A Smart, Connected, & Sustainable Campus Community:

Using the Internet of Things (IoT) and Sensor Technology to Improve Stormwater Management at UMD

Marccus D. Hendricks, Ph.D., MPH
Assistant Professor
Urban Studies and Planning Program
School of Architecture, Planning and Preservation
University of Maryland

A Smart, Connected, and Sustainable Campus Community: Using the Internet of Things (IoT) and Sensor Technology to Improve Stormwater Management at UMD

The Team

STORMWATER INFRASTRUCTURE RESILIENCE AND JUSTICE LAB

SIRJ

NCSG

DEPARTMENT OF ENVIRONMENTAL SAFETY, SUSTAINABILITY & RISK

FACILITIES MANAGEMENT

A. JAMES CLARK SCHOOL OF ENGINEERING

COLLEGE OF AGRICULTURE & NATURAL RESOURCES

COLLEGE OF INFORMATION STUDIES

ENVIRONMENTAL FINANCE CENTER

SCHOOL OF ARCHITECTURE, PLANNING & PRESERVATION

Marccus Hendricks
Jason Baer
Tara Burke
Jennifer Cotting
Allen Davis
Andy Fellows
Pierre Gaunaurd
Gerrit Knaap
David Loshin
Mitch Pavao-Zuckerman
Kaitlyn Peterson
Karen Petroff
Bryan Quinn
Tammy Clegg
Beth Bonsignore
Qianyao Si

Project Description

Goal(s)

The goal of this project is to use an Internet of Things (IoT) framework along with smart sensors to monitor and improve stormwater management on the University of Maryland Campus.

Real-time continuous monitoring.

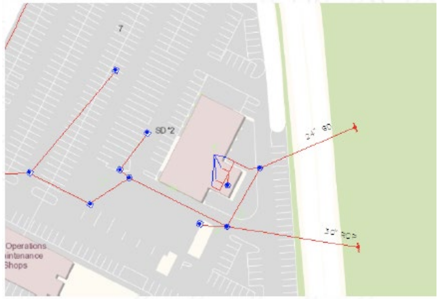
The UMD Campus is the perfect testbed for understanding the implementation of sensor technology for water quality monitoring because it currently operates under permitting requirements that exist for most smaller cities and some that don't.

Project Description

Under the EPA MS4 requirements, UMD campus must retrofit 20% of untreated impervious areas by 2025.

More and better data are needed to protect our waterbodies, address runoff issues, establish BMPs, and inform sustainable development.

IoT, sensor technology, big data analytics, and real time event monitoring are among the many ways that communities are getting "smarter".



Untreated Runoff

Treated Runoff

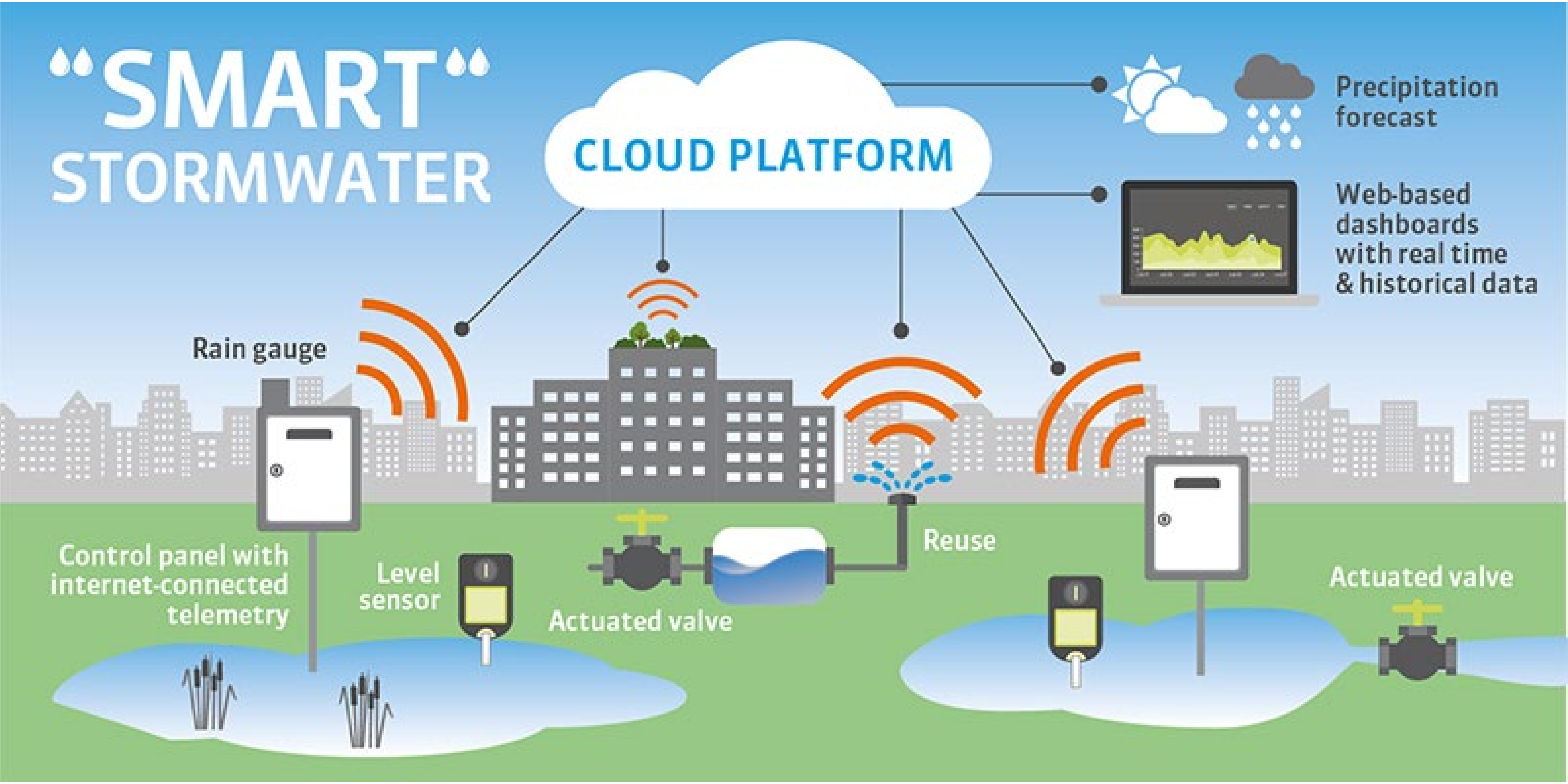
Project Objectives

(1) Install smart IOT sensors that measure water quality at 4 locations on the UMD campus;

(2) Conceptualize, design, and develop a robust and flexible database to house data

(3) Train students to install and read the stormwater sensors, manage the data platform, interpret the data; and

(4) Use the data to analyze current hyper-local conditions within the UMD stormwater system


"SMART"
STORMWATER
CLOUD PLATFORM
Precipitation forecast
Web-based dashboards with real time & historical data
Rain gauge
Control panel with internet-connected telemetry
Level sensor
Actuated valve
Reuse
Actuated valve

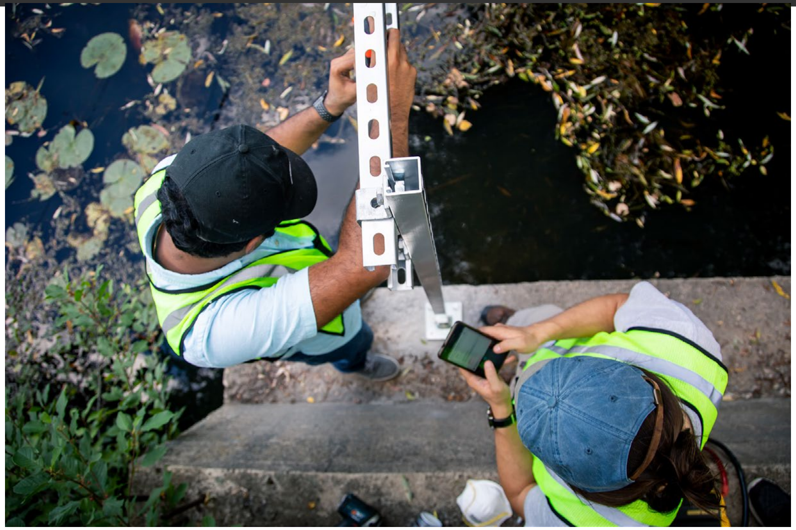
Sensor Description

Water quality sensors in enclosed sonde (Aqua Troll 500):

- Temperature
- Turbidity
- pH
- Dissolved Oxygen
- Salinity
- Conductivity

Each outfall has the following equipment set up:

- In Situ (manufacturer) computer box (FlowPro) with WiFi card; modem; and sensor sim cards
- Solar panel and attendant cords
- Area/velocity sensor and attendant fiber cord



Extreme Conditions #1

Before – July 2020

August 2020

Outfall 3:

Extreme conditions #1 -August 2020

Gravel
(arrow)

High and fast water (arrow)

Plan B

Reconfiguration

--Braces (arrow)
--depth sensor harness (arrow)
--new foam
--no change to sonde location

Extreme conditions #2 September 2020

-submerged depth sensor (top arrow)
-sonde out of place (2nd arrow)

Plan H

Harden

-- new depth sensor (different technology)

Hardened equipment can handle the conditions

Outfall 5

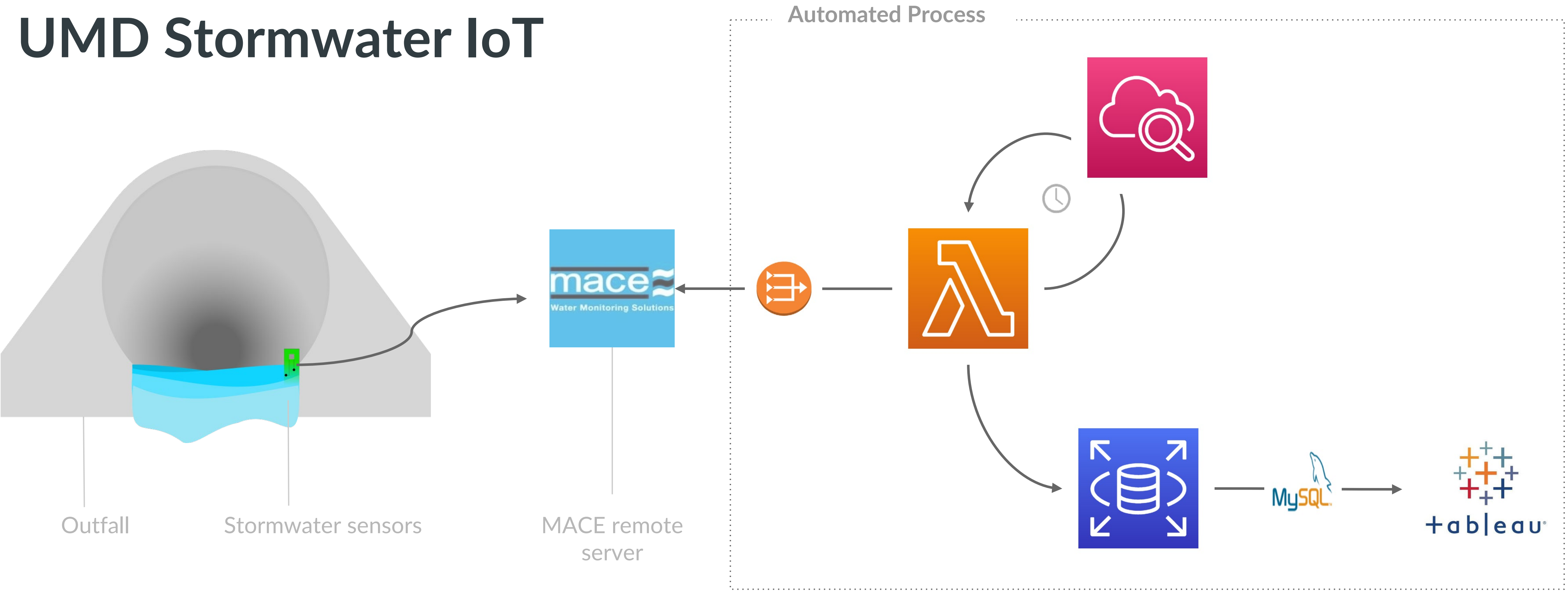
Outfall 19

Hardened

October 2020

New sonde position (arrow)

UMD Stormwater IoT



AWS

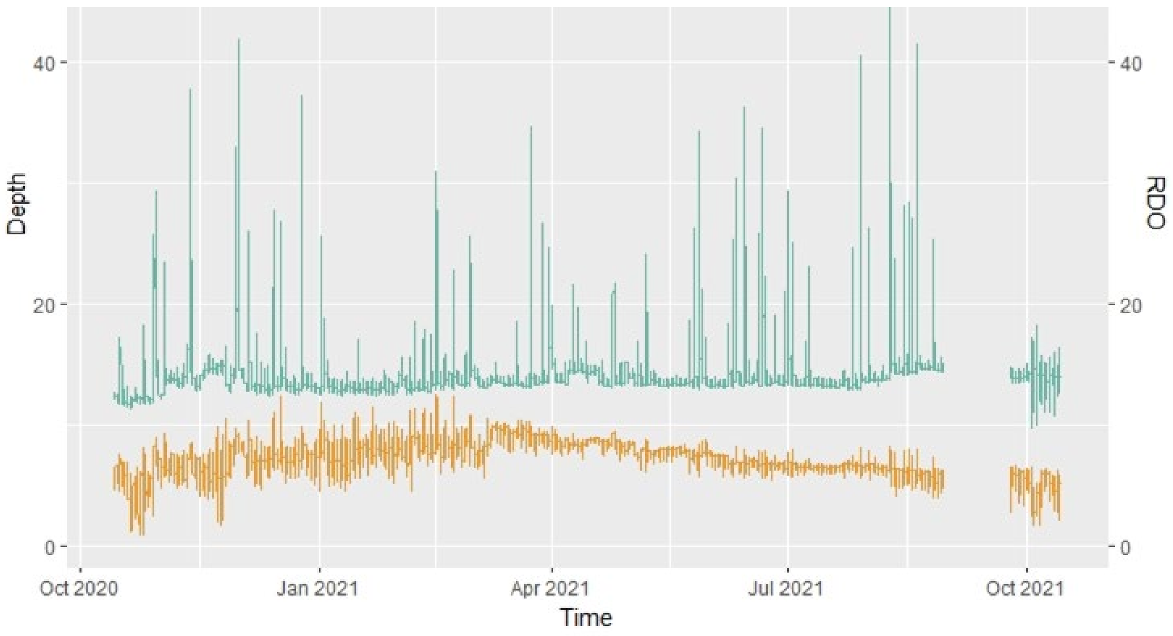
Lambda - serverless compute service that runs code in response to events

NAT Gateway - provides AWS resources access to the internet while maintaining privacy

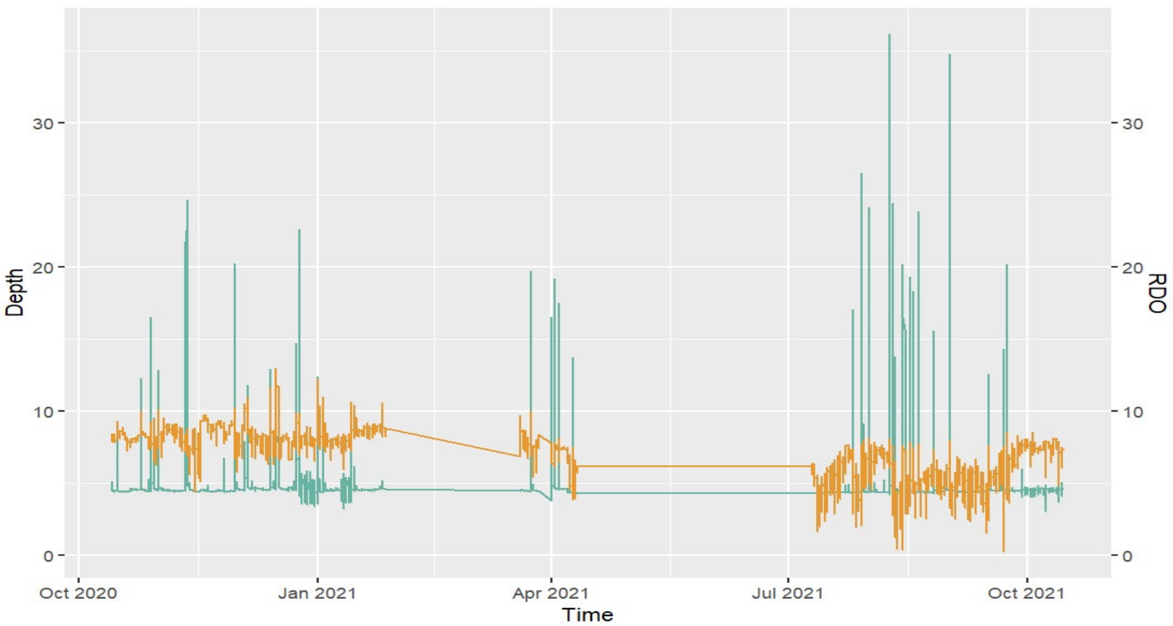
RDS - Set up, operate and scale relational database with engines like MySQL, Oracle, MariaDB

CloudWatch - Schedule events and set alarms

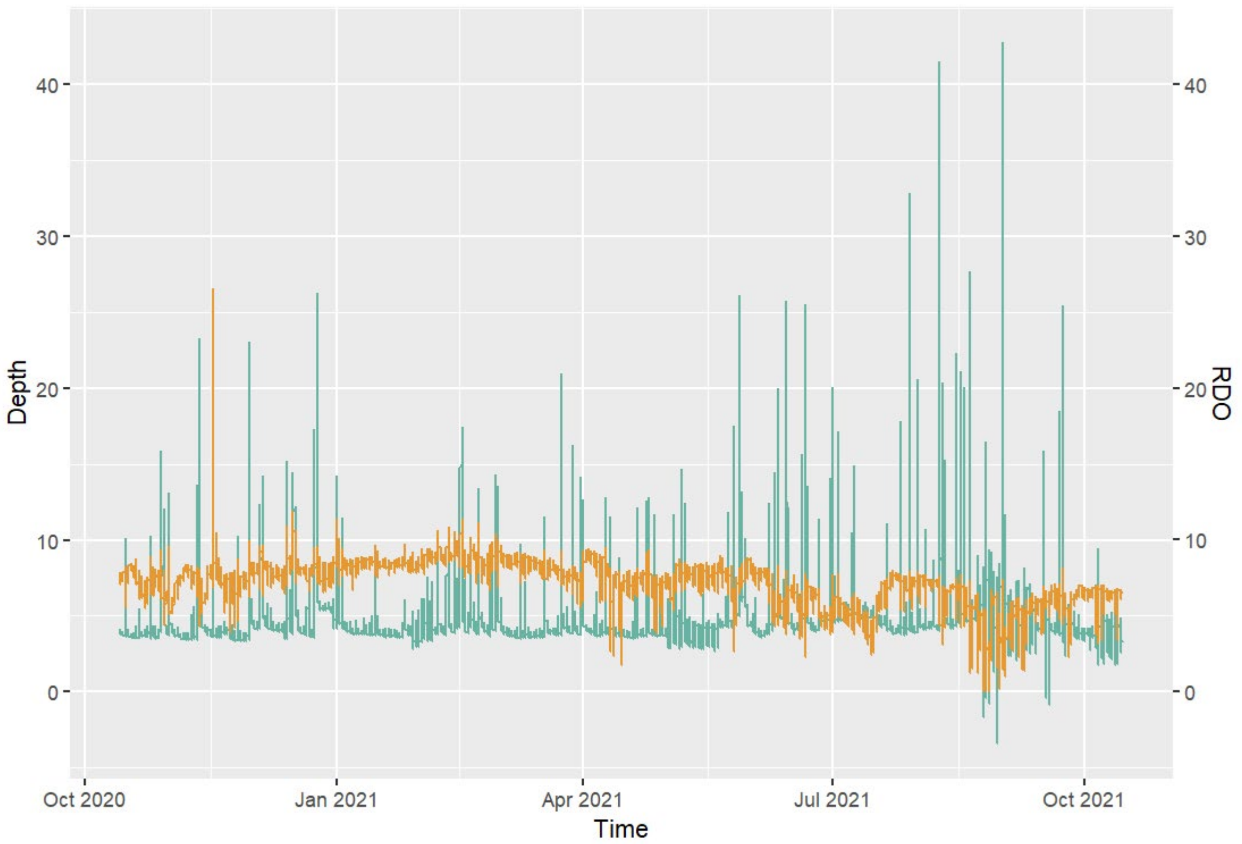
Time series of Depth and RDO at Outfall #5



Time series of Depth and RDO at Outfall #19



Time series of Depth and RDO at Outfall #3

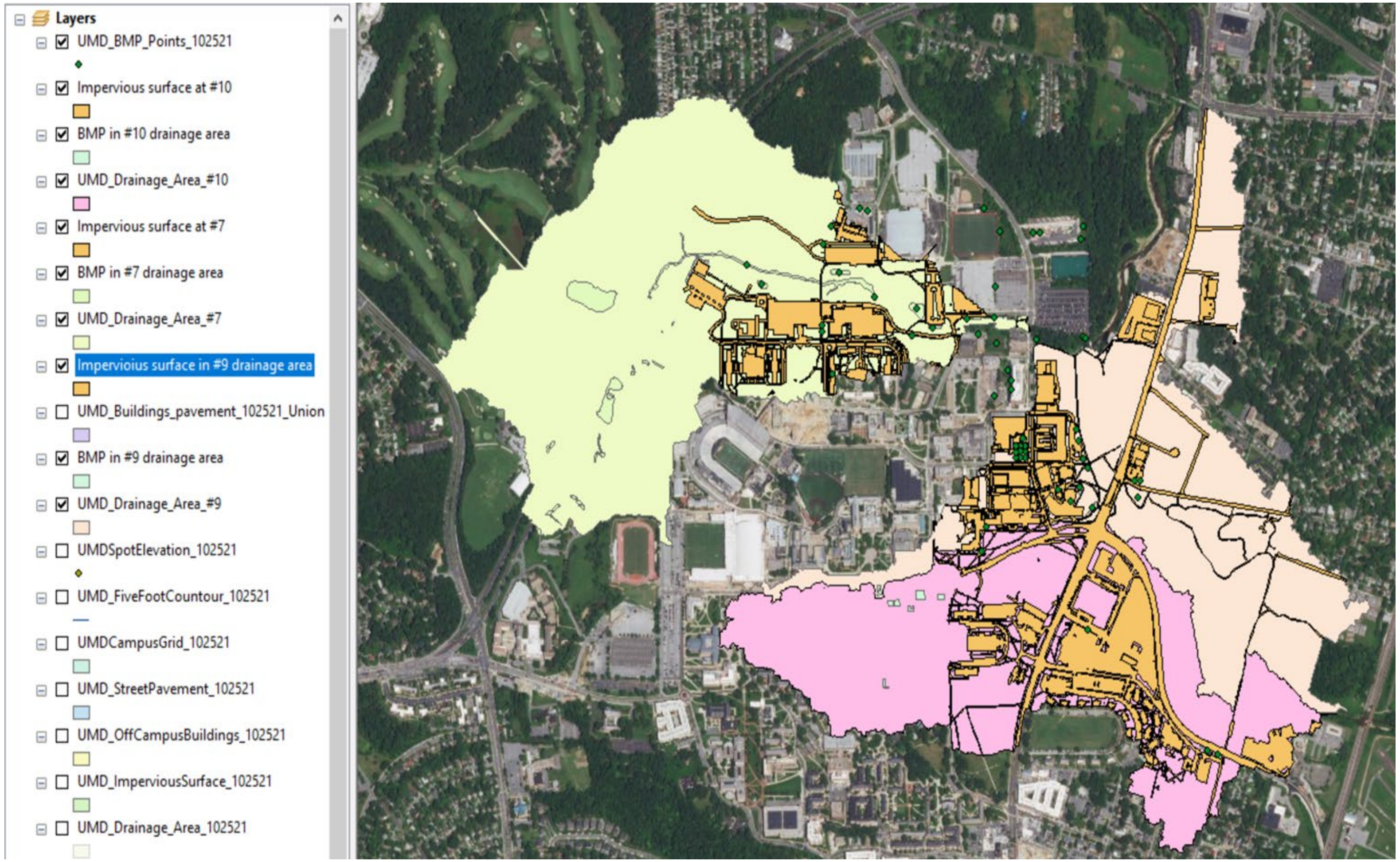


Repeated Measures Correlations (r) between Stormwater Quantity and Quality Variables

- From the preliminary analysis:
  - The runoff dissolved oxygen content and turbidity variables were slightly but significantly positive-correlated with the quantity variables
  - The conductivity of runoff had a slight negative correlation with all the quantity variables.
  - The correlations between pH and quantity variables were not consistent between three outfalls.

- The different r results from each outfall may also indicates that the impacts from storm-runoff source, pathway, and surface attributes play important roles in determining the characteristics of the outlet runoff.

		3	5	19
Velocity	pH	-0.008(*)	0.005	-0.024（**）
	RDO	0.023(**)	0.189(**)	0.202（**）
	Turbidity	0.027(**)	0.172(**)	0.043（**）
	Conductivity	-0.012(**)	0.072(**)	-0.027（**）
Depth	pH	-0.115(**)	0.045(**)	0.045（**）
	RDO	0.239(**)	0.327(**)	0.408（**）
	Turbidity	0.118(**)	0.329(**)	0.082（**）
	Conductivity	-0.058(**)	-0.048（**）	-0.067（**）
Current_Flow	pH	-0.019(**)	0.02（**）	-0.028（**）
	RDO	0.122(**)	0.148（**）	0.335（**）
	Turbidity	0.074(**)	0.179（**）	0.056（**）
	Conductivity	-0.204(**)	0.019（**）	-0.05（**）



Outfall	RDO_Mean	Drainage_Area	BMP_Area	Impervious_Surface_Percentage
3	7.289	6583458.187	25050.24392	21.41%
5	7.414	7322814.129	25738.05709	28.03%
19	7.618	9701985.706	233924.76	12.61%

The Linear Regressions between runoff variables and different surface attributes of the drainage area

1. Y= -1.45 (X) +7.74

where Y interprets as the RDO and X interprets as the %impervious surface.

2. y= 1.279e-06 (x) +7.319

where y stands for the RDO and x stands for the BMP area size.

Data in Hands

- Sensor Data (Oct,2020 --)

- Quantity: Velocity, Depth, Current Flow
- Quality: pH, RDO, Turbidity, Conductivity

- Campus Spatial Data

- Drainage Area
- Impervious Surface
- BMP/ Green Infrastructure
- Vegetation cover (under request)

Potential Analysis

- Data Quality Control & Clean-up (i.e. gap fixing)
- Spatial Regression Analysis
- Multivariate Regression of the sensor data
- Correlation between Q/Q and other surface attributes of the corresponding drainage area? (i.e. pipe network/size; vegetation cover rate/type)
- Application of SWAT/SWIM model to predict the runoff characteristics after rainfall events while utilizing the previous data to validate/calibrate.

Project Benefits

1) Produce adequate data to validate the proof of concept design
2) Provide data on the most sensitive ecological areas within the stormwater system (i.e. priority outfalls)
3) Demonstrate how real-time data and continuous monitoring can test the effectiveness of restoration retrofits required under the MS4 compliance permitting, and how dollars can be saved in penalties and fines, staff response time to pollutant discharges, and the overall ecological health of the system.

Broader Impacts

The sensors will provide a PILOT RESEARCH OPPORTUNITY to:

- collect new, current, and ongoing water quality data for campus
- test restoration retrofits for the treatment of water quality (pre- and post-data),
- engage students and faculty around these ever-growing problems and emerging technological solutions, and
- ensure MS4 compliance to avoid fines and become a more sustainable campus-community.
- Potentially expand beyond campus boundaries

Project Timeline & Phases

Phase 2 – Campus (Spr 2021 & Summ 2021)

- Summer sensor vetting
- Wire Frame
- Data Integration and visualization platform

Setting up physical and tech infrastructure and understanding operations!!!

Phase 3 – Community (Fall 2021 & Spr 2022)

- Expand pilot work to broader communities???

Potential for Broad Application