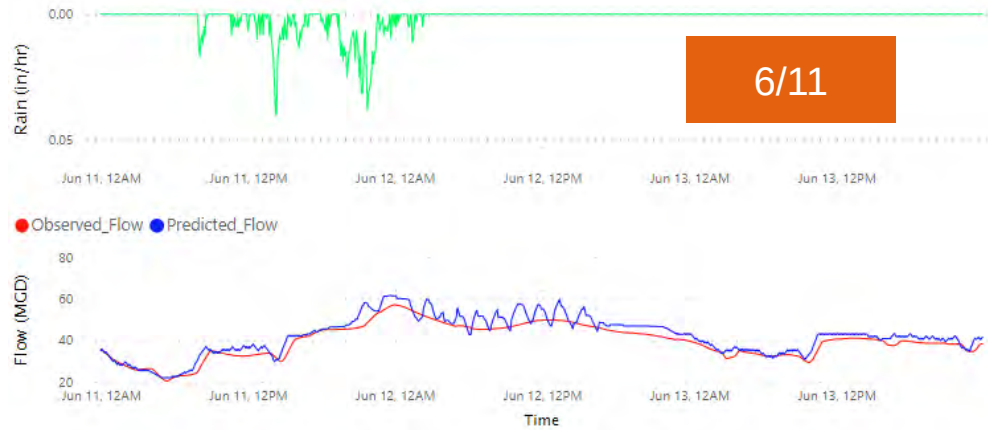

Volume



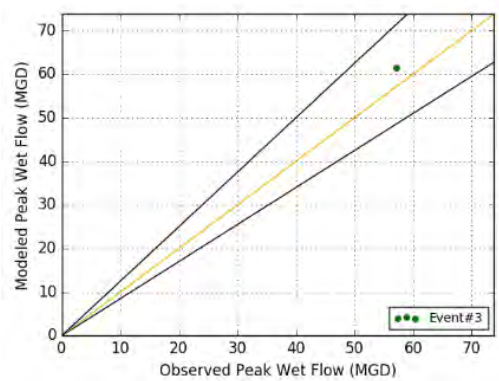
# Strengths – Strong Storm Calibrations

6/11

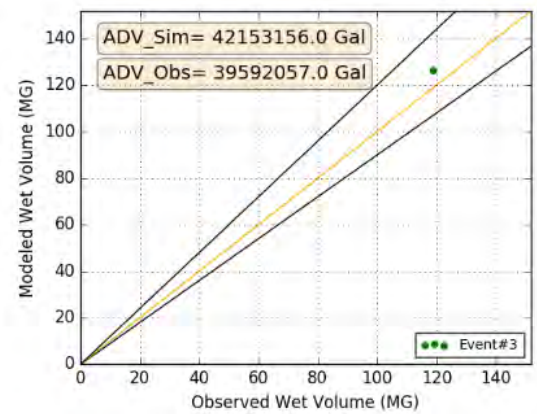
Kline's Island WWTP Main Influent- Excellent Match




Peak Flow




Volume



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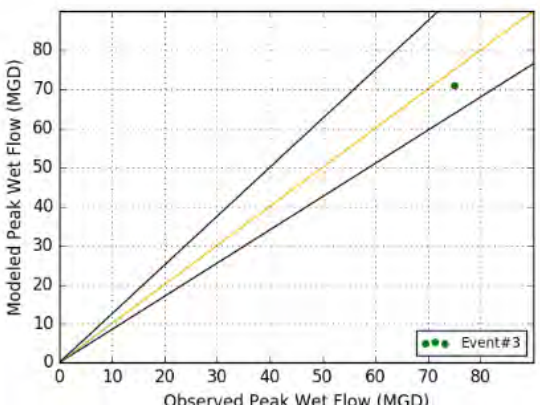
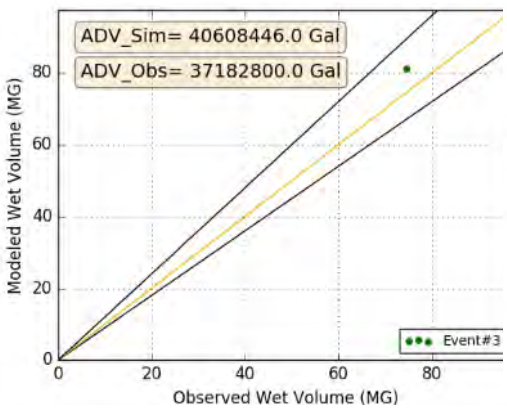
Kline's Island WWTP Main Influent- Excellent Match

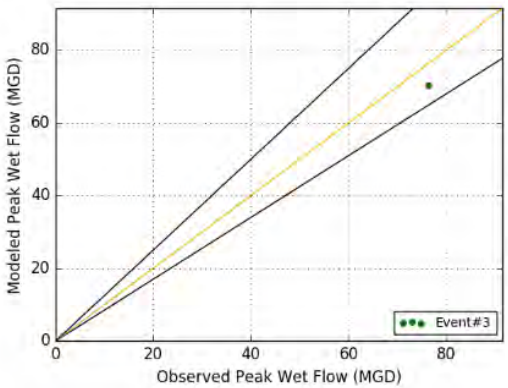
Peak Flow



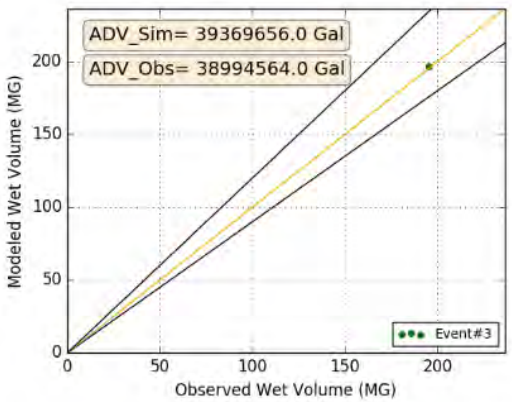

Volume




Peak Flow




Volume



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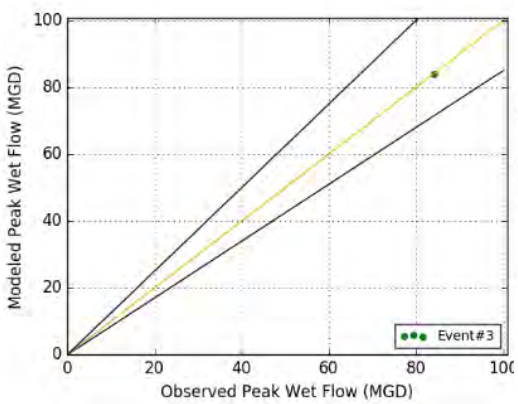
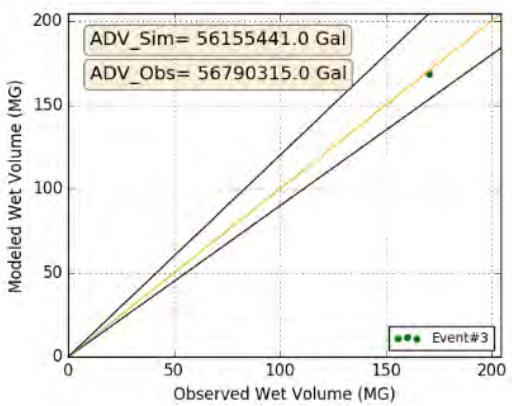
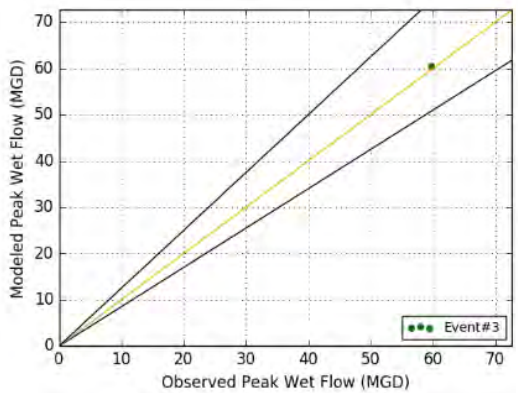


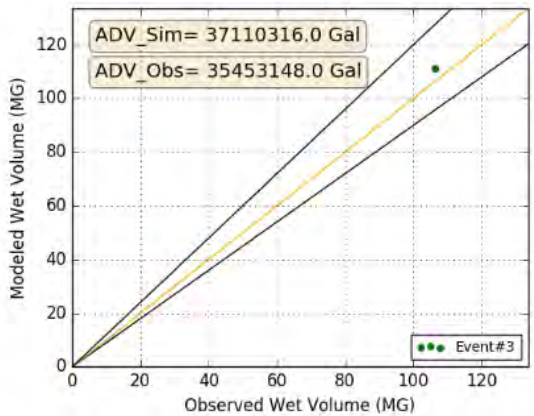

Volume




Peak Flow

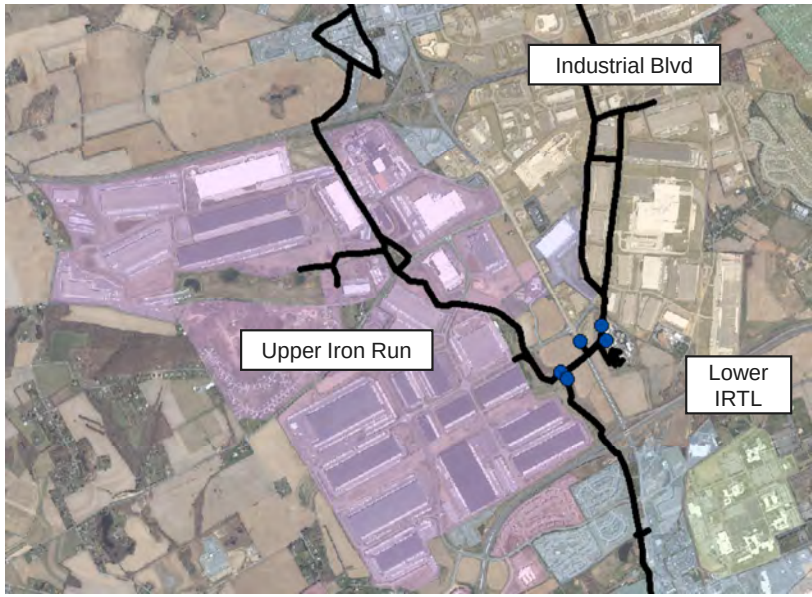


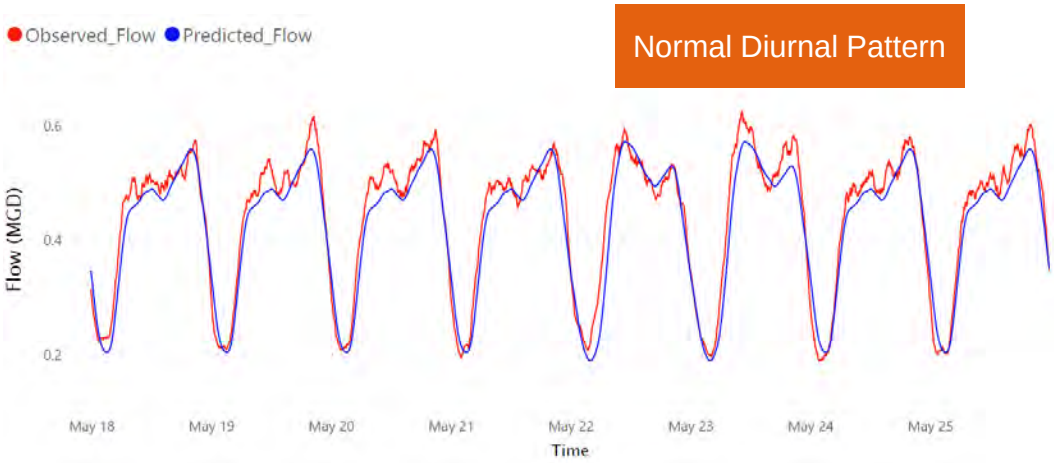

Volume

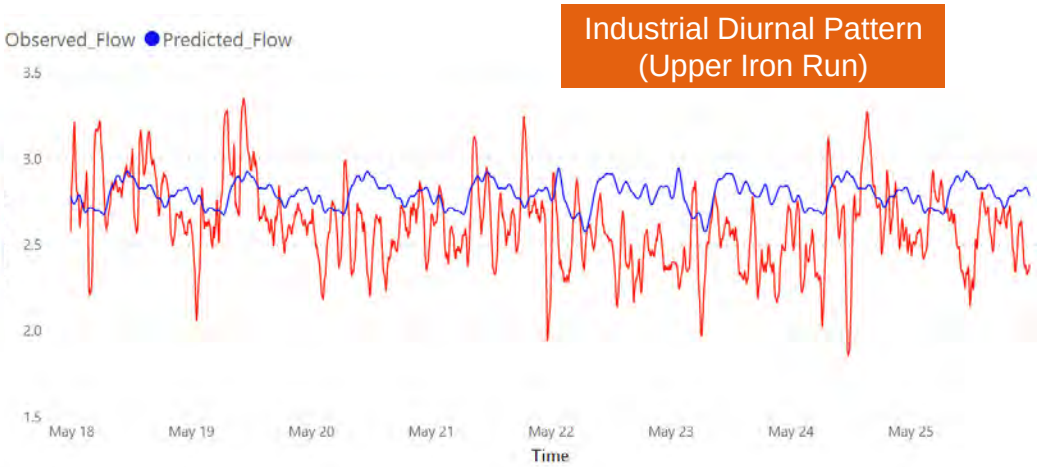


# Weakness – Highly Erratic Industrial Flows

- Industrial flows do not have pattern
  - Impacts Lower Iron Run Trunkline, Industrial Blvd, Upper Iron Run, EB2 (Cintas)
- Can only match volumes, not peaks or troughs from due to inconsistent industrial batch discharges
- Used average flow – means actuals during storms could be higher or lower…as much as 2 MGD at PTP



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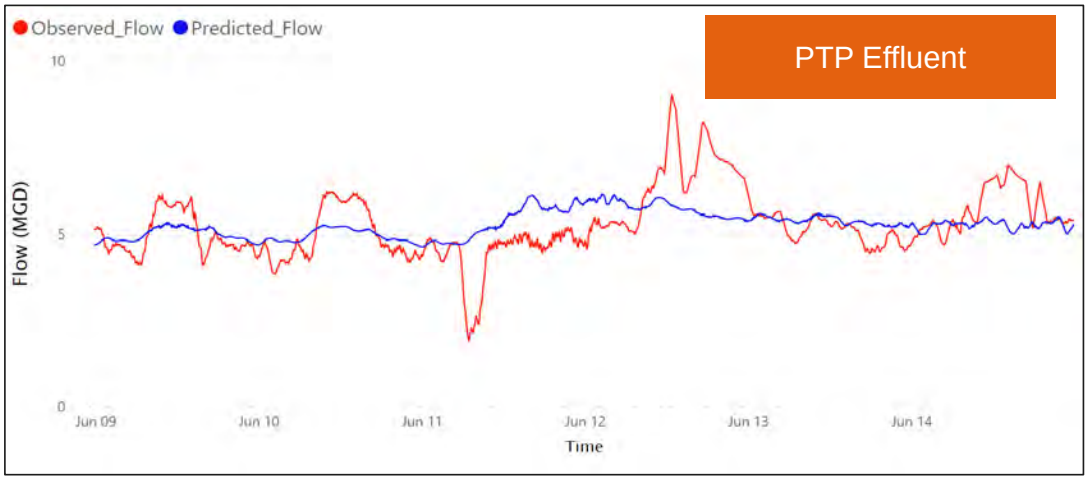
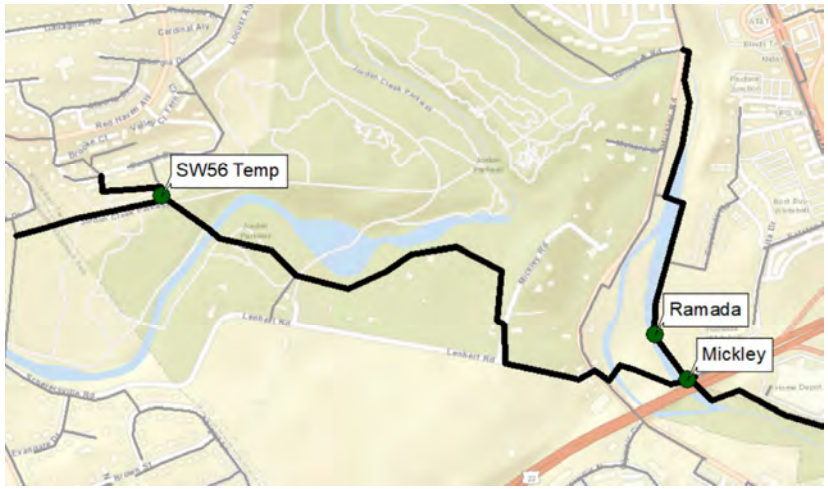
# Weakness – Operating Logic

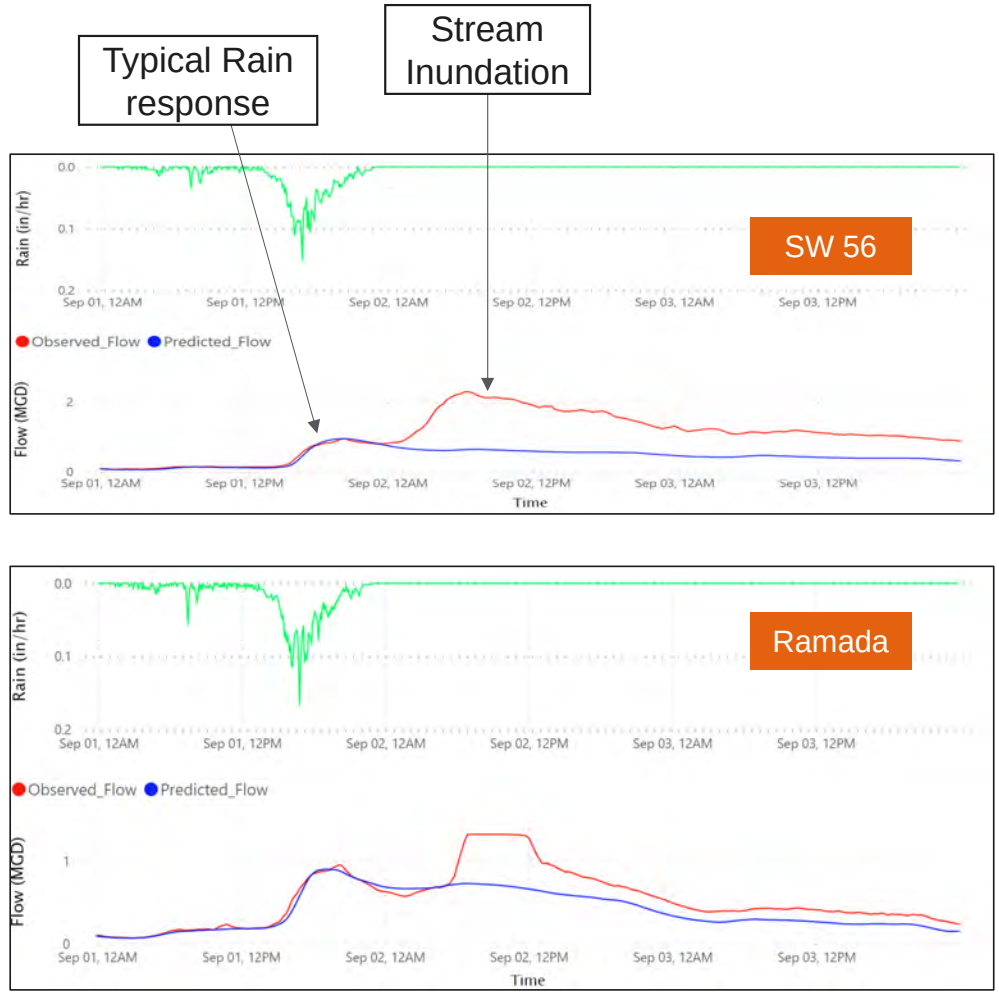
- Human operation for FEB Fill/Drain, Spring Creek Pump Station, Park Pump Station, and Kline's Island Wastewater Treatment Plant can't be replicated in model
  - Operation currently does not follow optimal real-time control logic




# Weakness – Stream Inundation

- Inflow flooding from streams creates a second non-rainfall peak following large storms (Ida)
- Impossible to model without stream data and multiple flooding events ($$$$)
  - i.e. SW56 Temp and Ramada



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# Improvements

- LCA wet weather and dry weather flows to City interceptors
- Park Pump Station split of flows to Little Lehigh Interceptor
- Spring Creek Pump Station split of flows to Western Lehigh Interceptor
- Split in flow at South Whitehall junction box in Cedarcrest Park
- Little Lehigh Interceptor from Hump Bridge to KI

- Huge improvements over 2009 model
- Handles extreme variations in weather/groundwater (New Normal)
- Very well calibrated to 10 year storms (with caveats….)

# What are the things we are doing now with the calibrated model?

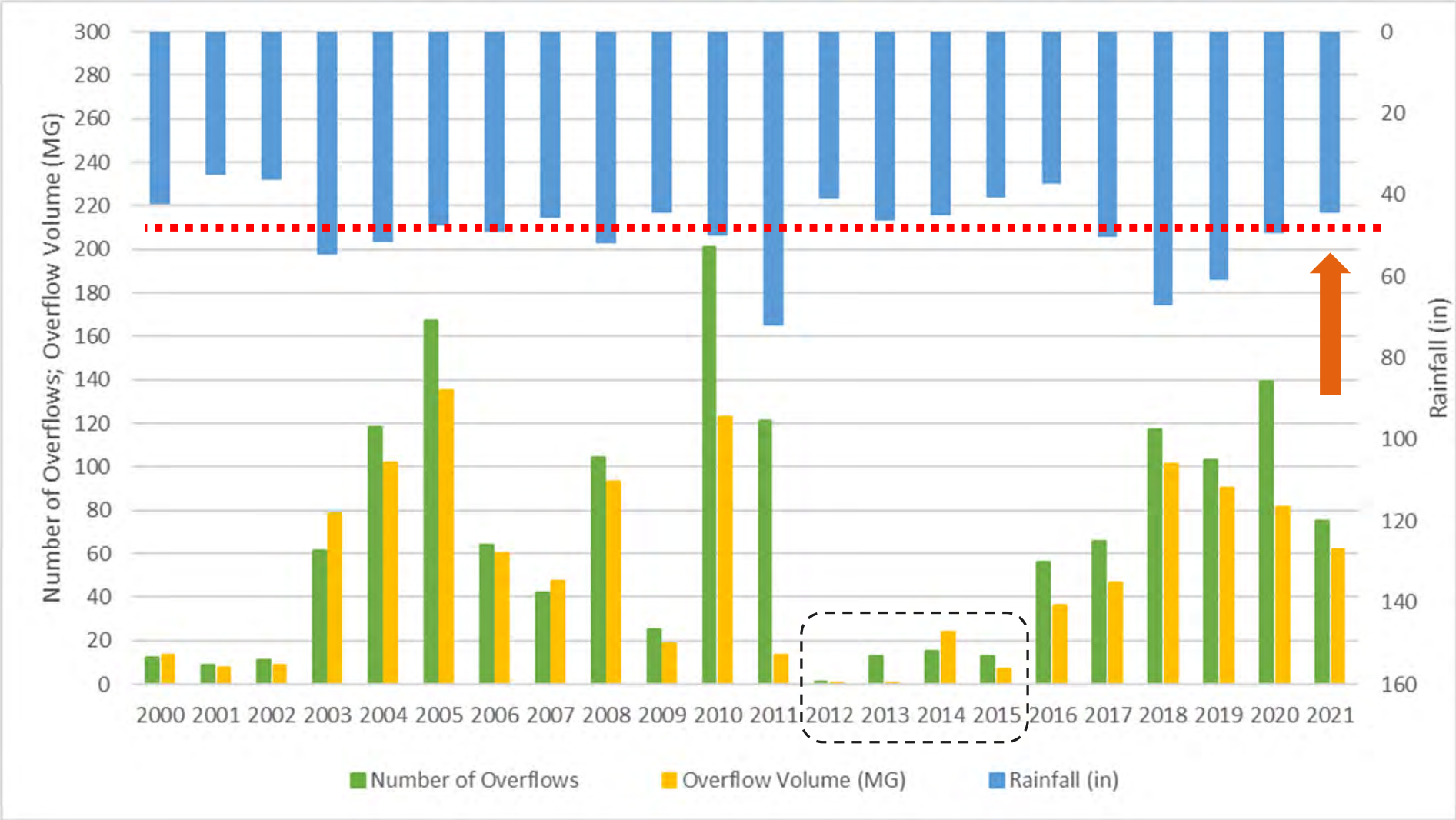
# Confirm sizing of Interim Relief Pumping from PTP to UMT Trunk Line


*Fall 2022*

# Design Storm Evaluation

- 22 year model run to evaluate historic storm impact to flow
  - 2000-2022 rainfall
  - Evaluate flows from all large events
  - Pick typical 3 year, 5 year, 10 year, and 20 year storm event to facilitate alternative
  - Full 24 year run will determine ultimate performance of selected solution(s)

*July 2022*


Number of Overflows; Overflow Volume (MG)
Rainfall (in)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Number of Overflows
Overflow Volume (MG)
Rainfall (in)

# 22 years of Storms

| Duration | Average recurrence interval (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 25 | 50 | 100 |
| 5-min | 0.324 (0.291-0.359) | 0.385 (0.347-0.427) | 0.452 (0.407-0.500) | 0.502 (0.451-0.555) | 0.563 (0.503-0.621) | 0.607 (0.539-0.669) | 0.655 (0.578-0.723) |
| 10-min | 0.516 (0.464-0.572) | 0.615 (0.554-0.681) | 0.722 (0.650-0.799) | 0.803 (0.721-0.887) | 0.897 (0.801-0.989) | 0.966 (0.858-1.07) | 1.03 (0.915-1.14) |
| 15-min | 0.645 (0.580-0.714) | 0.772 (0.696-0.855) | 0.913 (0.822-1.01) | 1.01 (0.909-1.12) | 1.13 (1.01-1.25) | 1.22 (1.08-1.35) | 1.31 (1.15-1.44) |
| 30-min | 0.882 (0.793-0.976) | 1.06 (0.959-1.18) | 1.29 (1.16-1.43) | 1.46 (1.31-1.62) | 1.67 (1.49-1.85) | 1.83 (1.63-2.02) | 1.99 (1.76-2.20) |
| 60-min | 1.10 (0.988-1.22) | 1.33 (1.20-1.48) | 1.66 (1.49-1.83) | 1.90 (1.71-2.10) | 2.23 (1.99-2.45) | 2.48 (2.20-2.73) | 2.74 (2.42-3.02) |
| 2-hr | 1.31 (1.18-1.46) | 1.58 (1.43-1.76) | 1.98 (1.78-2.20) | 2.29 (2.05-2.54) | 2.73 (2.43-3.02) | 3.09 (2.73-3.42) | 3.46 (3.04-3.84) |
| 3-hr | 1.44 (1.29-1.61) | 1.74 (1.56-1.94) | 2.17 (1.95-2.42) | 2.50 (2.24-2.79) | 2.98 (2.65-3.31) | 3.36 (2.97-3.73) | 3.78 (3.31-4.19) |
| 6-hr | 1.82 (1.65-2.03) | 2.19 (1.99-2.44) | 2.72 (2.45-3.02) | 3.15 (2.83-3.49) | 3.77 (3.37-4.18) | 4.29 (3.80-4.74) | 4.86 (4.27-5.37) |
| 12-hr | 2.25 (2.04-2.51) | 2.71 (2.45-3.02) | 3.37 (3.05-3.75) | 3.93 (3.53-4.37) | 4.76 (4.24-5.26) | 5.47 (4.83-6.04) | 6.26 (5.47-6.91) |
| 24-hr | 2.63 (2.44-2.85) | 3.17 (2.94-3.43) | 3.96 (3.68-4.28) | 4.63 (4.28-4.99) | 5.60 (5.18-6.03) | 6.43 (5.93-6.91) | 7.32 (6.68-7.88) |

- 2 storms >8”
- 7 storms >5”
- 22 storms > 3.17”
- 34 storms > 2.63”

# Top 30 storms over 22 years

| Event Start Time | Event End Time | Storm Name | Airport Rainfall (Inches) | Peak Hourly Intensit | Rain Duration (Hours) | Atlas 14 Event Return Perio |
|---|---|---|---|---|---|---|
| 7/10/2010 | 7/10/2010 | Alex | 5.7 | 2.6 | 6 | 405 |
| 10/7/2005 | 10/9/2005 | Tammy | 9.7 | 1.2 | 42 | 351 |
| 9/30/2010 | 10/1/2010 | Nicole | 8.1 | 2.1 | 31 | 259 |
| 8/18/2021 | 8/19/2021 | Fred | 3.2 | 1.4 | 4 | 34 |
| 8/18/2017 | 8/18/2017 | Non-tropical | 2.3 | 2.2 | 1 | 32 |
| 8/4/2020 | 8/4/2020 | Isaias | 5.0 | 1.3 | 13 | 28 |
| 8/28/2013 | 8/28/2013 | Non-tropical | 2.9 | 1.6 | 4 | 20 |
| 8/27/2011 | 8/28/2011 | Irene | 5.0 | 0.8 | 24 | 12.8 |
| 9/17/2004 | 9/18/2004 | Ivan | 4.3 | 1.1 | 19 | 10.6 |
| 9/4/2011 | 9/7/2011 | Lee | 5.6 | 0.6 | 58 | 10.2 |
| 6/25/2006 | 6/28/2006 | Non-tropical | 5.8 | 1.0 | 67 | 9.7 |
| 8/21/2018 | 8/22/2018 | Non-tropical | 2.4 | 1.0 | 3 | 8.0 |
| 9/28/2008 | 9/28/2008 | Kyle | 3.8 | 0.8 | 15 | 7.6 |
| 9/1/2021 | 9/1/2021 | Ida | 4.2 | 1.0 | 21 | 5.5 |
| 8/13/2011 | 8/14/2011 | Gert | 4.1 | 1.0 | 28 | 5.4 |
| 7/12/2004 | 7/12/2004 | Non-tropical | 3.4 | 0.7 | 11 | 4.4 |
| 7/1/2017 | 7/1/2017 | | 1.6 | 1.2 | 1 | 4.3 |
| 7/21/2003 | 7/23/2003 | Non-tropical | 3.9 | 1.3 | 33 | 4.2 |
| 8/3/2018 | 8/4/2018 | Non-tropical | 3.3 | 0.9 | 17 | 4.1 |
| 6/23/2011 | 6/24/2011 | | 2.1 | 1.4 | 3 | 4.0 |
| 2/12/2008 | 2/13/2008 | Winter | 3.5 | 0.3 | 29 | 3.0 |
| 11/2/2018 | 11/3/2018 | Non-tropical | 3.5 | 1.3 | 22 | 2.9 |
| 7/23/2008 | 7/24/2008 | Non-tropical | 3.0 | 0.9 | 13 | 2.8 |
| 10/16/2019 | 10/16/2019 | | 2.3 | 0.6 | 9 | 2.6 |
| 9/14/2003 | 9/16/2003 | Isabel | 3.0 | 0.9 | 32 | 2.5 |
| 11/30/2020 | 11/30/2020 | Non-tropical | 2.8 | 0.7 | 13 | 2.2 |
| 7/11/2019 | 7/11/2019 | Barry | 2.8 | 1.4 | 10 | 2.2 |
| 7/25/2011 | 7/25/2011 | | 2.2 | 1.2 | 6 | 2.2 |
| 7/30/2015 | 7/30/2015 | | 1.4 | 0.9 | 1 | 2.2 |
| 10/10/2002 | 10/12/2002 | Kyle | 3.7 | 0.3 | 46 | 2.1 |



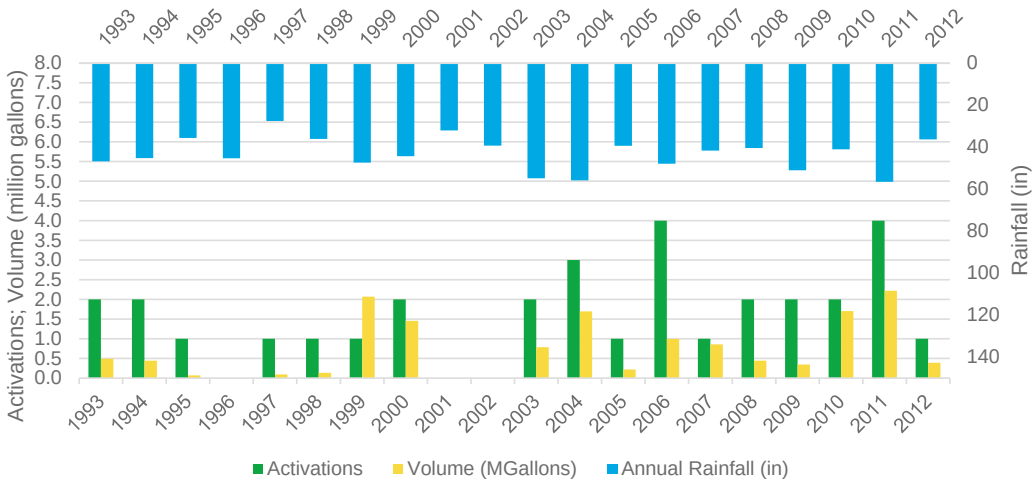
- 11 storms >10 year Atlas 14 frequency
- 15 storms >5 year Atlas 14 frequency

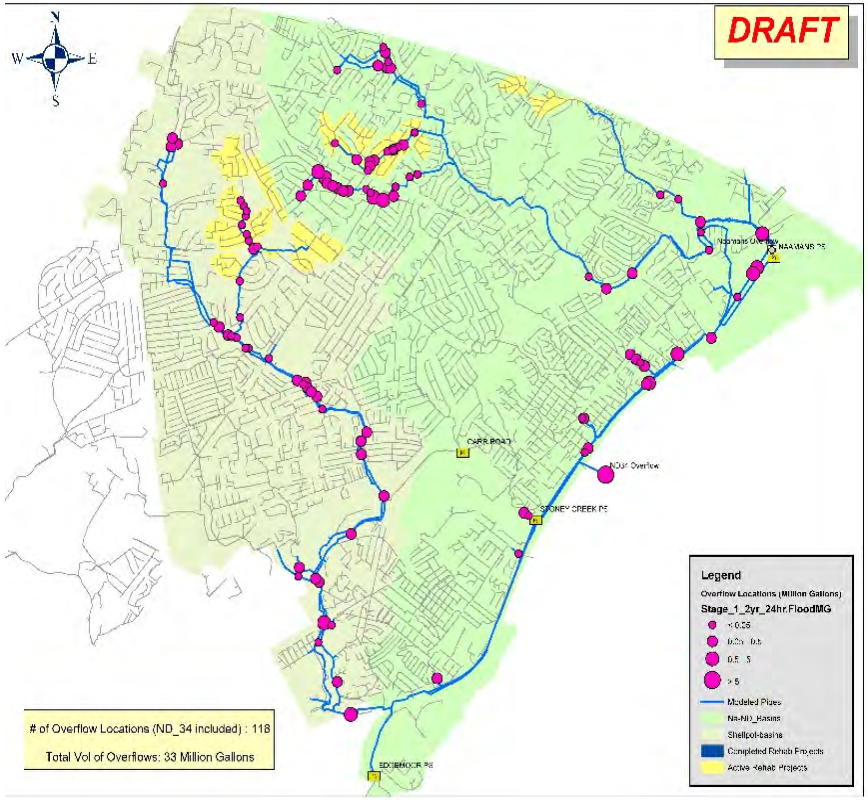
| Event Start Time | Storm Name | Airport Rainfall (Inches) | # MH SSOs | MH SSO Frequen | Peak Flow Total (MG | Peak Flow Frequenc | Overflow Volume (MG) | SSO Volume Frequen | Event Ra | Event Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/7/2005 | Tammy | 9.7 | 121 | 17.2 | 238 | 28.7 | 94 | 26.1 | 1 | > 20 year event |
| 8/4/2020 | Isaias | 5.0 | 87 | 8.6 | 200 | 13.1 | 47 | 5.6 | 2 | 10 year event |
| 7/10/2010 | Alex | 5.7 | 108 | 13.2 | 216 | 18.3 | 37 | 4.1 | 3 | 10 year event |
| 9/30/2010 | Nicole | 8.1 | 78 | 7.2 | 181 | 8.7 | 75 | 14.0 | 4 | 10 year event |
| 9/17/2004 | Ivan | 4.3 | 58 | 4.8 | 163 | 5.9 | 42 | 4.8 | 5 | 5 year event |
| 11/2/2018 | Non-tropical | 3.5 | 50 | 4.1 | 161 | 5.6 | 36 | 3.9 | 6 | 5 year event |
| 9/1/2021 | Ida | 4.2 | 42 | 3.5 | 155 | 5.0 | 31 | 3.3 | 7 | |
| 4/2/2005 | Winter | 3.7 | 31 | 2.8 | 129 | 2.9 | 31 | 3.4 | 8 | 3 year event |
| 9/28/2008 | Kyle | 3.8 | 42 | 3.5 | 145 | 4.1 | 24 | 2.7 | 9 | 3 year event |
| 2/23/2016 | Winter | 3.0 | 28 | 2.6 | 129 | 2.9 | 22 | 2.5 | 10 | 3 year event |
| 2/12/2008 | Winter | 3.5 | 27 | 2.6 | 124 | 2.6 | 30 | 3.2 | 11 | 3 year event |
| 11/30/2020 | Non-tropical | 2.8 | 28 | 2.6 | 127 | 2.8 | 20 | 2.3 | 12 | |
| 6/25/2006 | Non-tropical | 5.8 | 24 | 2.4 | 115 | 2.2 | 29 | 3.1 | 13 | |
| 8/13/2018 | Non-tropical | 2.6 | 19 | 2.2 | 120 | 2.4 | 24 | 2.6 | 14 | |
| 11/27/2004 | Non-tropical | 2.4 | 25 | 2.5 | 124 | 2.6 | 18 | 2.2 | 15 | |
| 8/3/2018 | Non-tropical | 3.3 | 25 | 2.5 | 116 | 2.2 | 20 | 2.3 | 16 | |
| 6/20/2003 | Non-tropical | 2.7 | 22 | 2.3 | 120 | 2.4 | 20 | 2.4 | 17 | |
| 7/11/2019 | Barry | 2.8 | 25 | 2.5 | 125 | 2.7 | 15 | 2.0 | 18 | |
| 7/22/2019 | Non-tropical | 2.6 | 15 | 2.0 | 112 | 2.0 | 17 | 2.2 | 19 | |
| 8/27/2011 | Irene | 5.0 | 50 | 4.1 | 116 | 2.2 | 8 | 1.6 | 20 | |
| 8/18/2017 | Non-tropical | 2.3 | 19 | 2.2 | 112 | 2.0 | 16 | 2.0 | 21 | |
| 4/29/2014 | Non-tropical | 3.6 | 9 | 1.8 | 100 | 1.6 | 21 | 2.4 | 22 | |
| 12/10/2008 | Non-tropical | 3.4 | 9 | 1.8 | 97 | 1.5 | 20 | 2.4 | 23 | |
| 9/14/2003 | Isabel | 3.0 | 10 | 1.8 | 99 | 1.5 | 18 | 2.2 | 24 | |
| 8/18/2021 | Fred | 3.2 | 13 | 1.9 | 113 | 2.1 | 11 | 1.7 | 25 | |
| 12/16/2000 | Winter | 2.5 | 11 | 1.9 | 108 | 1.8 | 14 | 1.9 | 26 | |
| 7/12/2004 | Non-tropical | 3.4 | 15 | 2.0 | 112 | 2.0 | 11 | 1.8 | 27 | |
| 8/21/2018 | Non-tropical | 2.4 | 11 | 1.9 | 109 | 1.9 | 13 | 1.9 | 28 | |
| 4/15/2007 | Non-tropical | 3.2 | 7 | 1.7 | 91 | 1.3 | 21 | 2.5 | 29 | |
| 9/28/2004 | Jeanne | 2.6 | 7 | 1.7 | 94 | 1.4 | 16 | 2.1 | 30 | |

# Existing System Performance

*August - September 2022*

- Without changes to system, under 4 design storms, what are flows and SSO with:
  - No new flows added
  - 2050 flow added



# What’s next?

# Alternative Scenarios

## Storage

a. Cedar Creek Park Tank
b. Spring Creek Tank
c. Lehigh Interceptor West Tank
d. Jordan Creek Tank
e. Kecks Bridge Tank
f. Emmaus Cedarcreek Boulevard Tank
g. Trout Creek Tank
h. Sumner Tank
i. Alburtis Macungie Tank
j. Hump Bridge Tank
k. U6 Tank
l. Breniegsville Tank

## Gravity Conveyance

a. Replacements with larger pipes
b. Parallels of existing pipes
c. Removal of bottlenecks
   - Water Treatment Plant siphons
   - Confluence of Jordan Creek and Little Lehigh Interceptors
   - Eastside Interceptor Lehigh River siphon

## Pumped Conveyance

a. Spring Creek Pump Station (as is and upgrade, and with various current and potential force mains discharging to LLRI (as currently), to Little Sister Pump Station, or to ahead of, at, or inside KIWWTP)
b. Little Sister Pump Station (with force main alignments and discharge points ahead of, at, and inside KI WWTP)
c. PTP Direct Discharge Pump Station and force main to Lehigh River outside KI WWTP
d. PTP Pump Station and force main to KI WWTP headwork or inside KI WWTP
e. Fogelsville Pump Station and forcemain capture ~1/2 the PTP flow before PTP treatment and conveying it to the Upper Macungie Trunk Line north of Grange Road
f. Various other pump stations and force mains, including but not limited to:
   - Breinigsville Pump Station and Force Main
   - Kecks Bridge Pump Station and Force Main
   - Cedar Creek Pump Station and Force Main
   - Jordan Creek Pump Station and Force Main
   - Lehigh River West Pump Station and Force Main
   - Lehigh River East Pump Station and Force Main
   - Eberhart Pump Station Expanse and Force Main extension

# Alternative Scenarios

## Source Reductions

a. Common-sense SRPs to significantly reduce peak inflow from the worst inflow-impacted areas of the KISS collection system
b. Common-sense SRPs to significantly reduce baseline infiltration and rainfall induced infiltration from the worst leaking areas of the KISS collection system
c. Signatory-proposed SRPs idiosyncratic to each Signatories' individual ideas about appropriate leakage rates and the need to control them
d. Moderate SRPs to eliminate leakage from catchments with high inflow and infiltration leakage
e. Aggressive public SRPs to eliminate leakage from catchments with moderately high and high inflow and infiltration leakage
f. Private lateral and private sump pump programs to increase I&I removals

## Treatment

a. Variations on treatment at Kline's Island
b. Variations on full NPDES treatment as a direct discharge from PTP to Lehigh River (discharge to Jordan Creek and discharge via land application were reviewed and dismissed during SCAPR/AO work).
c. Variations on partial treatment at PTP (8:30, 4:30, 0:30, and 0:40 dry:wet schemes) with multiple possible discharge points, including:
   - Iron Run
   - Spring Creek Pump Station wet well
   - Upper Macungie Trunkline
   - Park Pump Station wet well
   - Kline'ss Island headworks
   - Kline's Island expanded headworks
   - Kline's Island treatment system

# Final Alternative Analyses

- Revised/Finalized Source Reduction Plan(s)
- Revisions to operating guidelines
- Capital, O&M, Energy (carbon footprint), and Net Present Worth
- Design storm sensitivity
- Climate change considerations
- Sequence of construction

*April 2023 – February 2024*

# Selection of Solution

- Short list of options
- Final proof of performance via 24-year simulation
- Project sequence and schedule
- Bond and finance strategy
- Institutional approaches / inter-municipal agreements
- Decision-making
- Stakeholder involvement
- Approval & submission

*March 2024 – June 2025*


ARCADIS Design & Consultancy for natural and built assets

# Discussion