

P4 INFRASTRUCTURE

Digitalizing Stormwater Infrastructure

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APWA **ROAD&WATER**

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Texas A&M Hotel and Conference Center
College Station, TX

February 9-12, 2025

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Learning Objectives:

- 1.) **Review** digitalization tools available for stormwater infrastructure – what they are, how and why they are deployed.
- 2.) **Assess** how measured data can be used to improve hydrologic and pollutant source load modeling in stormwater infrastructure.
- 3.) **Assess** how measured data can define maintenance protocols for stormwater infrastructure.

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What is Digitalization?

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Why Digitalize? (BIG picture)

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<https://infrastructurereportcard.org/infrastructure/stormwater/infrastructure/>

CHALLENGES

Infrastructure Functionality

- MSAs rely on private infrastructure
- infrastructure functionality is uncertain

GIS Leveraging

- starved for incorporation of measured data
- public transparency and outreach

Stormwater Spending

- stormwater utilities with annual fees levied
- stormwater utility fees increasing – "rain tax"
- effectiveness of expenditures difficult to demonstrate
- CSO consent decrees
- MSA regulations
- TMDL basins

ASSESS PERFORMANCE

- Maintain Clean Surface Water
- Replenish Groundwater
- Regulatory Compliance

FINANCIAL OPPORTUNITY & RESPONSIBILITY

- Credit Trading
- Utility Fee Rebates
- Stakeholder Transparency

MAINTENANCE

- Remote Assessment
- Autonomous Assessment
- Maintenance Triggers & Forecasting

MODEL IMPROVEMENT

- Digitalized Asset – Calibration Point
- Measured Data – Improved Models

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MS4 Permit Spending - Wisconsin

MS4 Permittee	Annual Budgetary Spending	
Wisconsin County (2023 Annual Report)	Public Education & Outreach	\$100,000
	Public Involvement & Participation	\$50,000
	RCRA	\$50,000
	Public Protection Stormwater Management	\$450,000
	Stormwater Quality Management	\$1,000,000
	Total	\$1,850,000
City of Peoria (2023 Annual Report)	Public Education & Outreach	\$1,500
	Public Involvement & Participation	\$1,000
	RCRA	\$1,200
	Public Protection Stormwater Management	\$43,000
	Stormwater Quality Management	\$947,300
	Total	\$1,453,000
City of Okauchee (2022 Annual Report)	Public Education & Outreach	\$1,000
	Public Involvement & Participation	\$1,000
	RCRA	\$4,000
	Public Protection Stormwater Management	\$110,000
	Stormwater Quality Management	\$117,000
	Total	\$239,000
City of Wausau (2022 Annual Report)	Public Education & Outreach	\$1,200
	Public Involvement & Participation	\$1,200
	RCRA	\$11,000
	Public Protection Stormwater Management	\$1,200,000
	Stormwater Quality Management	\$1,845,000
	Total	\$4,800,000

Spending Total – 4 Permittees: \$5,645,699
244 MS4 Permittees in Wisconsin

TMDLs – Wisconsin

<https://apps.dnr.wis.gov/water/tmdmap.aspx>

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Community Consent Decree (CC) Spending:

- MWRD – Chicago, IL: \$3 billion
- Chattanooga, TN: \$250 million
- UG of Wyandotte County, KS: \$600 million
- King County & Seattle, WA: \$1.46 billion
- Washington DC: ??
- Philadelphia, PA: \$1 billion
- Scranton, PA: Nutrient Credits
- Boston, MA: ??
- St. Louis, MO: \$4.7 billion
- Evansville, IN: ??
- South Bend, IN: \$510 million
- NEORSJ – Cleveland, OH: \$3 billion
- Kansas City, KS: \$2.5 billion
- Akron, OH: ??
- Cincinnati, OH: ??
- Peoria, IL: \$100 million**
- Louisville, KY: \$500 million

Total \$17.6 billion

City of Peoria, IL Expects to spend \$109M by 2039

CSO PROJECT MILESTONES AND COSTS

PROGRAM BEGINS IN 2022

Project Name/Type	CSO Volume Reduction Goal (%)	Missed/Deadline (10/31/2006)	High-Level Capital Cost Estimate**	Avg. Annual Operational/Maintenance Costs**
Green Infrastructure projects and improvements to existing pipe system	20	2024	\$15M	\$200K
Green Infrastructure projects	35	2027	\$15M	\$600K
Green Infrastructure projects	50	2030	\$16M	\$1M
Green Infrastructure projects	70	2034	\$21M	\$1.5M
Storage projects	100	2039	\$41M	\$2.0M
Total Cost			\$109M	

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What Type of Infrastructure ?
and
What Type of Sensors ?

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Infiltration Dry Well

Infiltration Dry Well

- Precast Concrete Element
- Runoff Enters and Infiltrates into Ground
- Discharge to Combined Sewer Inhibited

Digitalization Tools

- Rain Gauge
- Water Level

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Trash-Collection Systems

Channelled Flow - Trash Capture

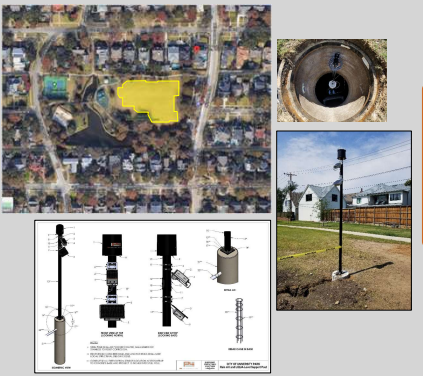
- Runoff channeled through nets
- Two net systems

Digitalization Tools

- Rain Gauge
- Camera System (image capture)
- Water-Level (head difference across nets)
- Flow velocity (between net systems)

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Below-Ground Detention / Retention / Infiltration




Below-Ground Systems

- Precast Concrete, Plastic Arch, Plastic Crate Tanks
- Runoff Enters and is Detained/Retained and/or Infiltrates into Ground
- Infiltration - Discharge Inhibited
- Detention / Retention – Discharge Controlled and/or Prevented

Digitalization Tools

- Rain Gauge
- Water Level
- Discharge Control

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Permeable Pavement Systems



Permeable Pavement

- Articulating Concrete Block
- Paver
- Others Possible


Digitalization Tools

- Rainfall and Environmental Data
- Water Level (below pavement)
- Discharge Control

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Below-Ground and Biofiltration Network




Multiple Systems

- Below-Ground System (ADS)
- Biofiltration System
- Exit Piping


Digitalization Tools

- Rainfall and Environmental Data
- Soil Moisture
- Water Level
- Area-Flow-Velocity
- Discharge Control

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Surface Infiltration




Surface-Infiltration Ponds

- Engineered / Graded
- Relatively Shallow


Digitalization Tools

- Rainfall and Environmental Data
- Water Level
- Discharge Control

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Surface Infiltration - Large







Surface-Infiltration Ponds

- Engineered / Graded
- Large / Deep





Digitalization Tools

- Rainfall and Environmental Data
- Water Level (via pressure)
- Discharge Control

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On-Structure Detention / Retention

Structure	Quantity	Unit
Roof 1 - # of Area Depth = 1.04 Gallons	2,020.00	gal
Roof 2 - # of Area Depth = 1.04 Gallons	4,040.00	gal
Roof 3 - # of Area Depth = 1.04 Gallons	2,020.00	gal
Roof 4 - # of Area Depth = 1.04 Gallons	2,020.00	gal
Roof 5 - # of Area Depth = 1.04 Gallons	2,020.00	gal
Roof 6 - # of Area Depth = 1.04 Gallons	2,020.00	gal
Estimated Total Gallons	14,160.00	gal

Depth of Water weighs approximately 8.34 pounds


Estimated Total Gallons = 14,160 Gallons

On-Structure Systems

- Existing Structure
- Proposed Addition

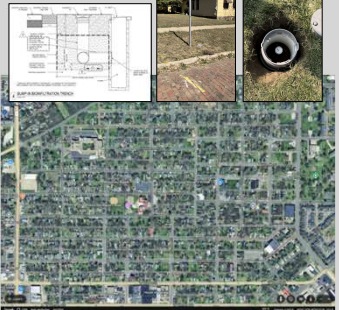

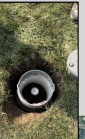
Digitalization Tools

- Rainfall and Environmental Data
- Water Level
- Valve Control (Roof Discharge)

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Back-of-Curb French Drain (Bump In)






Parkway French Drain

- Existing Parkway & Inlet
- Back of Inlet (Curb) Location
- French Drain-Type Infiltration


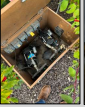

Digitalization Tools

- Rainfall and Environmental Data
- Water Level

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Surface Wet Detention Ponds






Subdivision Surface Pond

- Existing or New Construction
- Often Relied Upon by MS4

Digitalization Tools

- Rainfall and Environmental Data
- Water Level
- Aeration Control
- Discharge Control

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Modularity & Maintenance

Modularity

- Sensor Module
- Battery Module
- Solar Panel
- Computer Module

Maintenance

- Sensor
- Battery
- Computer

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What do you do with Digitalization ?

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State BEFORE Digitalization

5.6 STORMWATER MANAGEMENT

5.6.1 The Association shall maintain the stormwater management measures accordance with the Stormwater Management Practices Maintenance Agreement by and between Developer and City and recorded in the office of the Register of Deeds for Waukesha County, Wisconsin.

5.6.2 The Association, on an annual basis, shall provide maintenance of each measure, including but not limited to, removal of debris, maintenance of structural stormwater management measures, aeration equipment and sediment removal.

5.6.5 The City is authorized to perform corrective actions necessary by the inspection if the Association does not make the required corrections in the timeframe specified by the City.

5.5.6 The stormwater retention basins are required by the City to assist in the removal of sediment from and detention of stormwater.

Digitalization:

- Rainfall Documentation
- Water Level Documentation
- Aeration Control System
- Discharge Control

State AFTER Digitalization

Homeowner's Association

- Documentation of Functionality
- Easy Reporting to Municipality
- Data to Complement Sediment Mapping
- Data for Financial Planning - Building Reserves
- Maintain Property Values
- Peace of Mind
- Data for Utility Fee Rebate Request

Municipality - Stormwater Utility (MS4)

- Documentation of Performance
- Remote Access
- Regulatory Compliance Data
- Watershed Model Improvement

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State BEFORE Digitalization:

- Large Below-Ground Detention System
- Uncertain Effect on Ground-Water
- Manually Monitoring of Water Level
- Watershed Model Uncertainty

Digitalization:

- Rainfall Documentation
- Water Level Documentation

State AFTER Digitalization:

- Confidence No Effect on Ground Water
- ULTIMATE PEACE OF MIND
- Actionable Data to Improve Watershed Models

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State BEFORE Digitalization:

- Large Below-Ground Detention System
- Highly-Developed, Urbanized Watershed
- Uncertain Performance
- Desire for Stakeholder Transparency

Digitalization:

- Rainfall Documentation
- Water Level Documentation

State AFTER Digitalization:

- Continuous Data Streams (nearly one year)
- Demonstration of Function and Performance
- REAL DATA for Stakeholder Transparency
- Actionable Data to Improve Watershed Modeling
- Actionable Data for Decision Making

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State BEFORE Digitalization:

- Three Permeable Pavement Infrastructure systems
- Desire to Collect Runoff Samples from Systems
- Lack of Sampling Ability (no flow from systems)
- Lack of Understanding of System Performance

UDAHY

Digitalization:

- Rainfall Documentation
- Below-Pavement Water Level Documentation
- Flow-RTC (manual)

State AFTER Digitalization:

- Continuous Data Streams (nearly one year)
- Demonstration of Function and Performance
- REAL DATA for Stakeholder Transparency
- Actionable Data to Improve Watershed Modeling
- Actionable Data for Decision Making

Flow-RTC

INFIL-Tracker

INFIL-Tracker

Flow-RTC

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State AFTER Digitalization:

- Full Utilization of Gallery Volume
- Documentation - 100% Runoff Infiltration - no discharge to MS4
- Documentation - 54% Improvement in TSS Removal
- NEW LOOK AT PERMEABLE PAVEMENT EFFECTIVENESS

Maintenance - Surface Infiltration

- Rainfall Events and Volume Captured Correlated over Years of Service
- Gallons Captured for Similar Events used to Assess Maintenance
- Visual Assessment of Surface is Inaccurate

* Stein, J., Dyrnes, T., Henken, R. (2024). *Natural Partners - How Local Collaboration Could Help Fix Milwaukee County Parks*. Report to Milwaukee County Parks, Wisconsin Policy Institute, February.

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State AFTER Digitalization:

- Runoff Volume
- > 113,000 Gallons NOT in CSS (40 gal/sq.ft. - 1,200% more than estimates¹)
- Maintenance - Surface Infiltration
- Rainfall Events and Volume Captured Correlated over Years of Service
- Gallons Captured for Similar Events used to Assess Maintenance
- Visual Assessment of Surface is Inaccurate

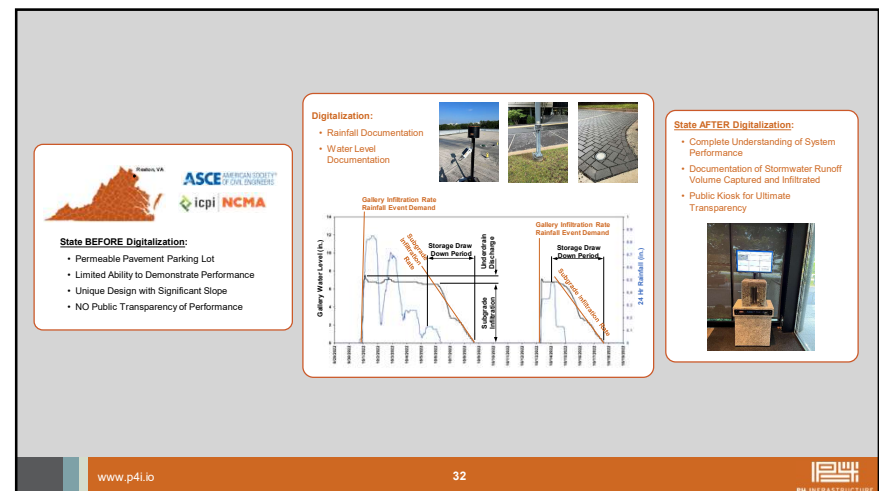
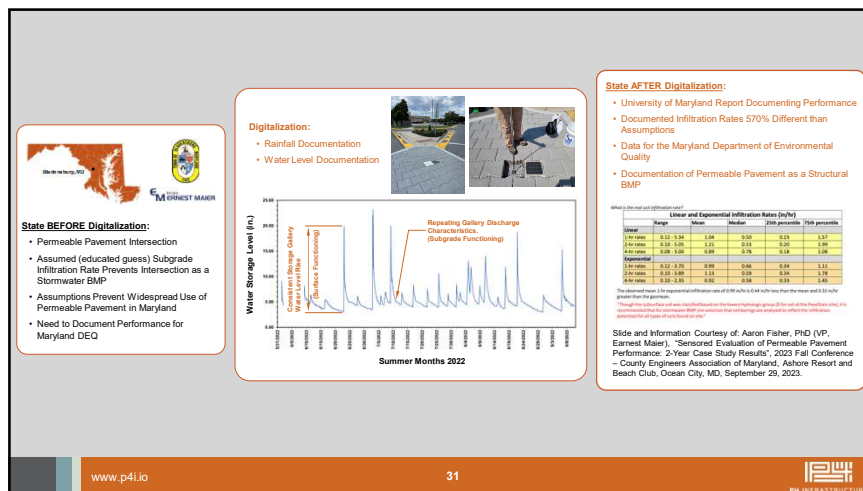
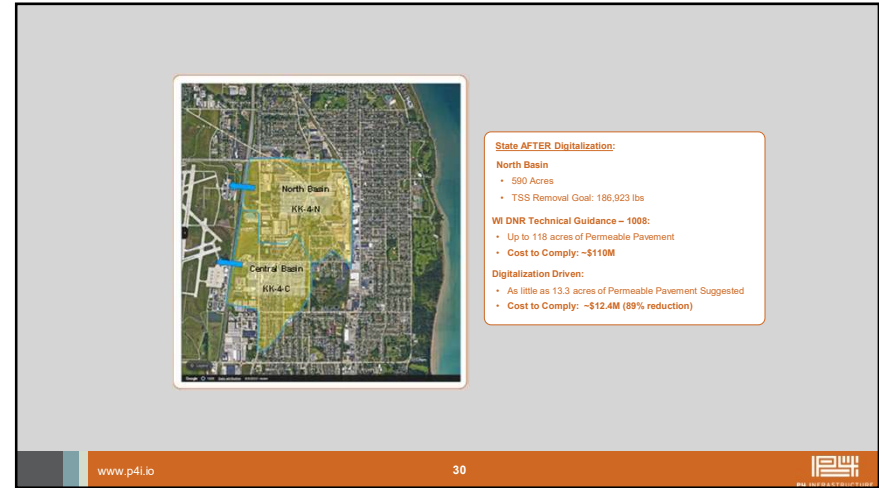
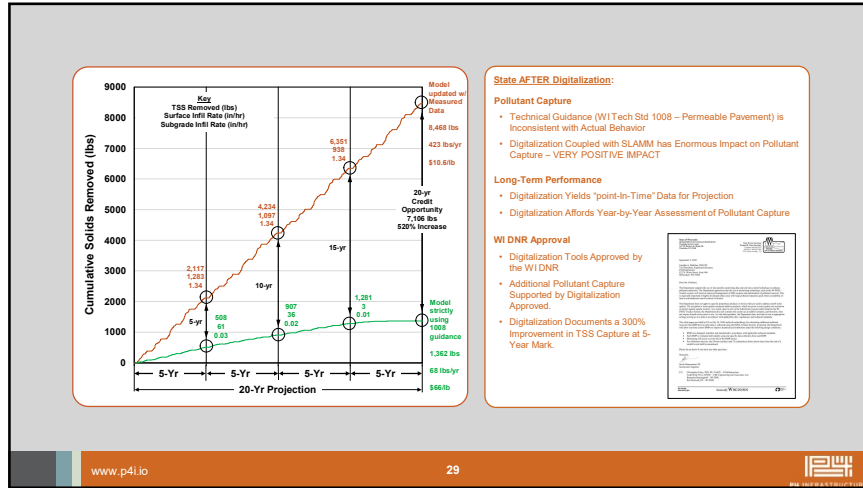
* Stein, J., Dyrnes, T., Henken, R. (2024). *Natural Partners - How Local Collaboration Could Help Fix Milwaukee County Parks*. Report to Milwaukee County Parks, Wisconsin Policy Institute, February.


May-September 2022 - Volume Calculations - Squire		
24 Hr Rainfall Event No.	Rainfall (in)	Volume Captured (gal)
1	0.8	0
2	0.77	90
3	0.25	0
4	1.8	4629
5	0.34	247
6	0.72	492
7	1.54	3327
8	0.77	0
9	1.75	12847
10	0.34	4134
11	0.54	3916
12	1.69	6240
13	1.51	5600
14	0.43	1140
15	0.69	3768
Totals	18.25	70860

May-September 2022 - Volume Calculations - Van Norman		
24 Hr Rainfall Event No.	Rainfall (in)	Volume Captured (gal)
1	0.8	392
2	0.77	1780
3	0.25	149
4	1.8	3128
5	0.34	413
6	0.72	2033
7	1.54	5511
8	0.77	2250
9	1.75	5080
10	0.34	506
11	0.54	778
12	1.69	2391
13	1.51	2417
14	0.43	202
15	0.69	3500
Totals	18.25	37018

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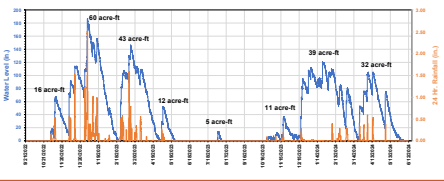


State BEFORE Digitalization:

- VERY LARGE Surface Infiltration Basin
- NEED to Measure Water Levels from 0" to 312"
- VERY HARSH Environmental Conditions
- Uncertain Performance
- No Documentation for SGMA Act Compliance


Digitalization:

- Rainfall Documentation
- Water Level Documentation

State AFTER Digitalization:

- Continuous Documentation of Local Rainfall Demand
- Continuous Documentation of Stormwater Runoff Captured
- Continuous Documentation of Stormwater Volume Infiltrated
- Documentation for SGMA Groundwater Recharge Credit Trading


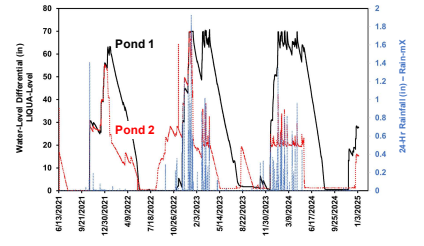


Customer BEFORE Digitalization:

- Three VERY LARGE Surface Infiltration Basins
- NEED to Measure Water Levels
- VERY HARSH Environmental Conditions
- Manual Documentation of Rainfall Amount and Intensity
- Manual Documentation of Stormwater Runoff Volume Infiltrated


Digitalization:

- Rainfall Documentation
- Water Level Documentation

State AFTER Digitalization:

- Continuous Documentation of Local Rainfall Demand
- Continuous Documentation of Stormwater Runoff Captured
- Continuous Documentation of Stormwater Volume Infiltrated
- Documentation for SGMA Groundwater Recharge Credit Trading

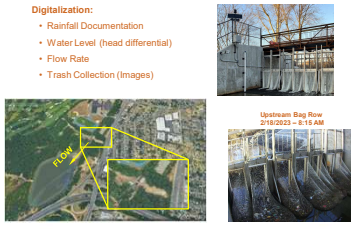
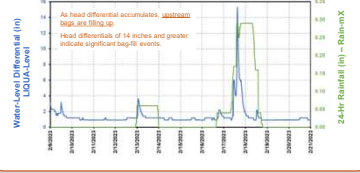


State BEFORE Digitalization:

- Large Surface Retention Basin with Trash Collection System
- Unknown Flow Velocity through Channel
- Unknown Trash Collection Maintenance Frequency
- Poor Understanding of Trash Accumulation


Digitalization:

- Rainfall Documentation
- Water Level (head differential)
- Flow Rate
- Trash Collection (Images)

State AFTER Digitalization:

- Rainfall Event Triggers for Trash Net Replacement
- Understanding of Seasonal Variation of Trash Accumulation
- Photographic Documentation of Trash Accumulation for Maintenance Triggering

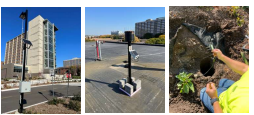
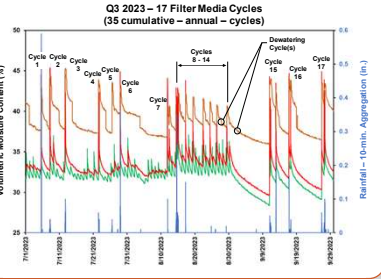


State BEFORE Digitalization:

- Biofiltration System (bioswale)
- Customer Maintenance Guarantee (personnel & fiscal resources)
- Recertification Requirements at Five-Year Interval
- Adherence to Campus Stormwater Management Plan

Digitalization:

- Rainfall Documentation
- Soil Moisture Content

State AFTER Digitalization:

- Continuous Documentation:
 - Soil Moisture Content
 - Infiltration Rate Characteristics
 - Dewatering Time
 - Water Holding Capacity
 - Filter Media Cycles
- Confidence in Fiscal Resource Commitments
- Confidence in Human Resource Commitments
- Confidence in Re-Certification



State BEFORE Digitalization:

- Combined Sewer Overflows (CSOs)
- Existing Building (multilevel roofs)
- Rooftop Detention Desired
- Detain Rooftop Rainfall
- Need for Controlling Discharge

Digitalization:


- Rainfall Documentation
- Water Level Documentation
- Real-Time Control



State AFTER Digitalization:

- Documentation of Rooftop Volume(s)
- Documentation of Rainfall Events
- Autonomous Detention and Discharge
- Documentation of Detention Time and Discharge Times
- Documentation to Apply for Rebates

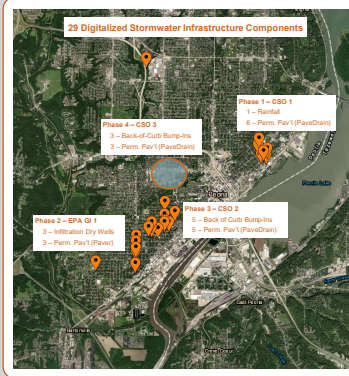
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State BEFORE Digitalization:

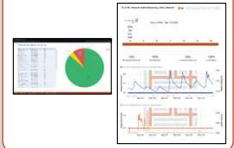
- US EPA Consent Decree
- Need to Eliminate Combined Sewer Overflows (CSOs)
- Multi-Phase Multi-Type Stormwater Infrastructure Implementation Plan
- Need to Document Performance
- Need to Schedule Maintenance

29 Digitalized Stormwater Infrastructure Components



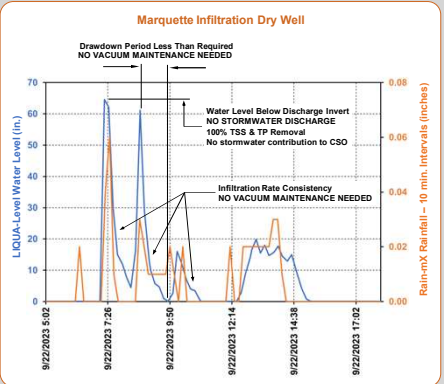
State AFTER Digitalization:

- Documentation of Network Performance
- Automated Network Health Reporting
- Performance Documentation
- Maintenance Assessment and Triggering
- EASY BUTTON for the Consent Decree
- Performance Data to Document Effectiveness of \$109 Million in Spending



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Marquette Infiltration Dry Well



**Drawdown Period Less Than Required
NO VACUUM MAINTENANCE NEEDED**

**Water Level Below Discharge Invert
NO STORMWATER DISCHARGE
100% TSS & TP Removal
No stormwater contribution to CSO**

**Infiltration Rate Consistency
NO VACUUM MAINTENANCE NEEDED**

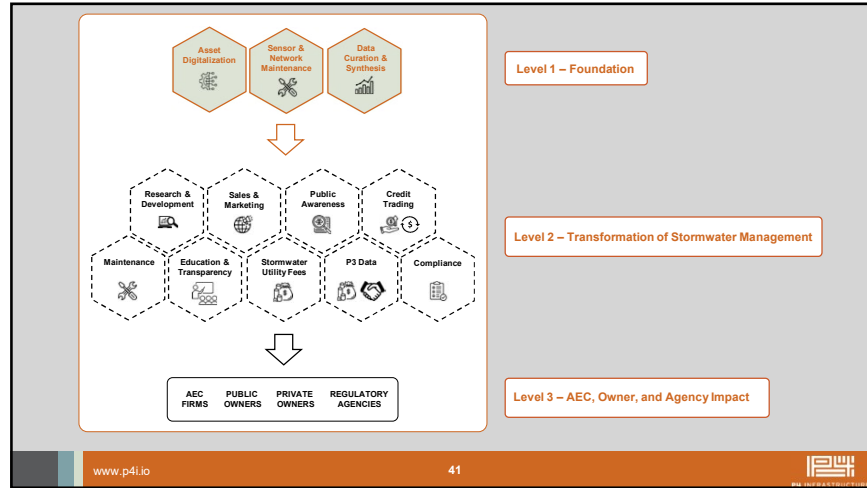
State AFTER Digitalization:

- Years of Contiguous Data (10-minute intervals)
- Drawdown Rate Consistency – MAINTENANCE TRIGGER
- Water Level Below Ext Invert – NO DISCHARGE TO CSS
- 29 Infrastructure Systems Included in Network
- IRREFUTABLE DATA FOR CONSENT DECREE
- ULTIMATE STAKEHOLDER TRANSPARENCY

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What does the future hold?

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Transformational Stormwater Management
Clean Surface Water
Replenished Groundwater Systems
Flood Mitigation

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