Wilmington Lead Project – Assisting the City of Wilmington in the Completion of their LCR Inventory.

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Dmitriy Rybin *Major: Civil Engineering*
May 9th, 2024

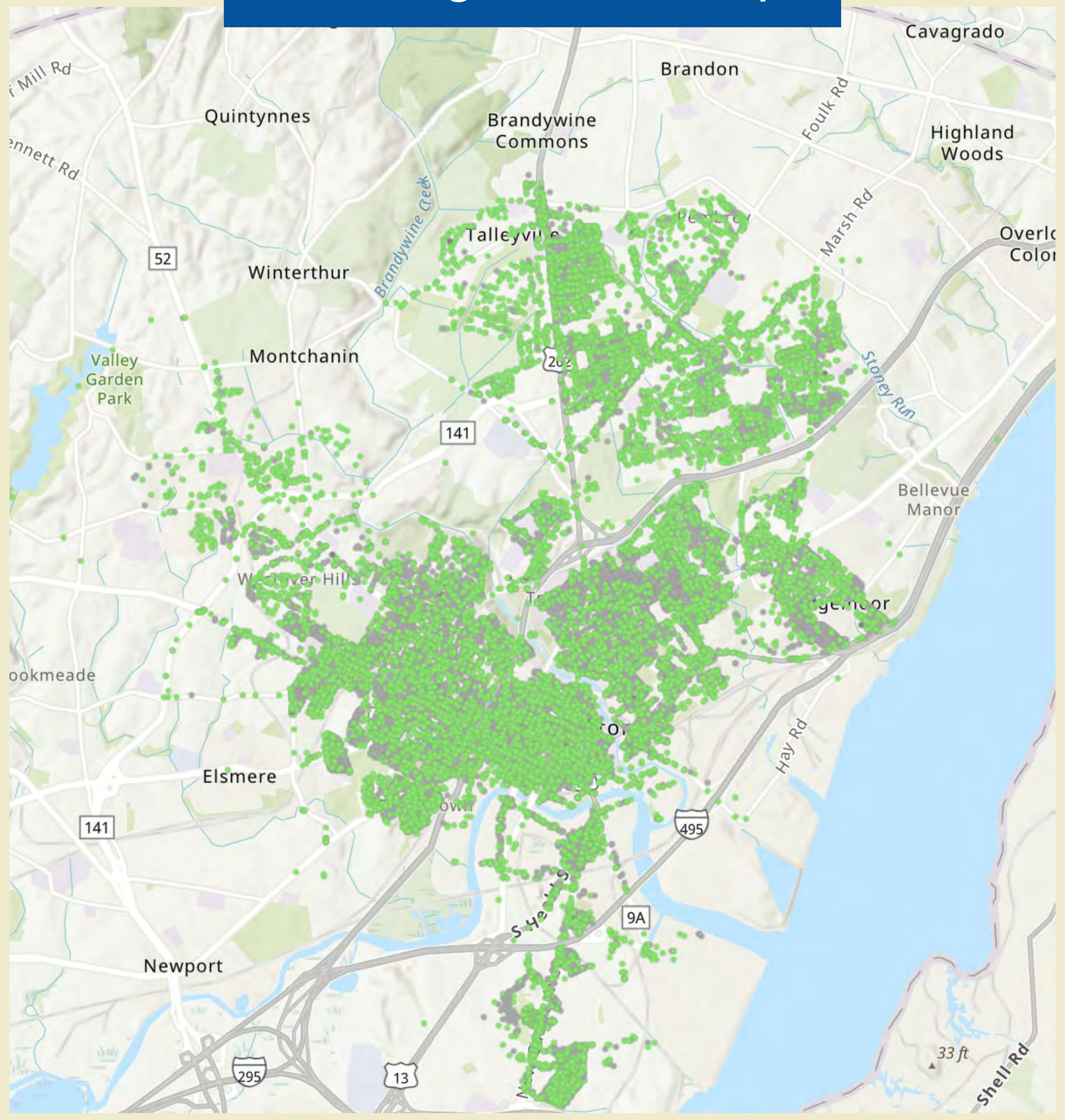
Objectives

This research is aimed at assessing the extent of the presence of lead and copper service lines in the city of Wilmington, Delaware's water supply and identifying the locations and quantity of said service lines. Additionally, this research will help to establish a plan for the systematic replacement of lead and copper service lines with safer alternatives and evaluate the health risks associated with lead exposure from the water system.

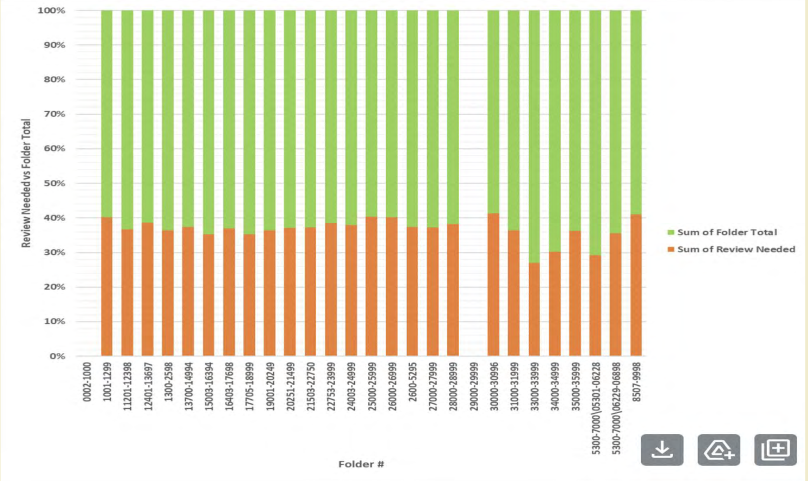
Methods

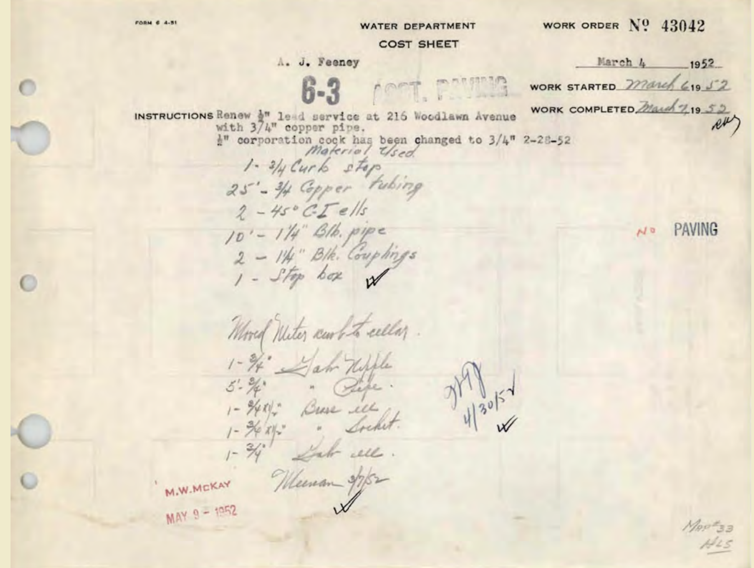
Lead service line identification was performed by examining the city of Wilmington water system work orders. Materials used corresponding to each work order, including lead, copper, iron, and galvanized metals, were analyzed to flag lead service lines. The location of service lines was indicated on GIS software, combining existing records with field surveys to ensure accuracy. This method facilitated the mapping of lead service lines within the city's water distribution system. Later on in the duration of the project, AI was implemented as a way to sort out meter and hydrant orders as opposed to service line and main related work orders.

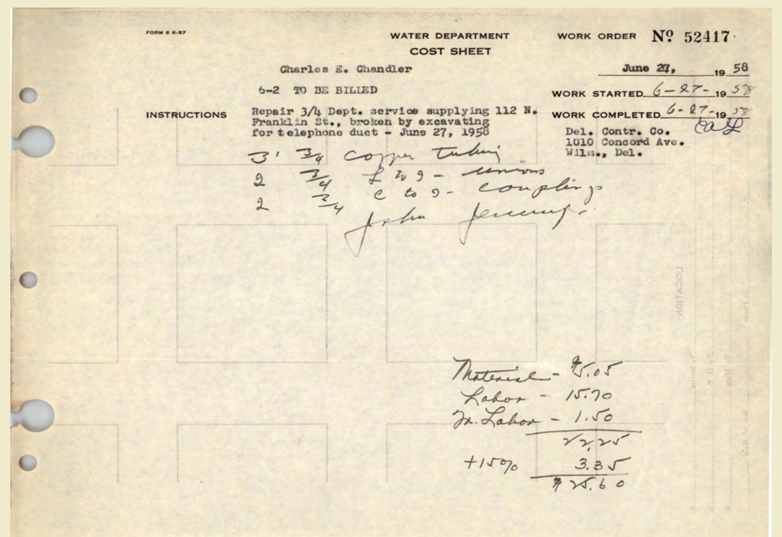
Wilmington GIS Map

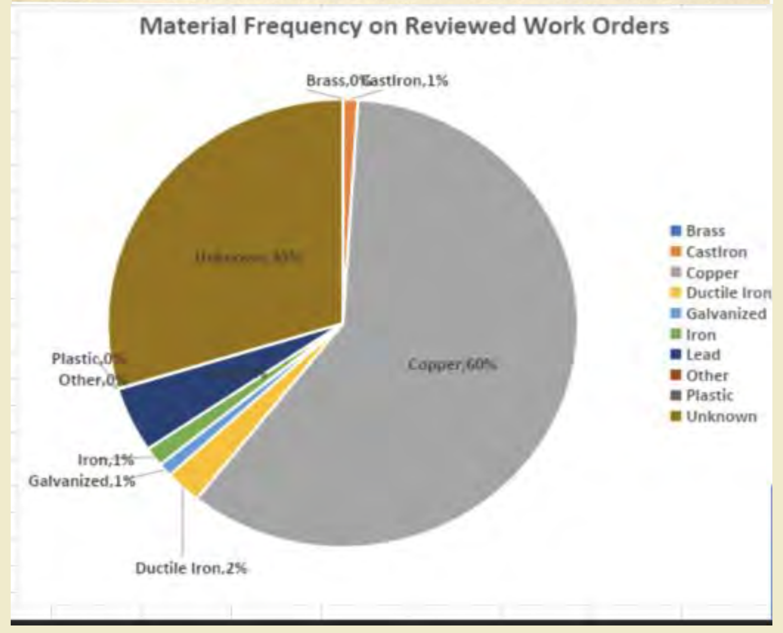


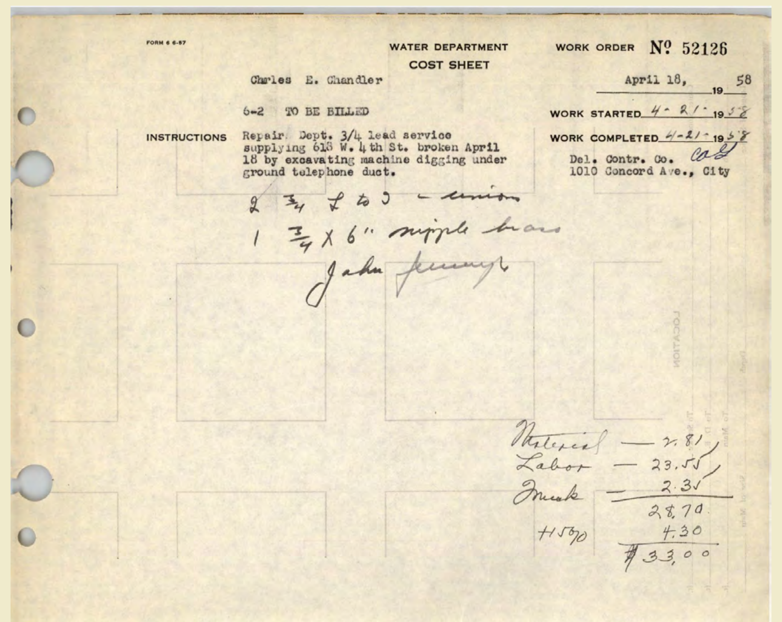
Results

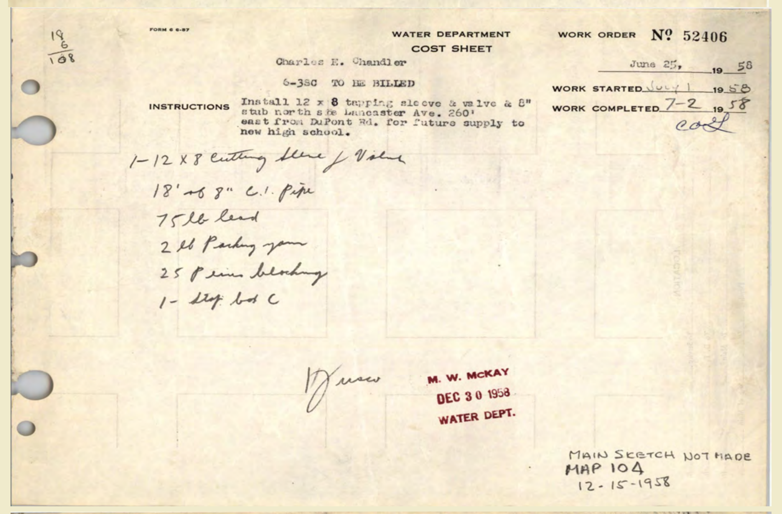


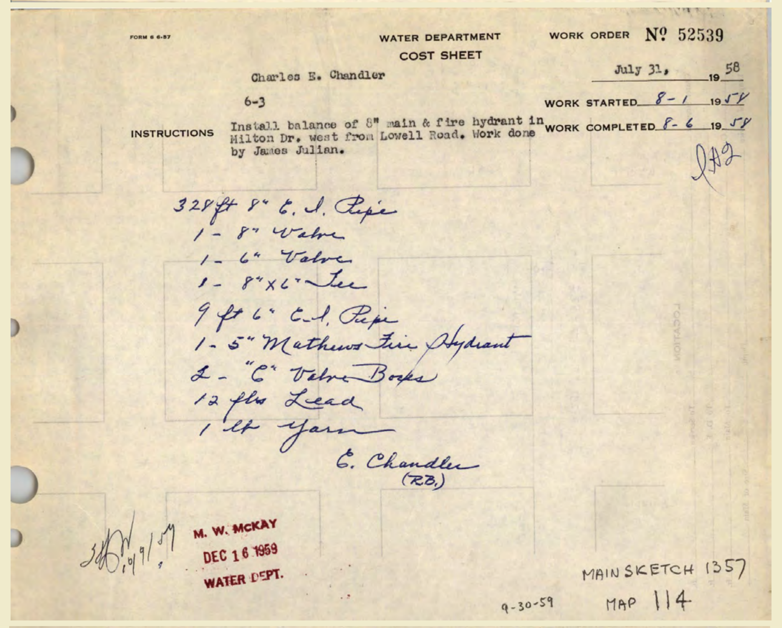


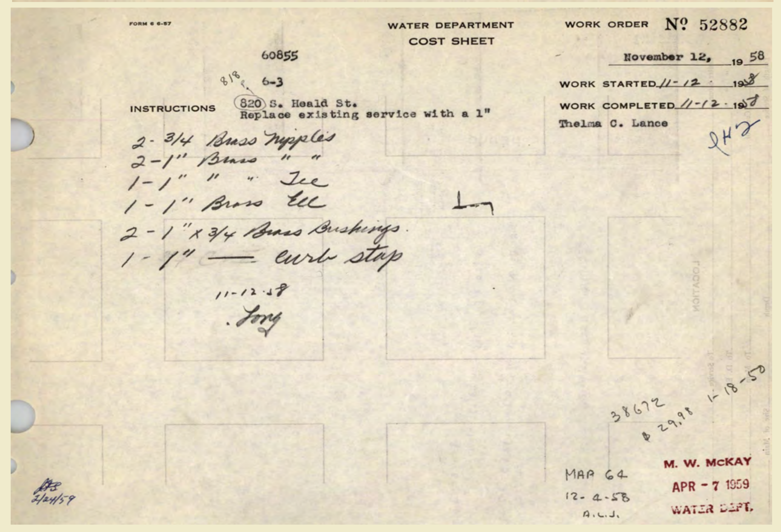












Folder #	Sum of Review Needed	Su Fo To
0002-1000		
1001-1299	199	29
11201-12398	695	11
12401-13697	813	12
1300-2598	739	12
13700-14994	775	12
15003-16394	754	13
16403-17698	755	12
17705-18999	703	12
19001-20249	711	12
20251-21499	736	12
21503-22750	726	12
22753-23999	778	12
24003-24999	607	99
25000-25999	669	98
26000-26999	669	99
2600-5295	979	16
27000-27999	593	10
28000-28999	618	10
29000-29999		
30000-30996	702	99
31000-31999	569	99
33000-33999	370	99
34000-34999	432	99
35000-35999	565	99

Observations

Of the 70,000 total work orders, with files dating back a total of 94 years,. there are only 18,000 remaining work orders to process. Of the total work orders completed, 60% contain copper materials, 5% contain lead materials, 1% contain galvanized iron, 2% contain ductile iron, 1% contain cast iron, 30% are unknown/unidentified, and less than 1% each contain plastic or brass respectively. These numbers, when taking into consideration the rate of replacement of services over time, dilution in the form of replaced services being tracked, as well as unknown materials being uncovered through either excavation or through non-work order related documentation, offer a rough estimate of the current state of Wilmington's LCR inventory. With full replacements of outdated lines expected to be completed within the next ten years, this data offers a look into the magnitude of expected necessary replacements to be expected over the next decade, thus giving a basis to look into expected fiscal costs associated with compliance with the LCR.

Recommendations

We would recommend continuing to work on this project through the October deadline for submissions of inventories. Doing so would allow for a more complete picture of potential costs associated with the costs of identifying "unknown" pipes, the cost of replacement, as well as economic implications of the replacement of outdated service lines. Obtaining information regarding the costs of identifying as well as replacing "unknown" pipes, as well as general lead and copper pipes, could be used to perform analysis on the economic outcomes of the carrying out of the LCR. Furthermore, upon the passing of the October 16th 2024 deadline for inventory submissions, sampling from other state and city inventories across the country could be beneficial in gaining insight into national LCR compliance costs.

Acknowledgements

We would like to thank the Delaware Water Resources Center as well as the US Geological Survey who provided the funding for this research through the US Dept. of Interior by the Water Resources Research Act of 1964 and 1984. Continually, we would like to thank Dr. Gerald Kauffman, Martha Narvaez, and Andrew Homsey for their guidance and advisement. Furthermore, we would like to extends our gratitude to Jacobs, as well as Cheryl Townsend-Braun for allowing us the opportunity to participate in this effort that has proven to offer us a genuine insight into important local and federal policy implementation.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GIS Use in Diamondback Terrapin Conservation in Delaware's Inland Bays

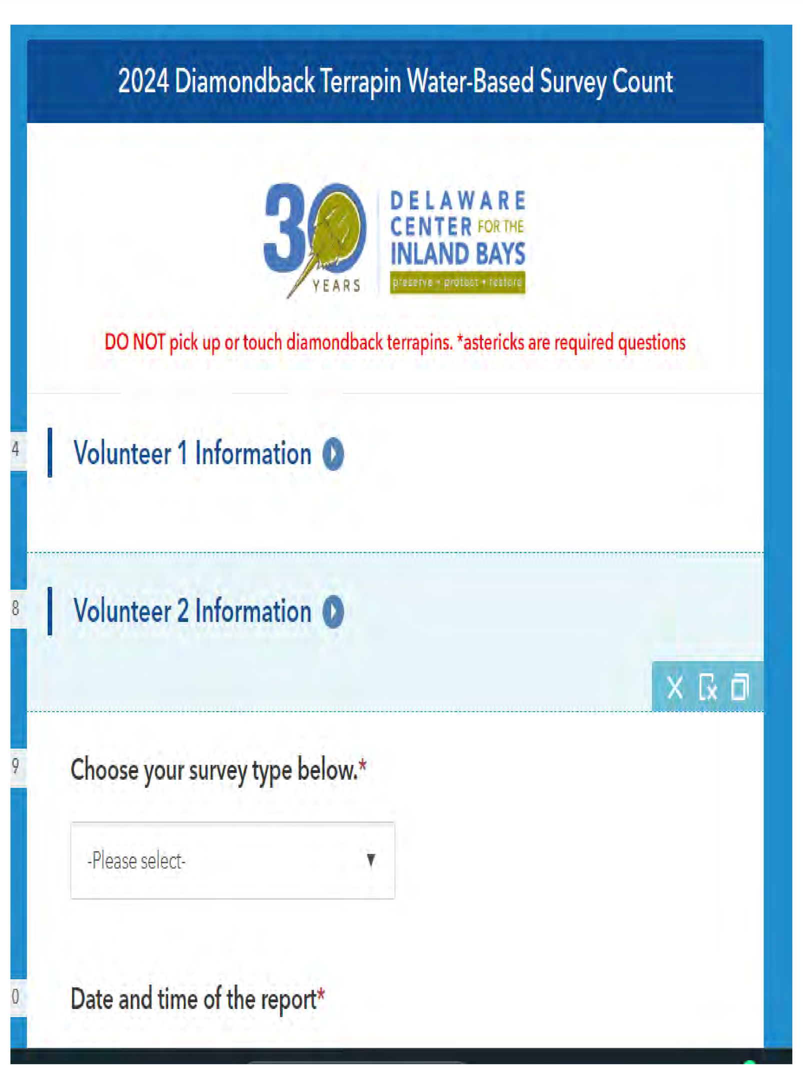
Ambre Crawford (Marine Science)
College of Earth, Ocean, and Environment
University of Delaware, Newark, DE 19716 USA, May 9th, 2024

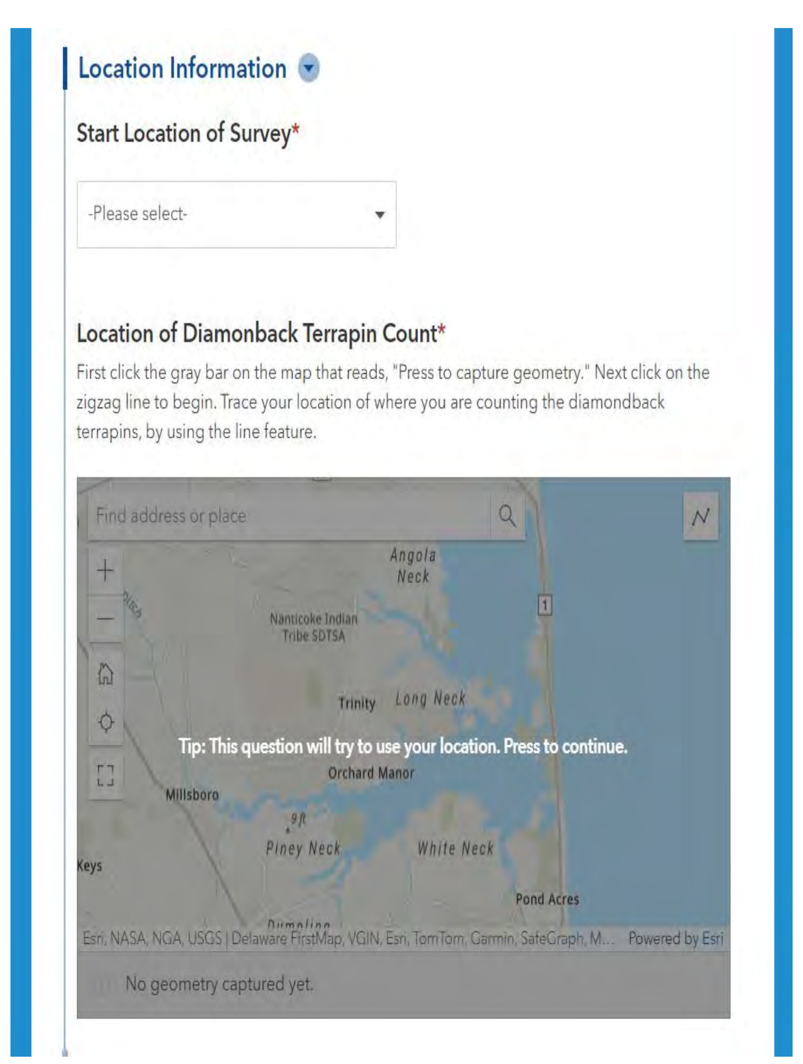
Background

- Diamondback Terrapins (*Malaclemys Terrapin*) are an important Keystone species in salt marshes along the east coast
- Only turtle species that lives exclusively in brackish water
- Endangered due to hazards produced by coastal development that interfere with their ability to nest in sandy areas
- 90 Terrapins were killed by cars while crossing the road last summer

Methods

ArcGIS Survey 123



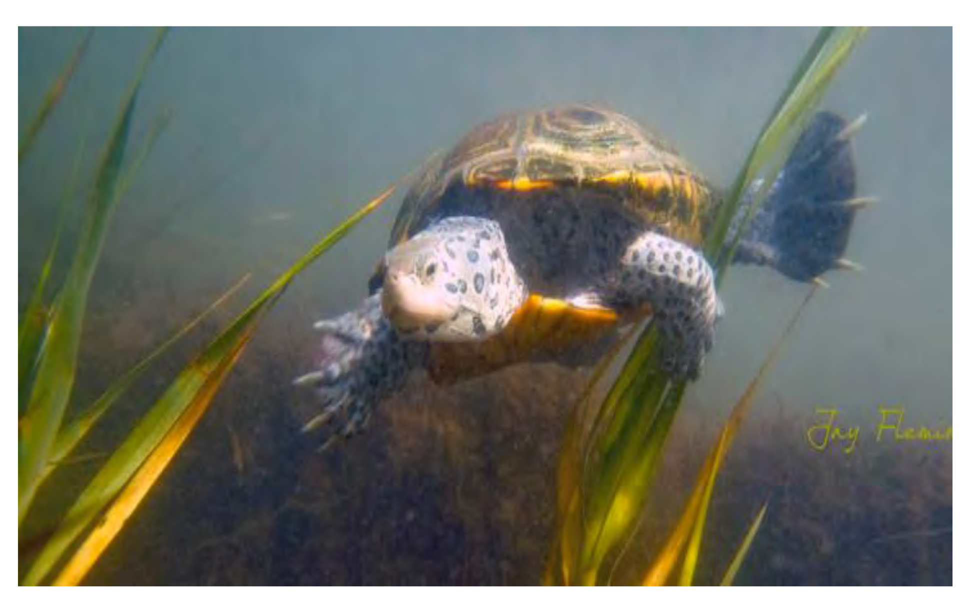


Two surveys have been developed; a land-based survey and a water-based survey. Using ArcGIS Story Map as the training tool provides the volunteers specific instructions on how to complete the terrapin survey count.

ArcGIS Story Map

The story map instructions are a convenient way for volunteers to access survey instructions on their devices while doing the survey.

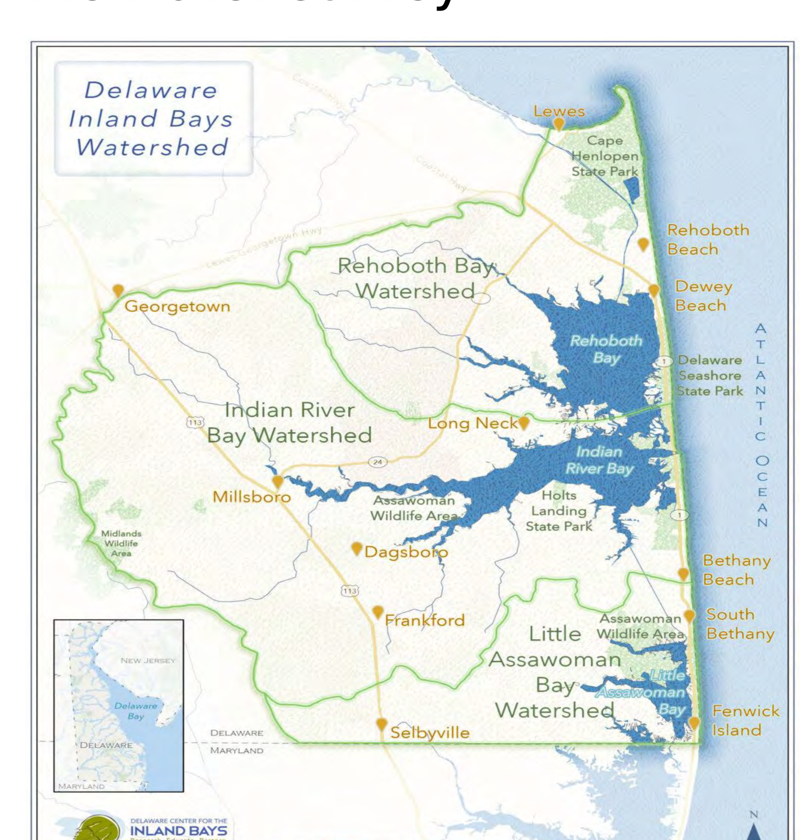
Photos from Past Surveys



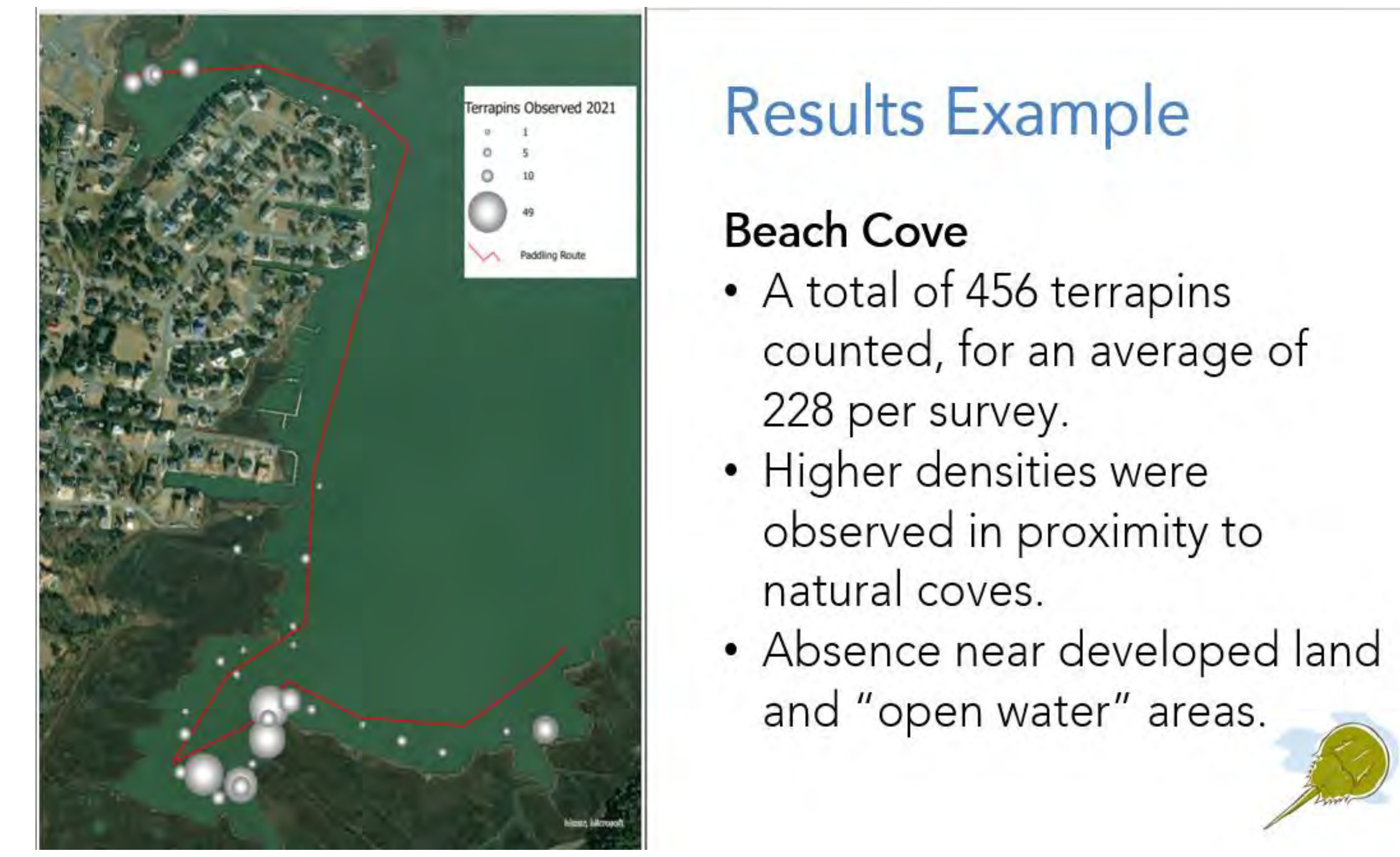
A swimming Diamondback terrapin

Surveyors on the beach doing a land survey and preparing for the water survey

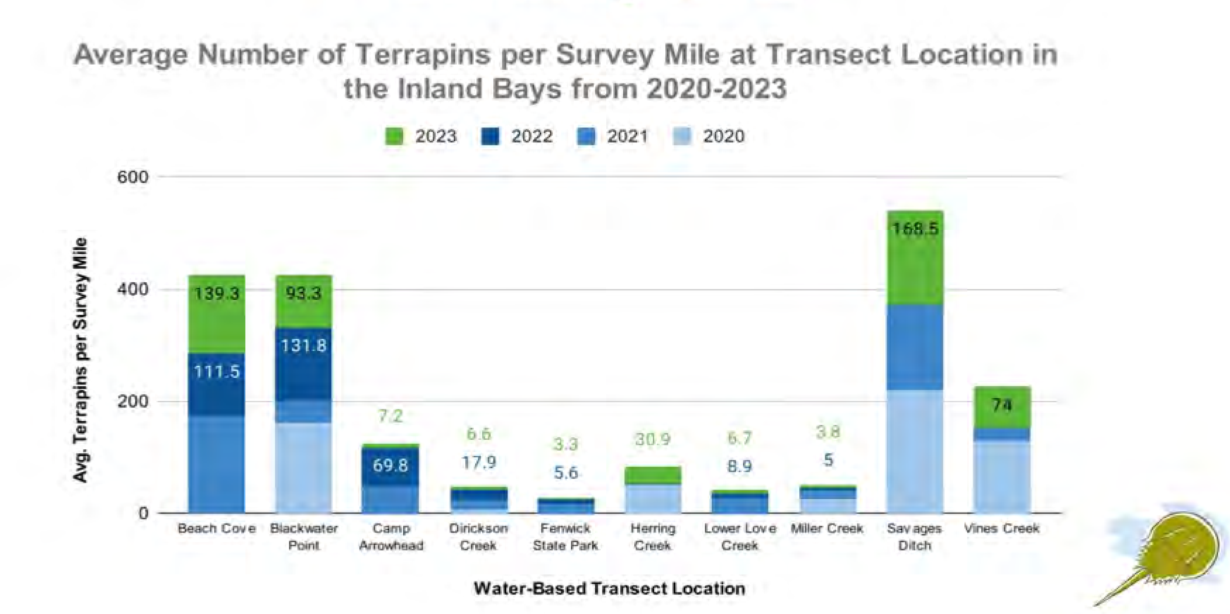
Abandoned crab pots are hazardous to terrapins getting trapped.



Results and Future Research



A map of terrapin data points from the Delaware Center for Inland Bays in 2023.

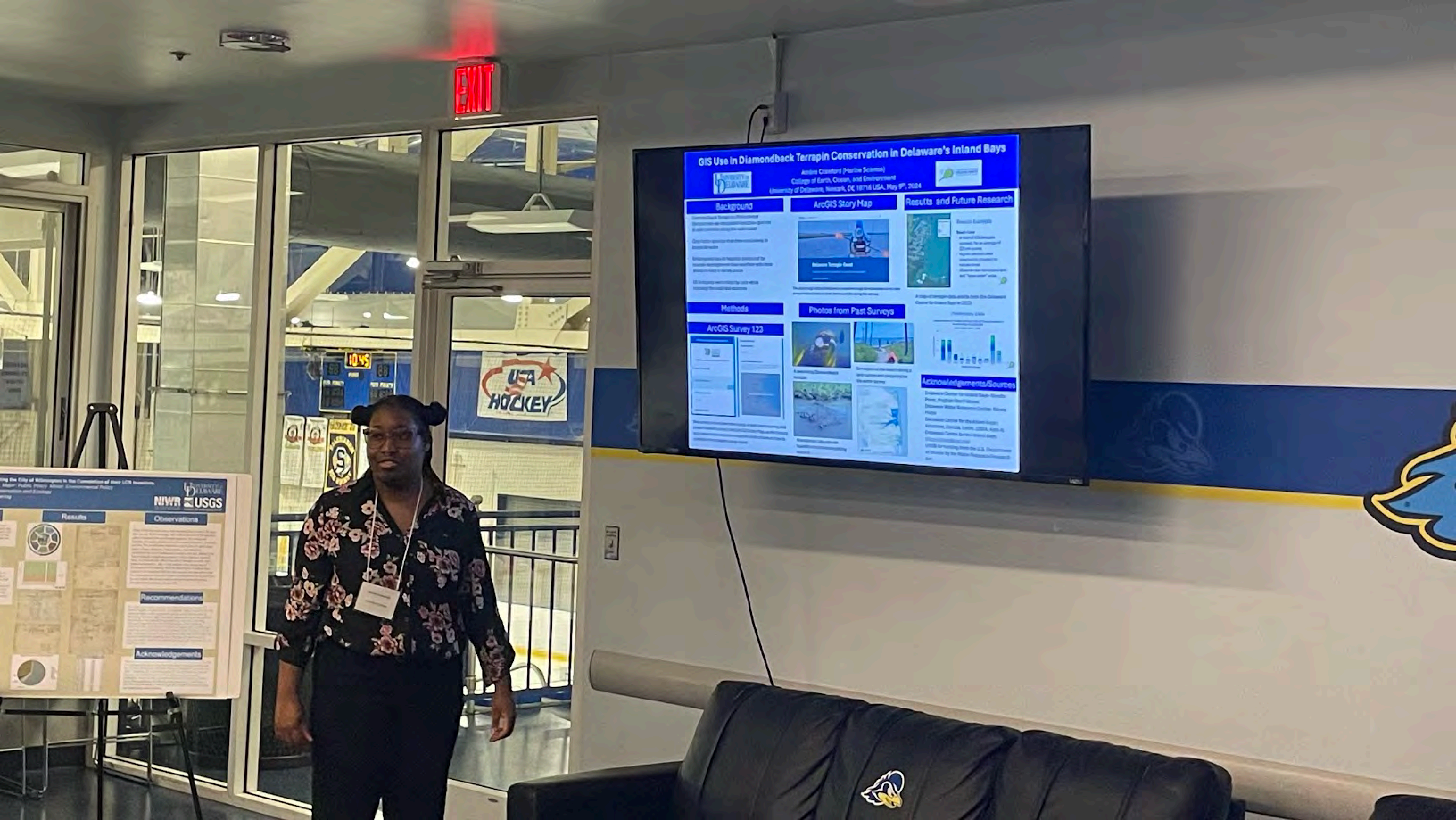


Acknowledgements/Sources

Delaware Center for Inland Bays- Nivette Perez, Meghan Noe Fellows
Delaware Water Resource Center- Nicole Minni

Delaware Center for the Inland Bays | Volunteer, Donate, Learn. (2024, April 4). Delaware Center for the Inland Bays. https://inlandbays.org/

USGS for funding from the U.S. Department of Interior by the Water Resource Research Act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GIS Use in Diamondback Terrapin Conservation in Delaware's Inland Bays
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Hydrologic and Hydraulic Modeling along the Brandywine River Floodplain in Delaware and Pennsylvania

Caroline Gilliard, Elizabeth Manning, Gerald Kauffman
College of Engineering – Civil and Environmental Engineering

May 9, 2024

Abstract

Delaware and Pennsylvania were hit with major storms as Hurricane Ida, a category 4 hurricane, passed through in early September 2021. Many flooding events occurred, especially in the Brandywine Creek Watershed, which comprises multiple subwatersheds spanning parts of both states. To mitigate future flooding damages, the watershed's floodplain needs to be mapped and analyzed. USGS streamflow and streamstats data were used to model the temporal nature of peak discharge over the course of September 1-3, 2021, on the WinTR-55 model program. From the hydrographs created, HEC-RAS modeling was utilized to look at Beaver Creek in Downingtown, PA to look at specific effects of flooding near the Pennsylvania-Delaware state line. From here, it was determined that the Brandywine Watershed floodplain is susceptible to floods in the case of 100-year storm events.

Methods

For each subwatershed within the Brandywine River floodplain, the land use and landcover were categorized and the primary hydrologic soil group (A, B, C, or D) was identified. The USGS Streamstats web application was used to delineate each watershed to get the total drainage area and time of concentration data (sheet, shallow concentrated, and channel flow) was collected using the measure tool.

This compiled data was then used to populate the WinTR55 model which calculates the weighted CN and time of concentration that the model uses with regional precipitation data to calculate the peak flows and hydrographs for 2-, 10-, and 100-year storms after the model is run. From the USGS stream gauge historical data available, hydrographs depicting the streamflow occurring during Hurricane Ida can be pulled and then compared with the TR-55 model to classify what storm the floodplain was being affected by.

A HEC-RAS model of specifically Beaver Creek in Chadds Ford, PA, which branches off Brandywine Creek right at the Pennsylvania-Delaware state line. HEC-RAS uses survey and hydraulic data to model water levels along specific channels. This data was provided in the scope of this project, so HEC-RAS was only used for developing profiles and cross sections that show exactly where flooding is occurring in this area.

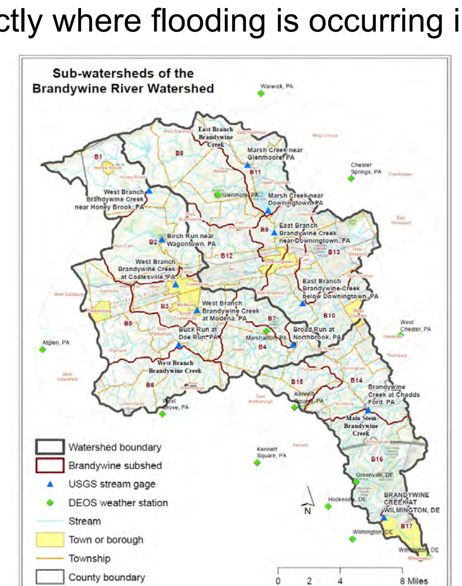

Figure 1: Map of sub-watersheds

Results

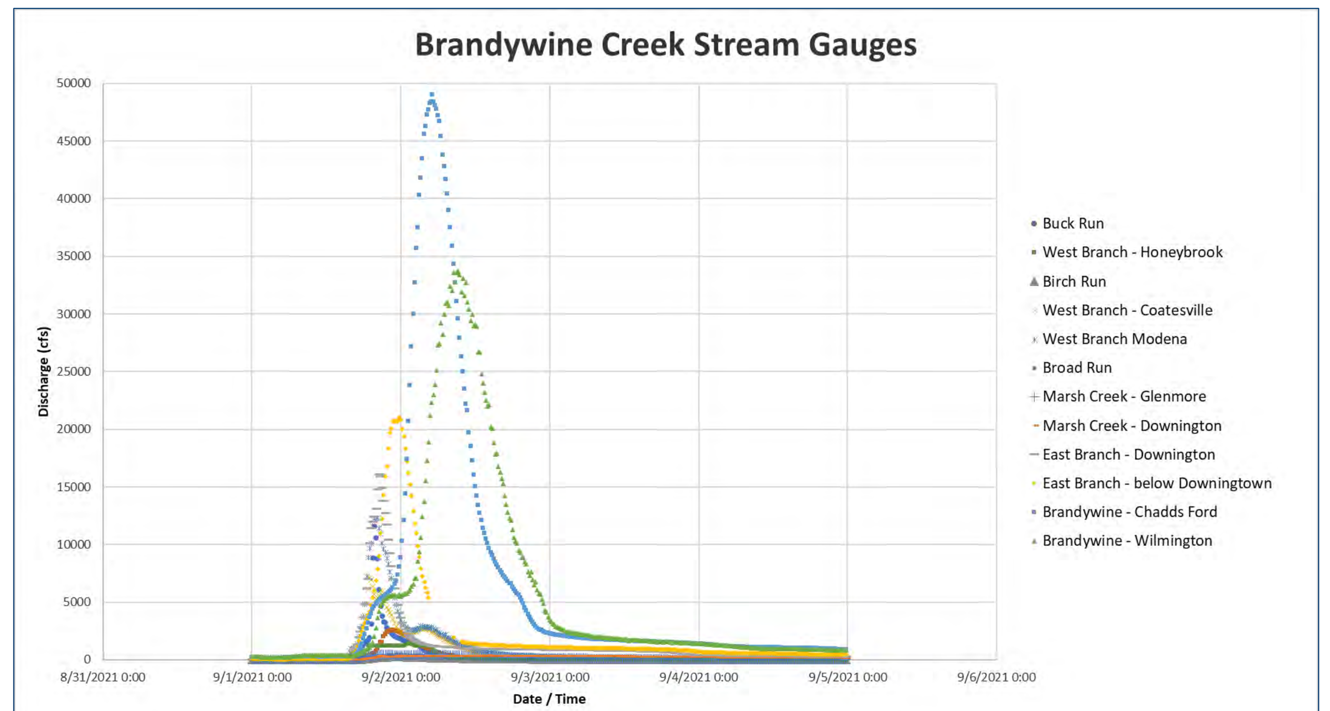

Figure 2: Superimposed stream gauge data for the Brandywine Creek Watershed

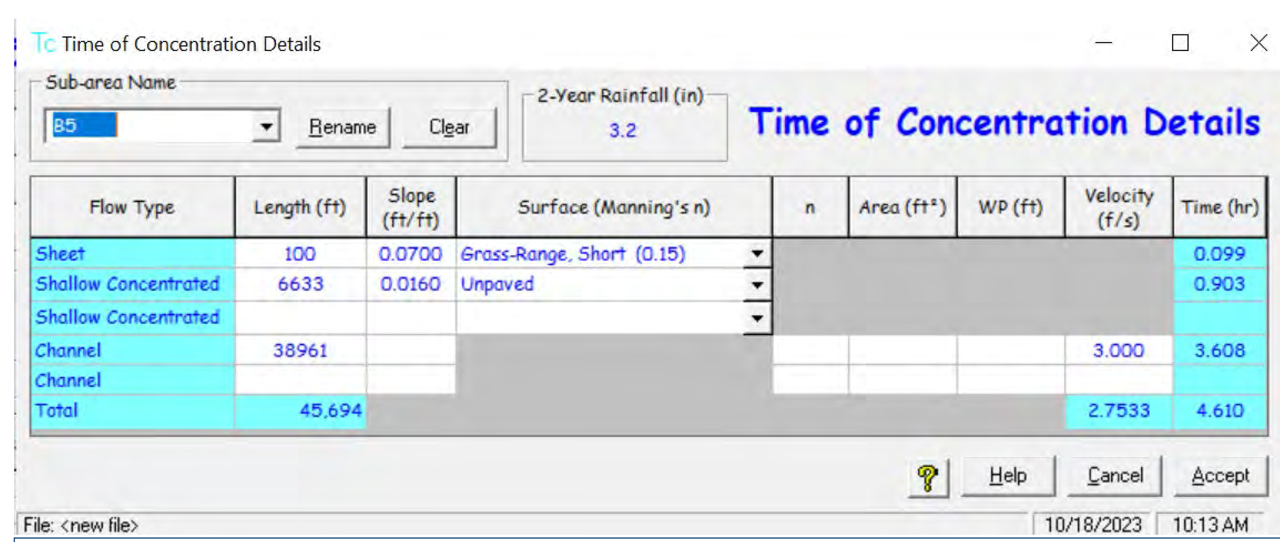

Figure 3: Example of TR-55 Time of Concentration input for B5 (Buck Run)

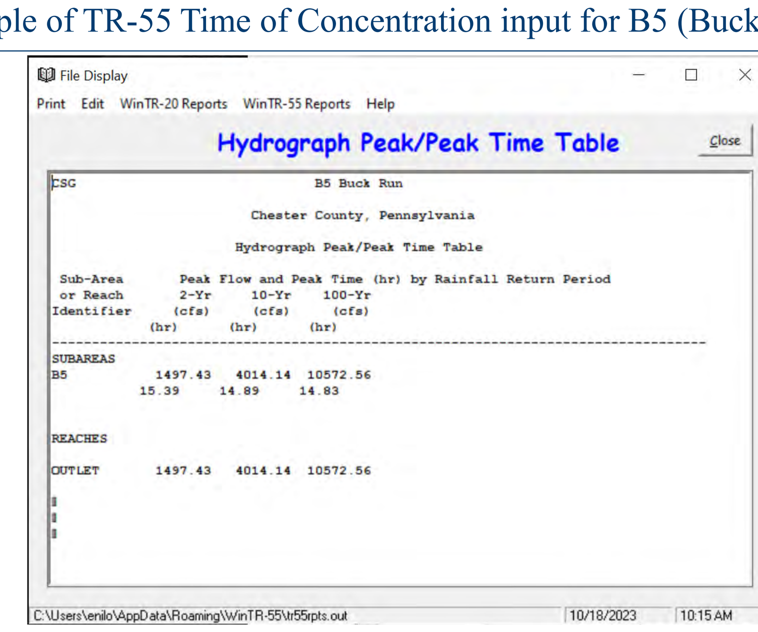

Figure 4: Example Output table for B5

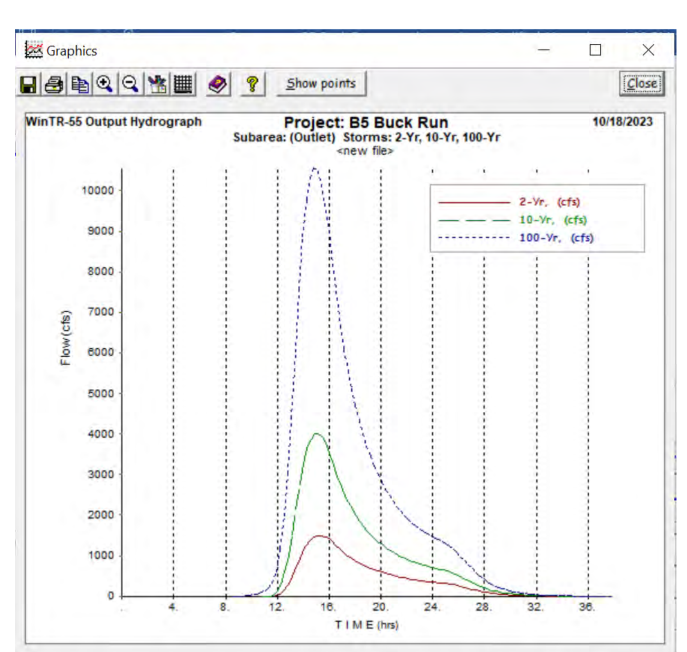

Figure 5: Example hydrograph for B5

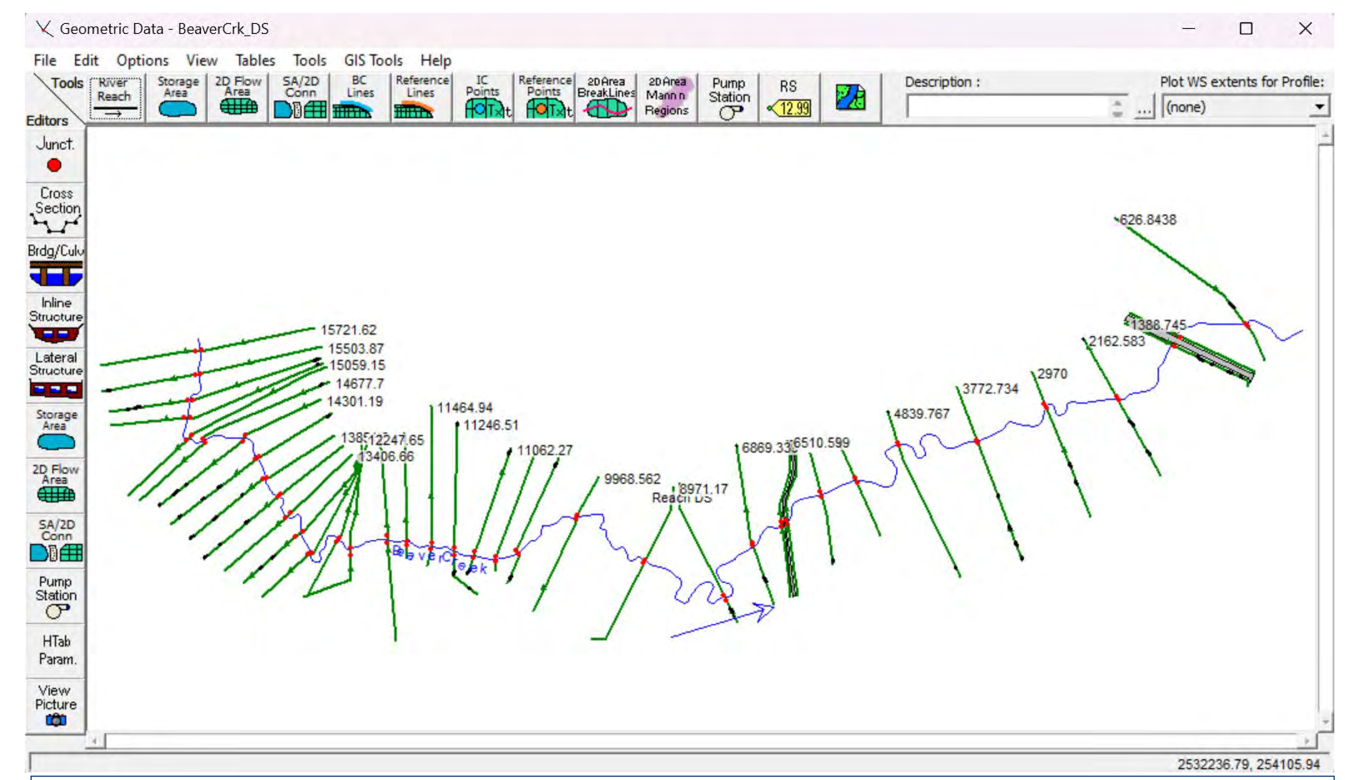
Figure 6: HEC-RAS Overview of Beaver Creek Downstream

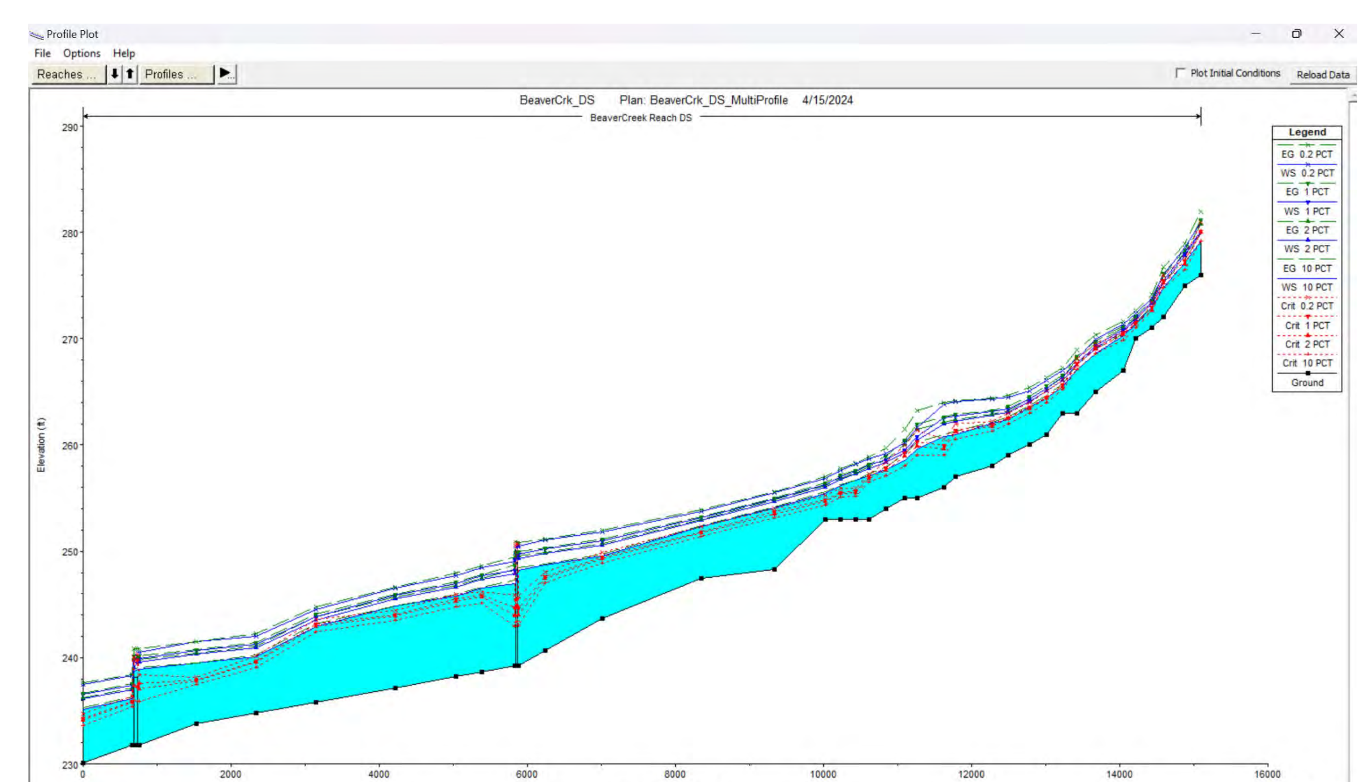
Figure 7: HEC-RAS Profile of Beaver Creek Downstream

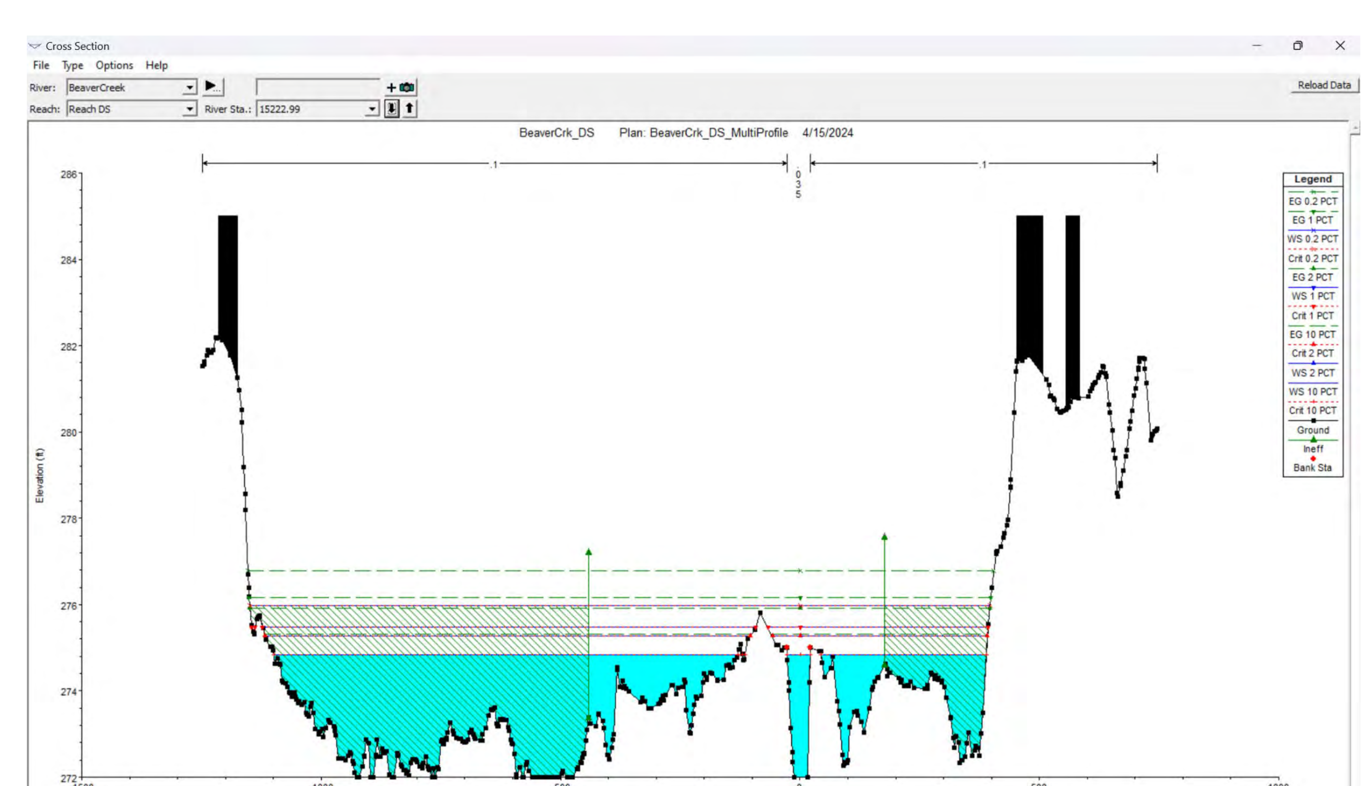
Figure 8: HEC-RAS typical cross-section of Beaver Creek Downstream

Conclusions

By comparing the results of the TR-55 model and the USGS streamgauge data, it was found that a 100-year storm caused by Hurricane Ida traveled down the Brandywine Watershed starting around Wagontown, PA and ending in Wilmington, DE (Figure 1). The highest discharges occur around the Pennsylvania-Delaware state line, indicating possible flood events within the floodplain. Looking at the HEC-RAS model, which is located in Chadds Ford, PA where the highest peak discharge occurred during the storm, flooding is evident in multiple locations along the profile of Beaver Creek (Figures 3 and 4).

Recommendations

- Future research could include HEC-RAS modeling of Wilmington, DE
- These results can be used to plan stormwater management and flood mitigation projects

Acknowledgements

This project was funded by USGS from the U.S. Department of Interior by the Water Resources Research Act of 1964 & 1984. Thank you to Gerald Kauffman, Martha Narvaez, and Andrew Homsey for their support and guidance throughout this project.


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Evaluating the Effectiveness of Reimplementing a Bottle Bill for Cleaner Waterways in Delaware

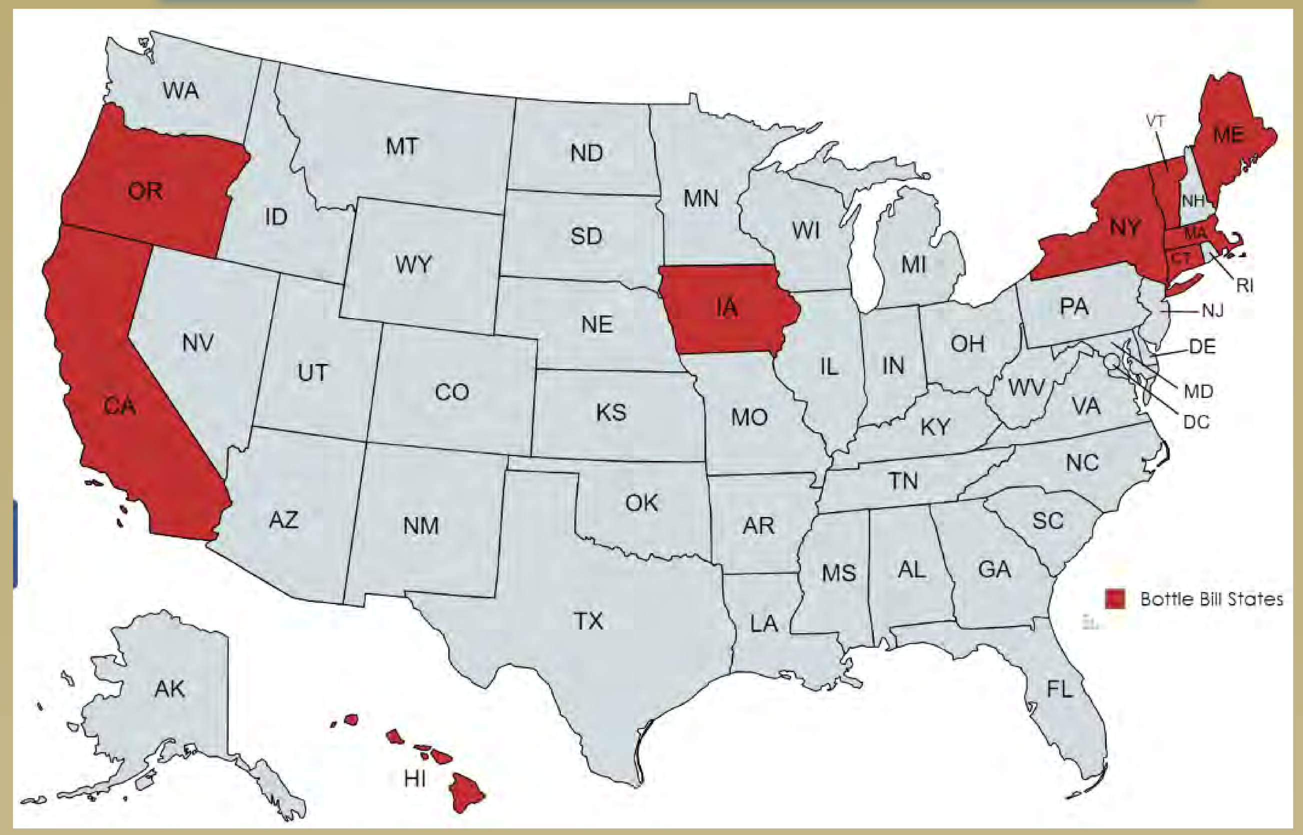
Catherine Gilman, Energy and Environmental Policy
Advised by Dr. Casey Taylor, Joseph R. Biden School of Public Policy & Administration

Presented on May 9, 2024

Purpose and Research Question

- Background: In the year 2010, the state of Delaware removed its Container Deposit Program.
- Purpose: Understand changes in Delaware's recycling policy and how that affected recycling rates in the state.
- Research Question: How does recycling behavior in Delaware compare to other states that have maintained their CDLs?

Bottle Bill States



What is a Bottle Bill?

- Used to curb mismanaged waste and debris, also known as a Container Deposit Law.
- A 5, 10, or 15-cent deposit is placed on glass, aluminum, and plastic beverage bottles.
- Deposit is returned to when brought to recycling facility.
- States with bottle bills had fewer containers in coastal debris surveys than those without.
- Highway litter surveys in Iowa, Maine, Michigan, Oregon, New York, and Vermont showed a 40-80% reduction in container litter following the introduction of bottle bills.

How Does It Work?

Recycling Behaviors

Key Predictors

- Consumer knowledge and commitment are the strongest, followed by monetary rewards and social influence
  - Some research suggests consumers may stop recycling if rewards are purely financial
  - Organizers of recycling programs should notice the role of consumers' environmental knowledge when designing incentives
- Education, youth, and home ownership
- Frequency of collection

Delaware's Recycling History

Delaware's Bottle Bill was enacted in 1982 and placed a 5 cent value on returned beverage bottles.

On November 30, 2010 Senate Bill 234 (The Universal Recycling Law) replaced the bottle deposit program, establishing a 4-cent nonrefundable fee.

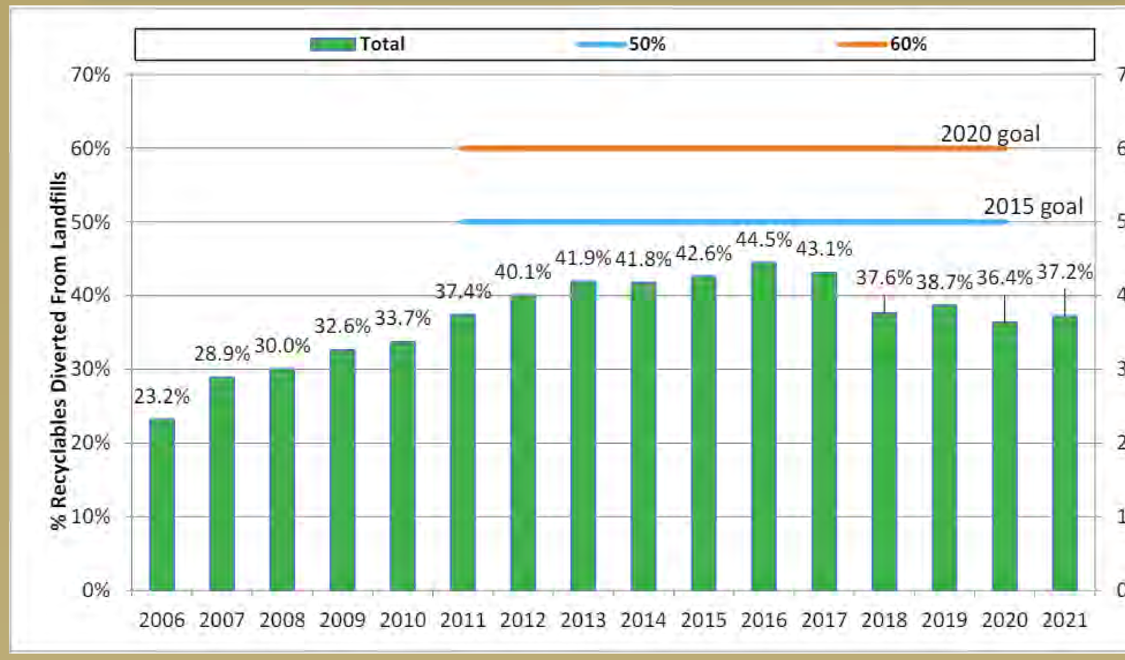
Curbside recycling program began on January 1, 2013.

Delaware's recycling rates changed from 30% in 2008 to 41% in 2014.

State Recycling Comparison

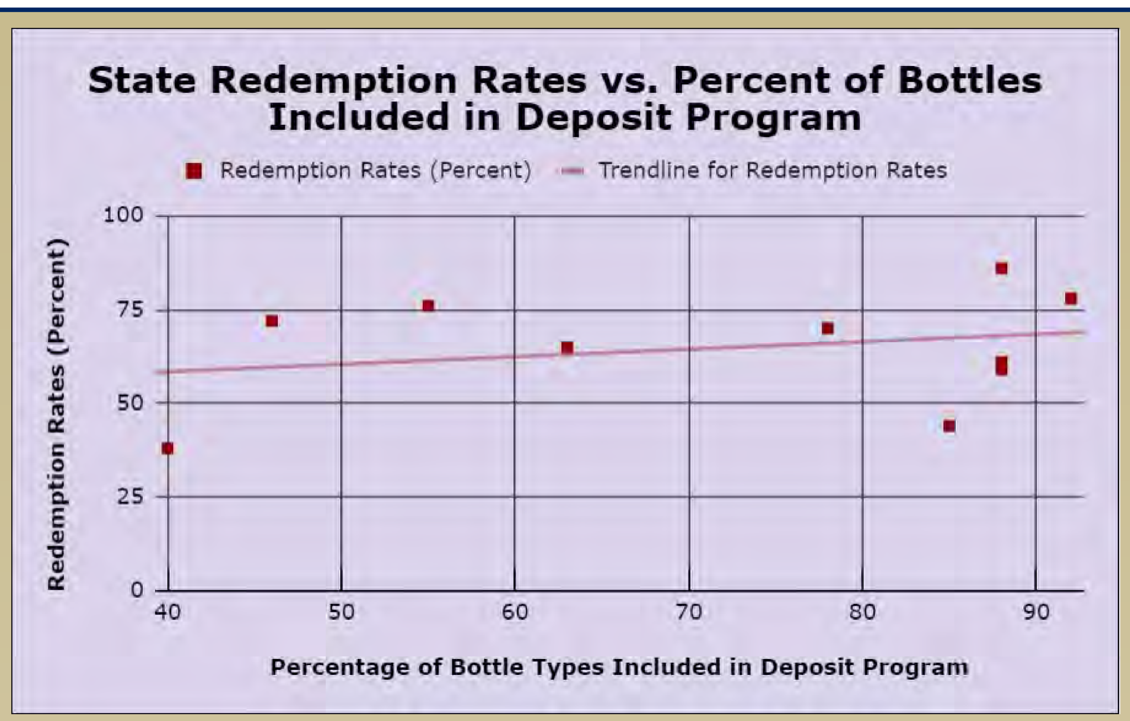
	Delaware	California	Connecticut	Hawaii	Iowa	Maine	Massachusetts	Michigan	New York	Oregon	Vermont	New Jersey
Bottle Bill Now?	NO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NO
Timeline for Bottle Bill	1979-2010	1986 -	1978 -	2002 -	1978 -	1976 -	1976 -	1976 -	1982 -	1971 -	1972 -	N/A
Deposit $ Amount	5 cents	5 and 10 cents	5 cents	5 cents	5 cents	5 and 15 cents	5 cents	10 cents	5 cents	2 and 10 cents	5 and 15 cents	N/A
Recycling Rate (without FFP)	26%	41%	39%	22%	45%	65%	48%	40%	44%	45%	51%	39%

Delaware Recycling Rates



Comparison to Peer States

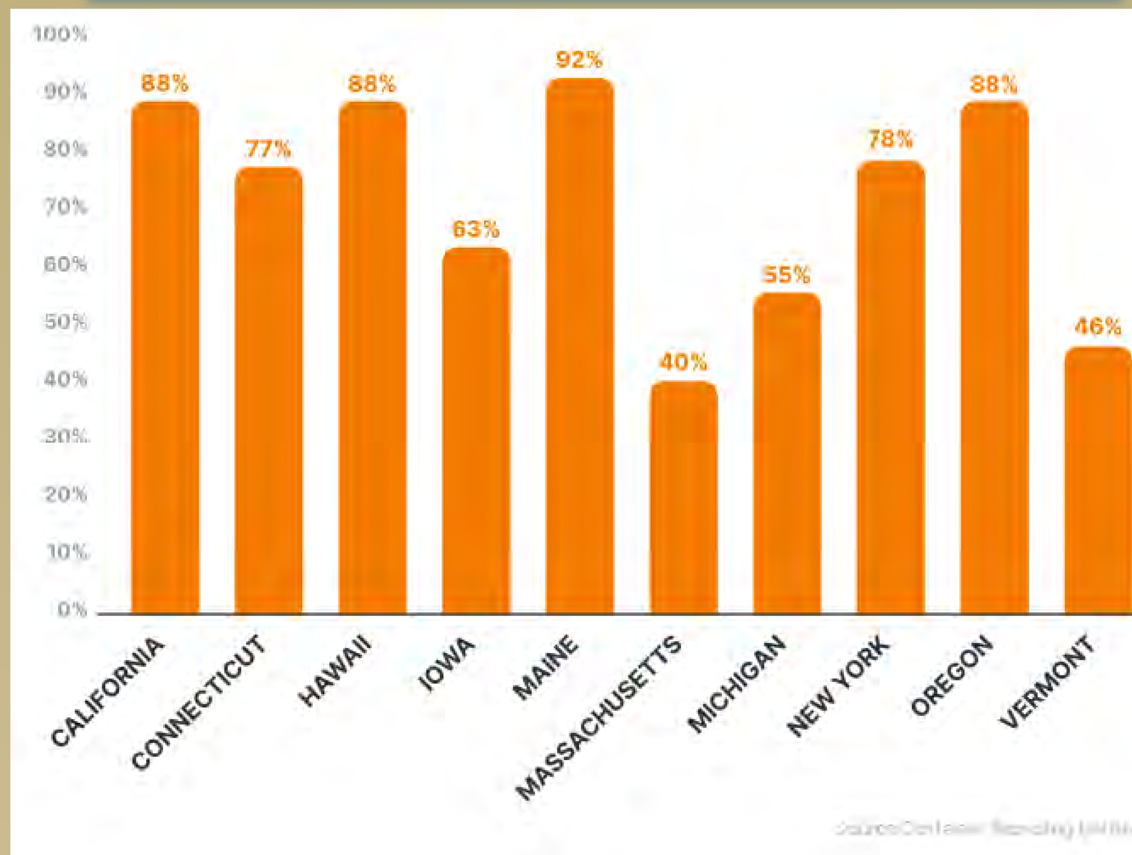
- States with bottle bills are more likely to have higher recycling rates than states without them.
- New Jersey tried implementing a Bottle Bill in 2016, 2018, and 2020 but never passed.
- Ways to enable high-performing recycling refund programs:
  - Include all beverage containers of all sizes and formats
  - Incentivize returns through a meaningful consumer refund
  - Policymakers should set a high return rate target with phased targets for new programs
  - Reinvest unredeemed deposits in the recycling system
  - Create convenient return points for consumers
- New Jersey (peer state without a Bottle Bill but with high recycling rates), and Connecticut (peer state with a Bottle Bill) are all states with a majority Democratic voter registration status and higher than the US average median income



Further Research

- This project will be continued throughout the Summer of 2024.
- After receiving IRB approval and approval through the University, I will be conducting interviews with key personnel including:
  - People involved in Delaware's recycling policies in the past and present.
  - People involved in recycling policy in peer states that have a Bottle Bill, such as Connecticut
  - People who work in recycling policy in peer states without a Bottle Bill, such as New Jersey
- Goal is to determine why Delaware's bottle bill was seen as unsuccessful in Delaware and evaluate Delaware's current recycling policies and whether it's bottle bill should be reintroduced.

Percent of Bottles Covered in Bottle Bill States



Resources

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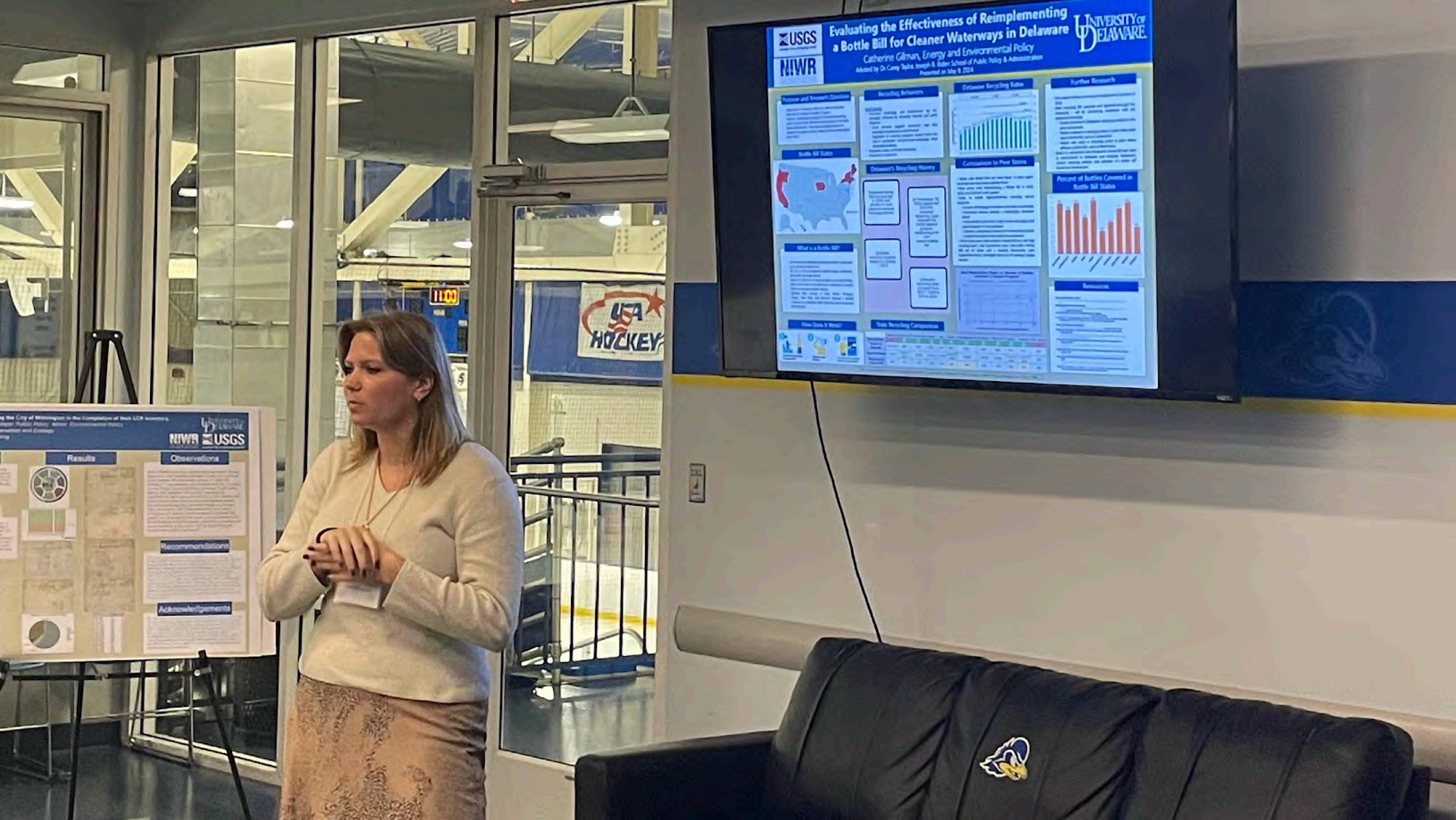
Thank you to the USGS for providing this project funding from the United States Department of Interior through the Water Resources Research Act of 1964 and 1984.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PFAS Assessment of Delaware Raw and Treated Drinking Water Supplies (May 9, 2024)

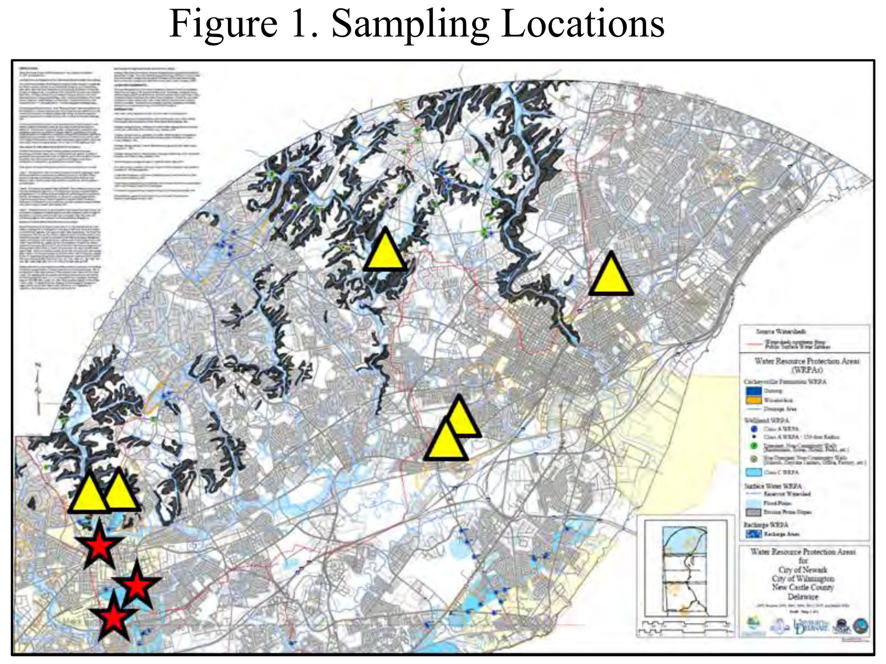
Megan Wassil – Graduate M.S. Water Science and Policy
Nicole Gutkowski – Undergraduate B.S. Honors Marine Science
Advisor: Dr. Gerald Kauffman

Purpose/Objective

- Analyze raw surface water from Red Clay Creek, White Clay Creek, and Brandywine Creek for Per- and Polyfluoroalkyl Substances (PFAS),
- Analyze treated tap water from Newark for PFAS
- Understand PFAS prevalence in Delaware drinking water sources

Methods

Figure 1. Sampling Locations



Legend:

△ : Surface Water Sites ★: Tap Water Sites

Raw Surface Water Sampling on March 7, 2024
- 1: WCN1 - White Clay Creek at Newark
- 2: WCS2 - White Clay Creek at Stanton extrapolated from Hale-Byrnes House
- 3: RCS3 - Red Clay Creek at Stanton
- 4: RCH4 - Red Clay Creek at Hoopes Reservoir
- 5: BCW5: Brandywine Creek in Wilmington
- 7: WCR7: White Clay Creek Newark Reservoir

Treated Tap Water Sampling on April 11, 2024
- 6: UDP6 - Pencader Dining Hall Tap
- 8: UDW8 - UD Water Resources Center
- 9: UDS9 - UD Star Tower

Water Sample Collection and Analysis
- Replicate 250 mL water samples
- Collection using EPA standard bottles
- Analyzed using US EPA method 1633 which includes measuring 40 PFAS compounds
- Compared returned data to current state and EPA standards

Results

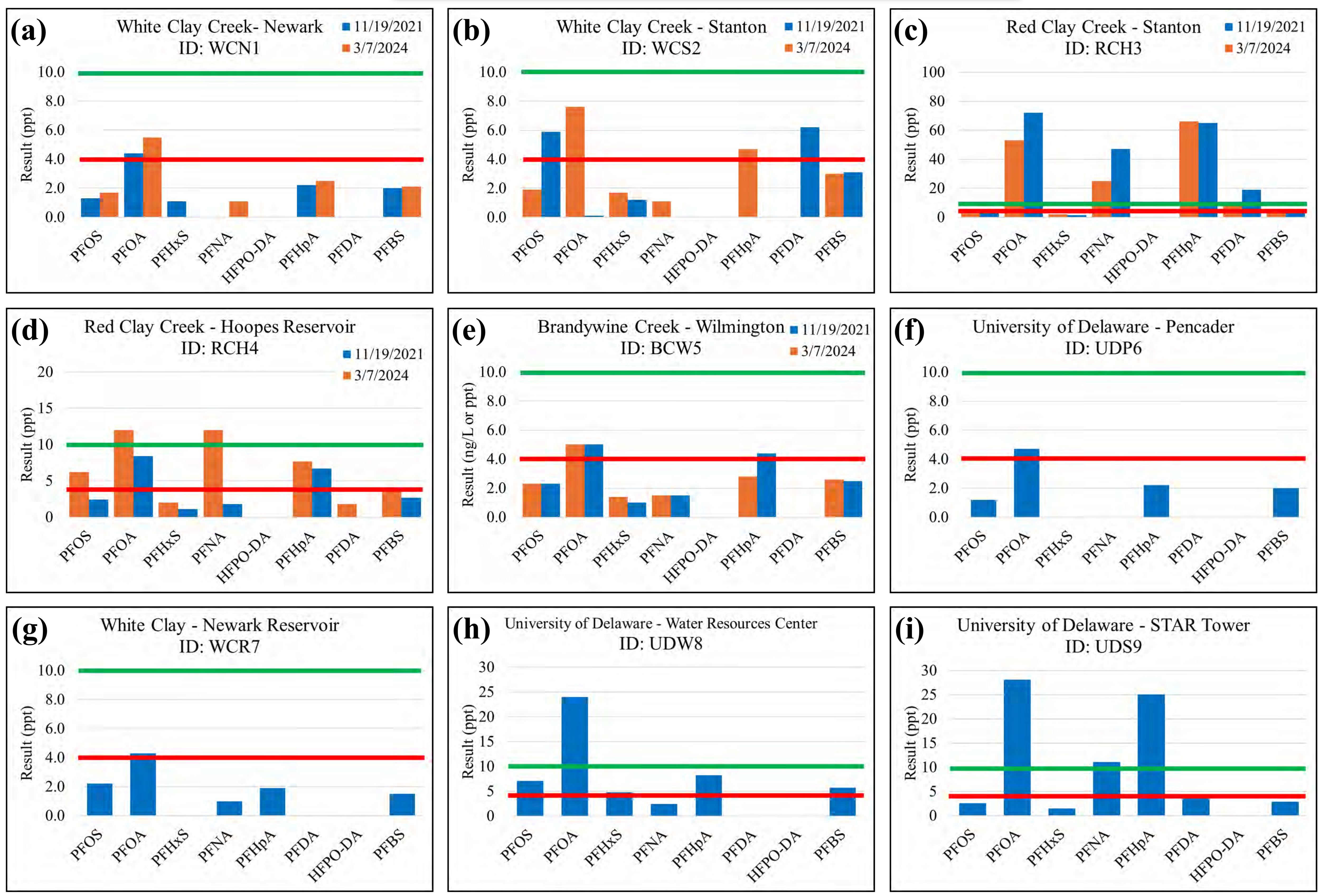


Figure 2 (a-i) Sample Site PFAS Levels:
- Compounds determined by EPA MCLs and state PFAS standards
- Green line (▬) indicates EPA MCL for PFHxS, PFNA, and HFPO-DA
- Red line (▬) indicates EPA MCL for PFOS and PFOA

Site	Date	MA	VT	DE	EPA HI
WCN1	11/19/2021	9.0	9.0	5.7	0.1
	3/7/2024	13.3	7.2	5.9	0.2
WCS2	11/19/2021	17.0	17.0	9.5	0.3
	3/7/2024	13.3	7.1	5.9	0.2
RCS3	11/19/2021	156.7	148.7	55.6	2.7
	3/7/2024	208.2	189.2	75.7	4.9
RCH4	2/18/2022	41.7	32.2	58.2	1.4
	3/7/2024	20.4	20.4	10.8	0.3
BCW5	11/19/2021	12.9	12.9	7.3	0.3
	3/7/2024	14.2	14.2	7.3	0.4
WCR7	4/11/2024	9.4	9.4	6.5	0.1

Figure 3: Total PFAS Levels in Raw Surface Water by State and Federal MCLs

Site	Date	MA	VT	DE	EPA HI
UDP6	4/11/2024	8.1	8.1	5.9	0.0
UDW8	4/11/2024	46.5	46.5	31.1	0.8
UDS9	4/11/2024	72.0	67.9	30.5	1.3

Figure 4: Total PFAS Levels in Treated Tap Water by State and Federal MCLs

PFAS	EPA	MA	VT	DE
	ppt	SUM	SUM	SUM
PFOS	4.0	PFOS	PFOS	PFOS
PFOA	4.0	PFOA	PFOA	PFOA
PFHxS	10.0*	PFHxS	PFHxS	
PFNA	10.0*	PFNA	PFNA	
HFPO-DA	10.0*			
PFBS	*			
PFHpA		PFHpA	PFHpA	
PFDA		PFDA		
SUM		**20**	**20**	**17**

Figure 5. State and Federal MCLs by Compound
- Asterisk indicates compound used in Hazard Index calculation
- Compounds summed for state standards are indicated in respective columns

$$Hazard\ Index = \frac{[HFPO-DA_{ppt}]}{[10\ ppt]} + \frac{[PFBS_{ppt}]}{[2000\ ppt]} + \frac{[PFNA_{ppt}]}{[10\ ppt]} + \frac{[PFHxS_{ppt}]}{[10\ ppt]}$$

Observations

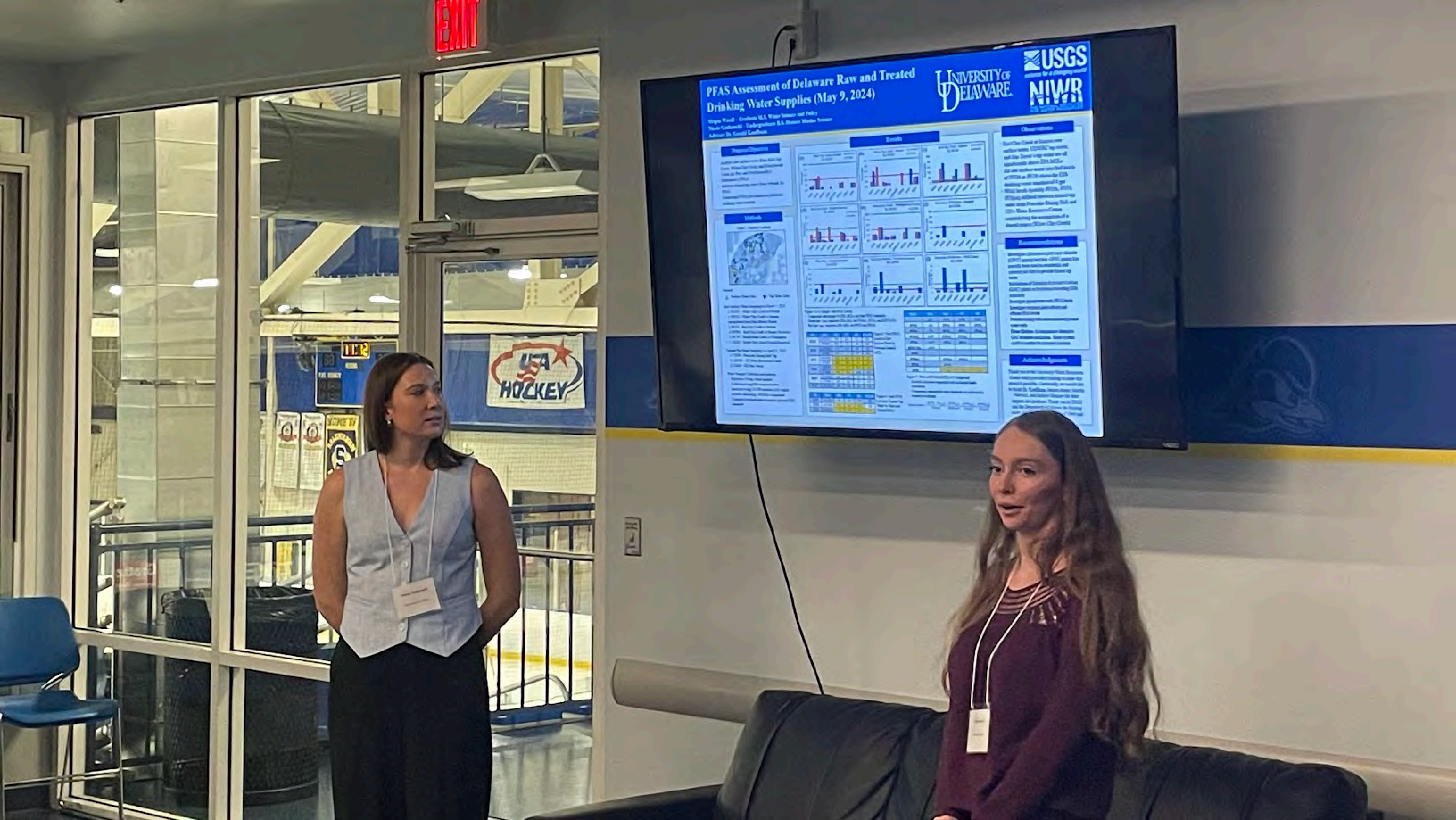
- Red Clay Creek at Stanton raw surface water, UDWRC tap water, and Star Tower's tap water are all significantly above EPA MCLs
- All raw surface water sites had levels of PFOA or PFOS above the EPA drinking water standard of 4 ppt
- PFAS levels (notably PFOA, PFOS, PFHpA) differed between treated tap water from Pencader Dining Hall and UD's Water Resources Center, contradicting the assumption of a shared source (White Clay Creek)

Recommendations

- Investigate chlorinated polyvinyl chloride (CPVC) piping leachate. CPVC piping has recently been used in residential and commercial sites to provide faucet tap water
- Installation of Granular Activated Carbon (GAC) plants in locations exceeding EPA standards
- Investigate groundwater wells PFAS levels
- Investigate treatment plant influent and effluent PFAS levels
- Potential mixing with uncontaminated ground-water wells
- Home filtration: An inexpensive alternative GAC treatment installation. Home systems could be installed for interested residents

Acknowledgments

Thank you to the University Water Resources Center which provided funding to make this research possible. Continually, we would like to thank Dr. Kauffman, Jessica Anton, Martha Narvaez, and Andrew Homsey for their support and guidance. Thank you to USGS and the Department of Interior for funding under the Water Resources Act of 1964 and 1984.


EXIT
PFAS Assessment of Delaware Raw and Treated Drinking Water Supplies (May 9, 2024)
UNIVERSITY OF DELAWARE
USGS
NIWR
Results
Methods
USA HOCKEY

Water Quality Trends in the Brandywine-Christina Watershed at the State Line in Delaware

Caroline Gilliard, Elizabeth Manning, Gerald Kauffman
College of Engineering – Civil and Environmental Engineering May 9, 2024

USGS science for a changing world

NIWR THE NATIONAL INSTITUTES FOR WATER RESOURCES

UNIVERSITY OF DELAWARE

Purpose

This study provides water quality parameters in four tributaries of the Brandywine-Christina Watershed over a 30-year period. Comparing these values to the water quality standards gives information regarding potential public health and ecosystem health concerns. It also gives information regarding what remediation may be needed to lower limits of a respective parameter.

Methods

Obtain data from the Water Quality Portal (WQP) for four monitoring stations within the Brandywine-Christina Watershed:

- Brandywine Creek at Smith Bridge (104051)
- Red Clay Creek at Barley Mill Road (103041)
- White Clay Creek at Chambers Rock Road (105031)
- Christina River at Cooches Bridge (106191)

Compile the following water quality parameters: dissolved oxygen (DO), enterococcus bacteria, total phosphorus, total suspended solids (TSS), and total nitrogen

- Organize the data set and graphically portray the temporal results of parameter fluxes at each testing location
- Analyze water quality trends and identify potential concerns if water quality standards are not met

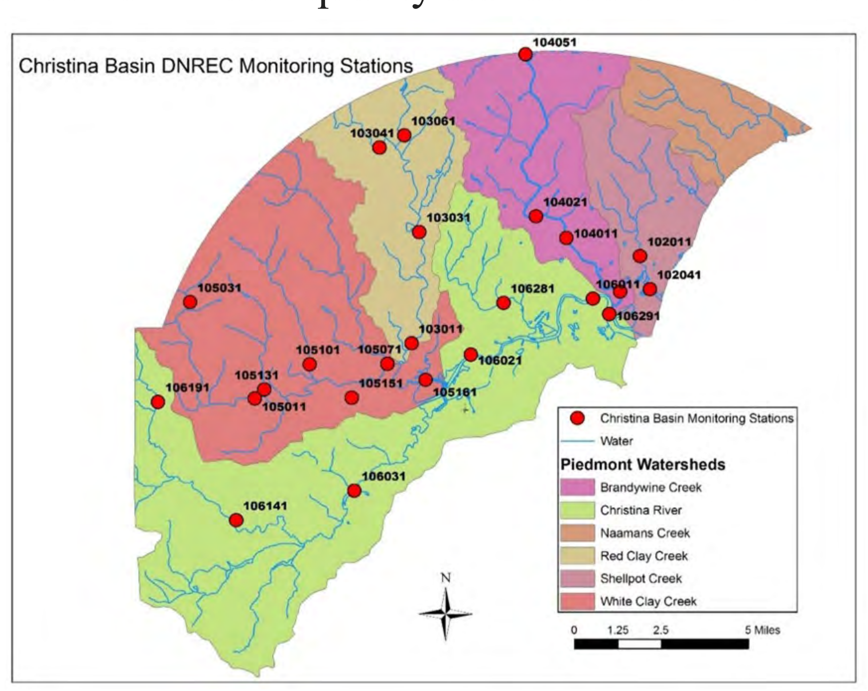


Figure 1. Christina Basin DNREC Monitoring Stations in New Castle County

Results

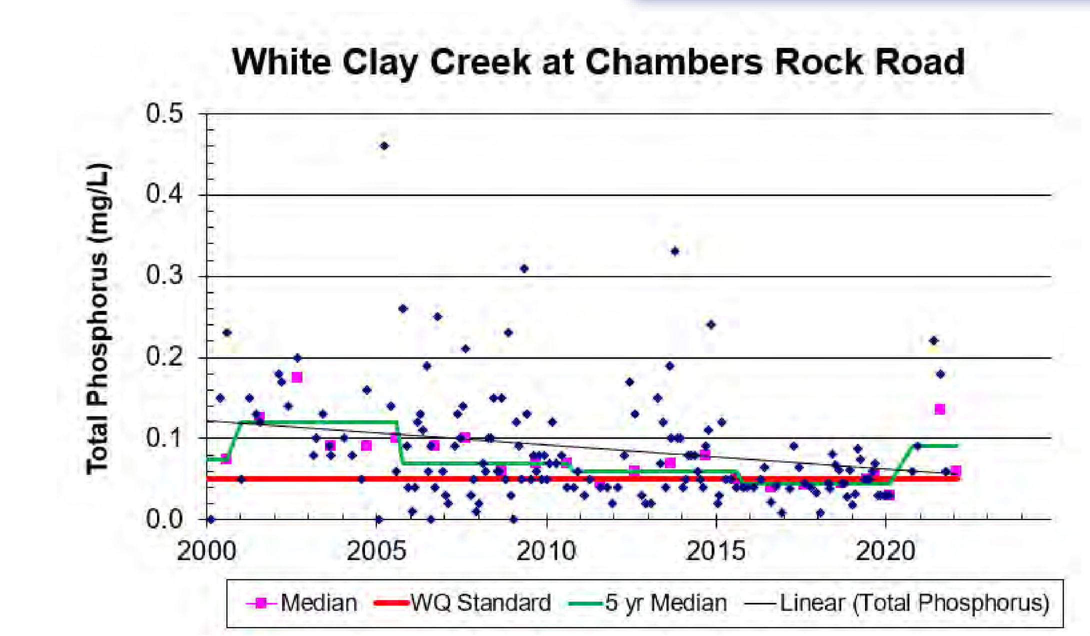


Figure 2. Total Phosphorus Levels in White Clay Creek at Chambers Rock Road Station

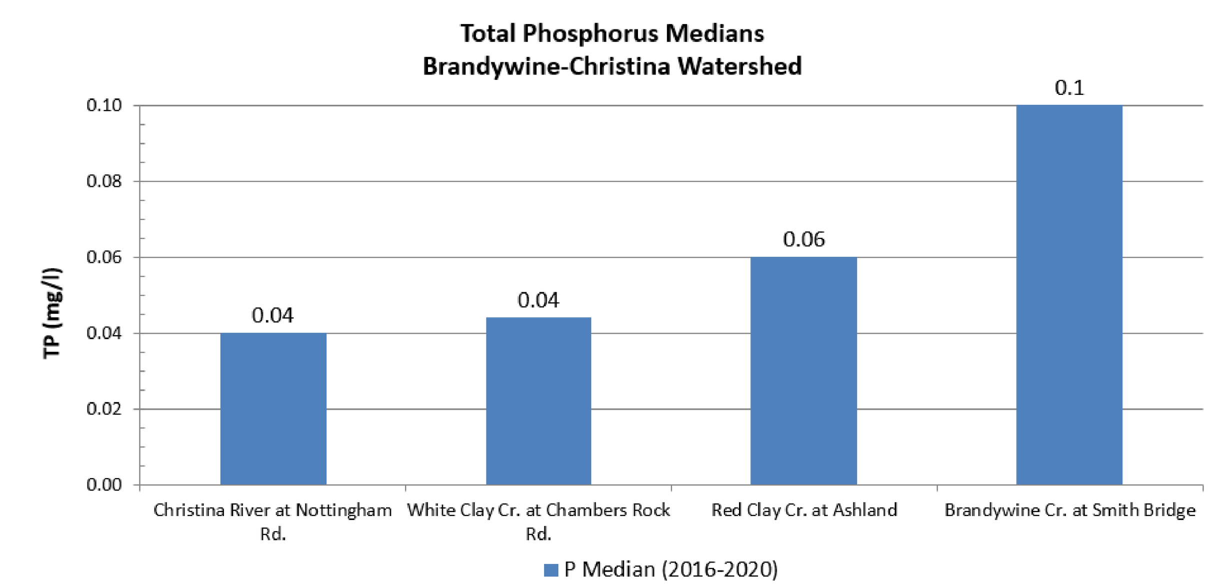


Figure 3. Total Phosphorus Medians in the Brandywine-Christina Watershed

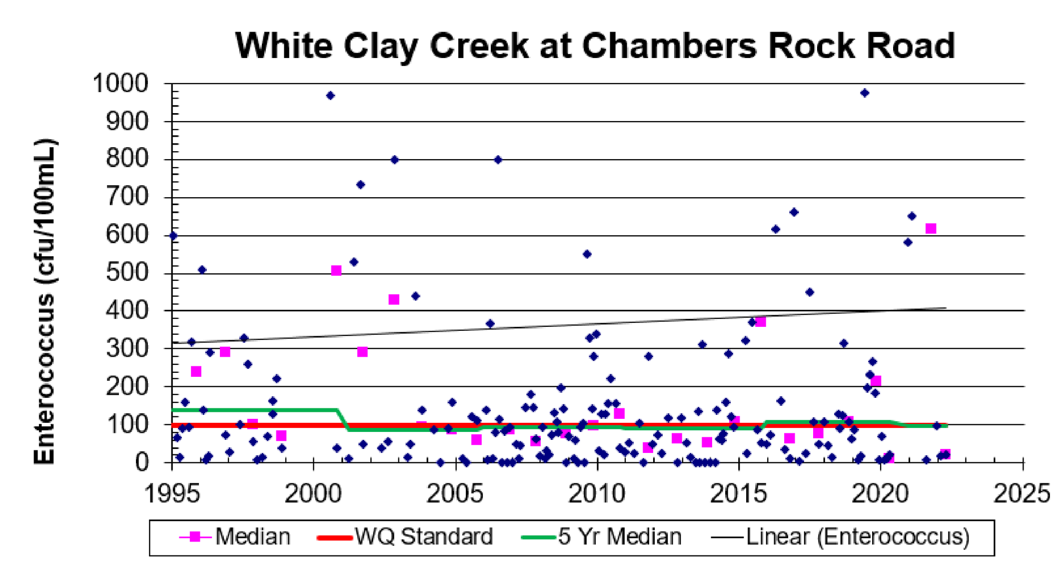


Figure 6. Enterococcus Bacteria Levels in White Clay Creek at Chambers Rock Road Station

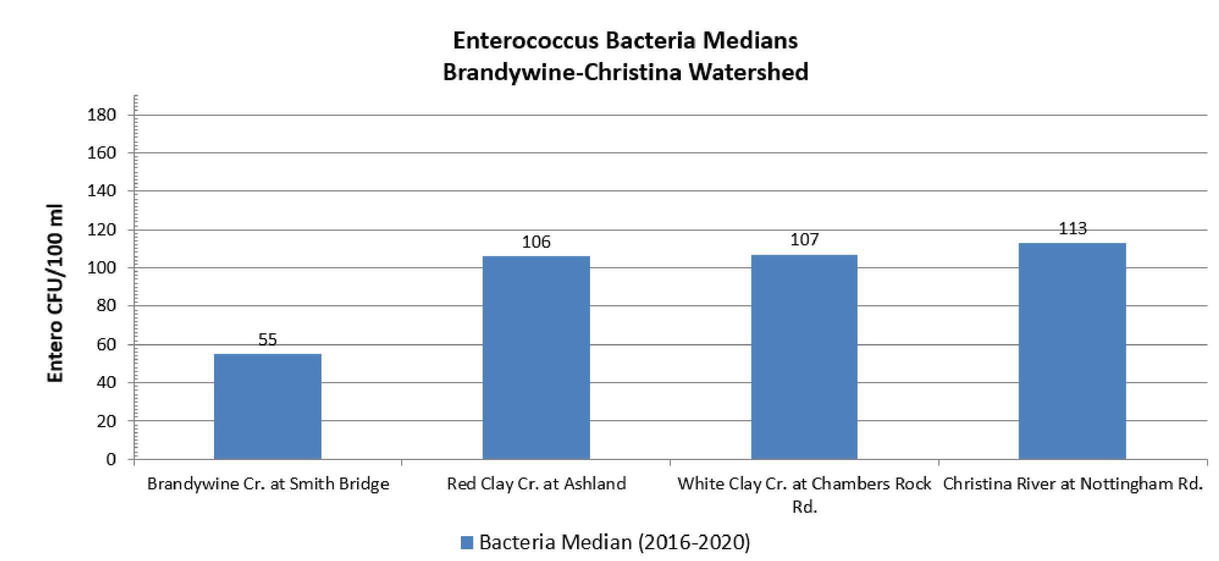


Figure 5. Enterococcus Bacteria Medians in the Brandywine-Christina Watershed

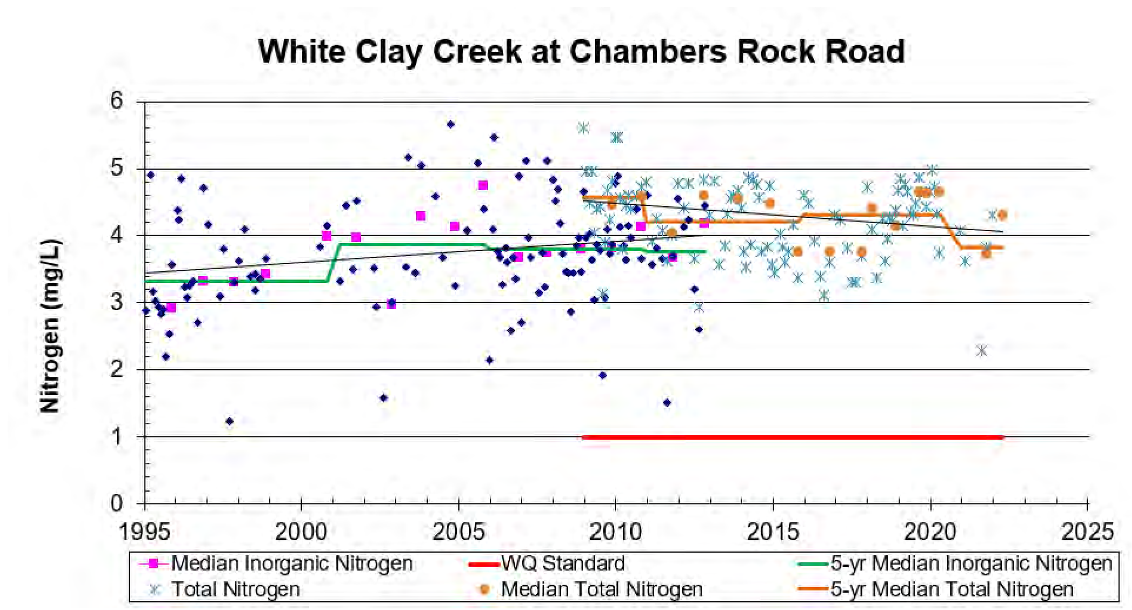


Figure 6. Total Nitrogen Levels in White Clay Creek at Chambers Rock Road Station

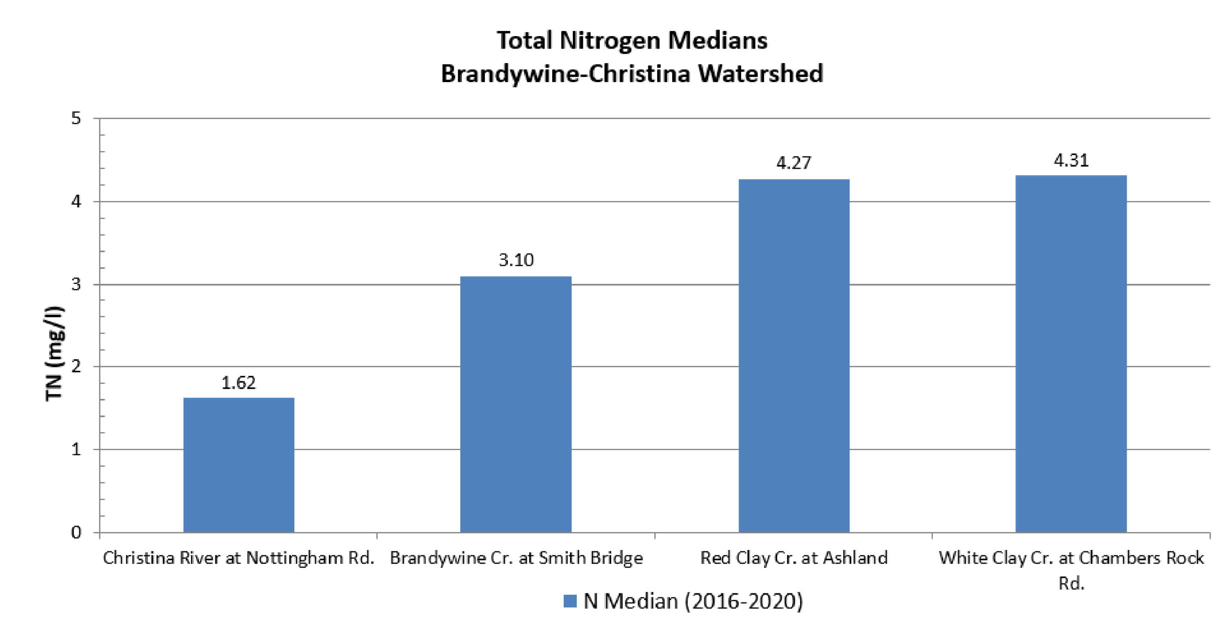


Figure 7. Total Nitrogen Medians in the Brandywine-Christina Watershed

Acknowledgements

This project was funded by USGS from the U.S. Department of Interior by the Water Resources Research Act of 1964 & 1984. Thank you to Gerald Kauffman, Martha Narvaez, and Andrew Homsey for their support and guidance throughout this project.

Discussion

Scatter plots display water quality parameter data from 1995 to 2023 in the White Clay Creek tributary at Chambers Rock Road. The results are as followed:

- The concentration of total phosphorus is steadily declining, though it was above the standard prior to 2015.
- The amount of Enterococcus bacteria is above the WQ standard but maintains a constant concentration over the past 30 years.
- Total Nitrogen in White Clay Creek is four times larger than the WQ standard, which is concerning for this watershed.

Bar graphs of Water Quality Parameters are median values from 2016-2020. The following observations were made:

- The Total Phosphorous levels in Red Clay Creek and the Brandywine Creek exceeded WQ Standard levels of 50 ppb with 60 and 100 ppb, respectively.
- Levels of enterococcus were slightly above the WQ standard of 100 cfu/ 100ml in three out of the four tributaries.
- The standard for Total Nitrogen is 1 ppm. However, all four tributaries exceed this level, with White Clay, Christina River, Red Clay, and Brandywine Creek containing values of 1.62, 3.10, 4.27, and 4.31 ppm, respectively.

Parameters in the Brandywine-Christina Watershed are often above the WQ standard, which is concerning for ecosystem health and public recreation. This watershed supplies drinking water plants, which should continue to monitor these levels, as they exceed recommended values.

Future Research

Compiling of water quality data should continue as time progresses to ensure that all standards are being met. In addition, more stations could be selected in the surrounding region to identify spatial differences in parameter values. Remediation and further monitoring of these waterways may be necessary, as high Total Nitrogen levels from agriculture exceeded WQ standards and are a cause for concern.


USA
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Methods
Future Research

Comparing the Efficacy of Floating Wetland (*Pontederia cordata*) and Submerged Wetland (*Sagittaria subulata*) Treatments for Excess Nitrogen and Phosphorus Removal from Aquaculture Water

Summer Moals, Grant Blank, Mingxin Guo, Ph.D., Dennis McIntosh, Ph.D., and Gulnihal Ozbay, Ph.D.*

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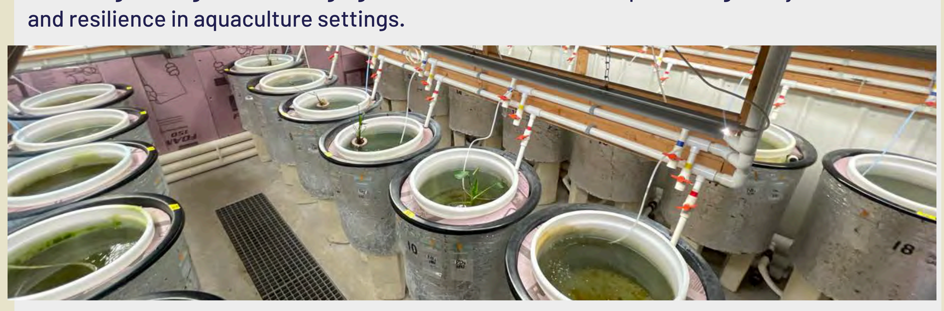
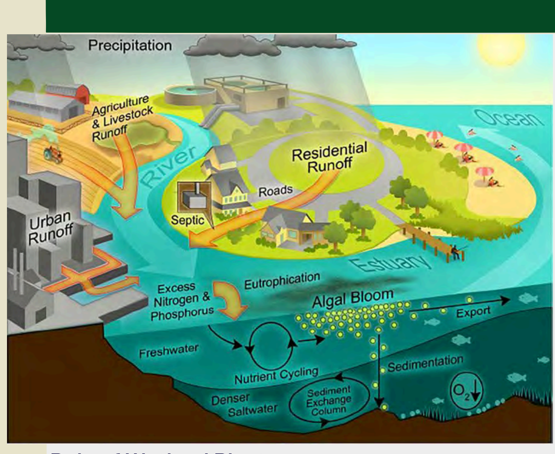
Abstract

Aquaculture, crucial for sustainable food sources, faces challenges with nutrient pollution. The effectiveness of wetland plant treatments, including floating (Pontederia cordata) and submerged (Sagittaria subulata), in removing excess nitrogen and phosphorus from aquaculture water is explored in this study. Methodologically, five key approaches were employed: (1) setting up wetland treatment systems, (2) quantifying nutrient concentrations, (3) installing plants and determining biomass, and (4-5) testing physical and chemical parameters, to comprehensively assess the impact of wetland plant treatments on aquaculture water quality. Stable temperature and dissolved oxygen levels were observed, with Dwarf Sagittaria showing higher oxygen levels. Increased salinity was attributed to dissolved salts from fertilizers, and varied nitrate and phosphate uptake abilities were noted. Biomass analysis revealed higher initial biomass in Pickerelweed but greater variability in final biomass, while Dwarf Sagittaria treatments consistently exhibited increased final biomass, suggesting consistent growth. The absence of plants exacerbated nutrient fluctuations, highlighting the importance of understanding plant-algae-microorganism interactions for effective aquatic ecosystem management. Understanding these interactions is crucial for effective aquatic ecosystem management, informing strategies for managing nutrient fluctuations, and promoting ecosystem health and resilience in aquaculture settings.



Introduction



Aquaculture:
- Controlled cultivation of aquatic organisms for food.
- Vital for global food security and economic development.

Challenges with Nutrient Pollution:
- Excess nutrients from fish feed, excretion, and waste.
- Leads to algal blooms, oxygen depletion, and habitat degradation.

Eutrophication (Figure to the Left):
- Human activities aggravate natural processes.
- Enrichment of aquatic environments with nutrients.
- Results in algal blooms, reduced water clarity, and oxygen depletion.

Role of Wetland Plants:
- Absorb nitrogen and phosphorus, contributing to water purification.
- Improve water clarity, stabilize sediments, and enhance habitat.

Objective:
- Investigate the efficacy of wetland plant treatments in enhancing water quality in aquaculture.

Timeline:
- Data collection over 12 weeks.
- Continuous monitoring includes baseline testing, nutrient addition, and plant introduction, with ongoing tracking of nutrient uptake throughout the research.

Objective

The study aims to investigate how wetland plant treatments can enhance water quality and sustainability in aquaculture operations.

Legend

- HN: High Nutrient Concentration
- LN: Low Nutrient Concentration
- PW: Pickerelweed (*Pontederia cordata*)
- DS: Dwarf Sagittaria (*Sagittaria subulata*)
- DO: Dissolved Oxygen

Methods

(1) Setting Up Wetland Treatment Systems at DSU Aquaculture Facility

(2) Quantification of Nutrient Concentration (Phosphate, Nitrogen, and Potassium) for Each Treatment

$$\frac{\text{Desired Concentration (mg/L) x Volume in Tank (L)}}{\text{Fertilizer Percentage \%}} = \text{Nutrient Concentration}$$

Nutrient	Level	Desired Conc. (mg/L)	Volume in Tank (L)	Fertilizer Percentage %	Final Nutrient Concentration (g)
Phosphate	Low	0.03	48.65	11	0.013
Phosphate	High	0.15	48.65	11	0.664
Potassium	Normal	10	48.65	22	2.120
Nitrate	Low	1	48.65	20	0.243
Nitrate	High	5	48.65	20	1.220

Fig. 1 NPK Water Soluble Fertilizer Concentrations (Added to Tanks (1-18) During Week 2

(3) Plant Installation and Biomass Determination

(4) Physical Parameter Testing (YSI Multiparameter Meter)

(5) Chemical Parameter Testing (Photometer)

Scan for Full Presentation

Results

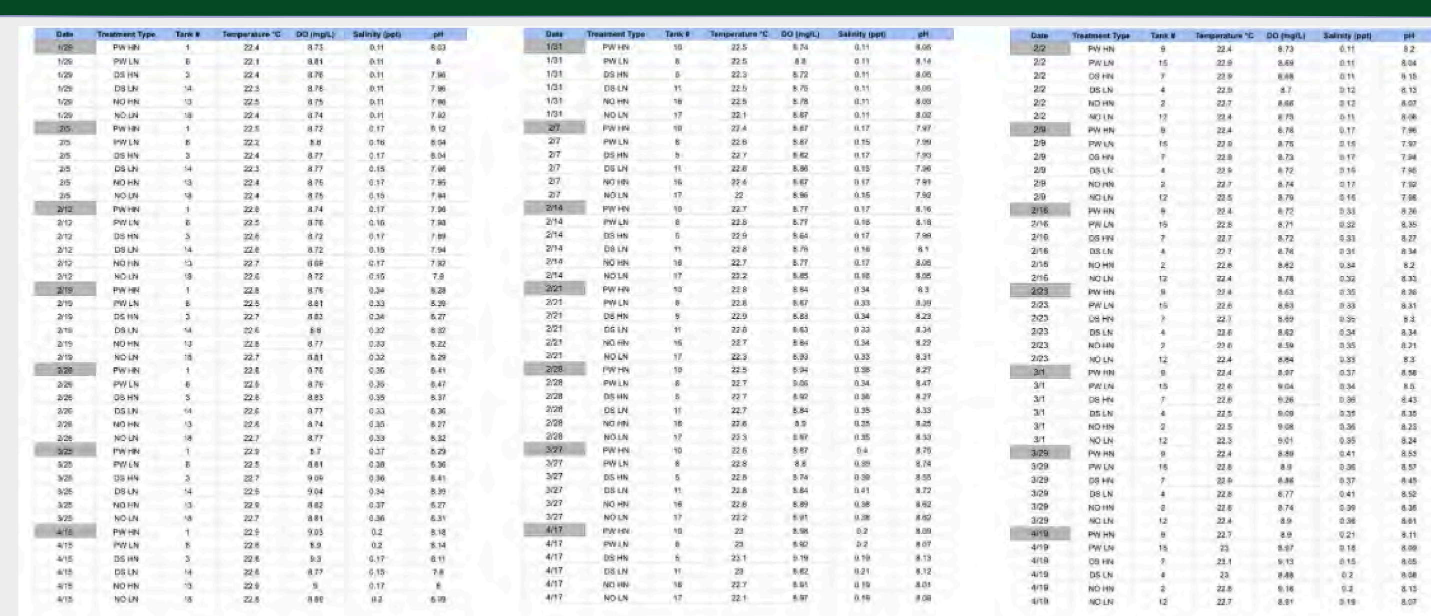


Fig. 2 Weekly Variation in Tank 1-18 Physical Parameters (Temperature °C, Dissolved Oxygen, Salinity, pH) for Monday, Wednesday, and Friday Groups Over 12 Weeks

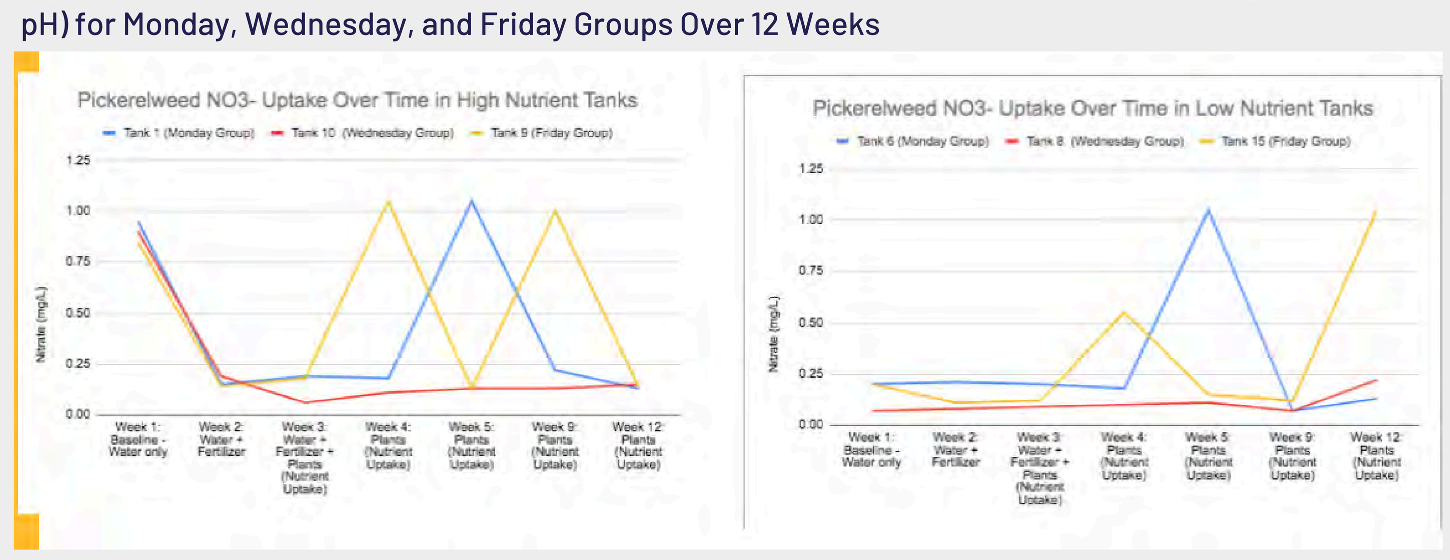


Fig. 3-4 Pickerelweed Nitrate Uptake Over 12 Weeks in High vs. Low Nutrient Tanks

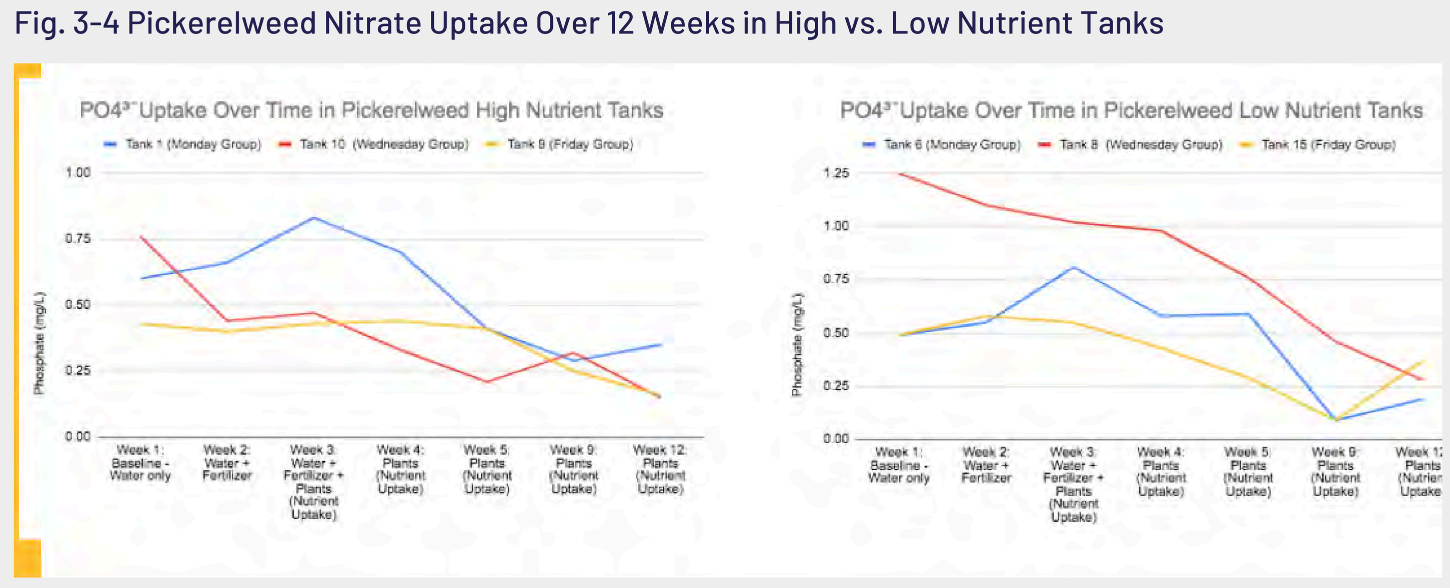


Fig. 5-6 Pickerelweed Phosphate Uptake Over 12 Weeks in High vs. Low Nutrient Tanks

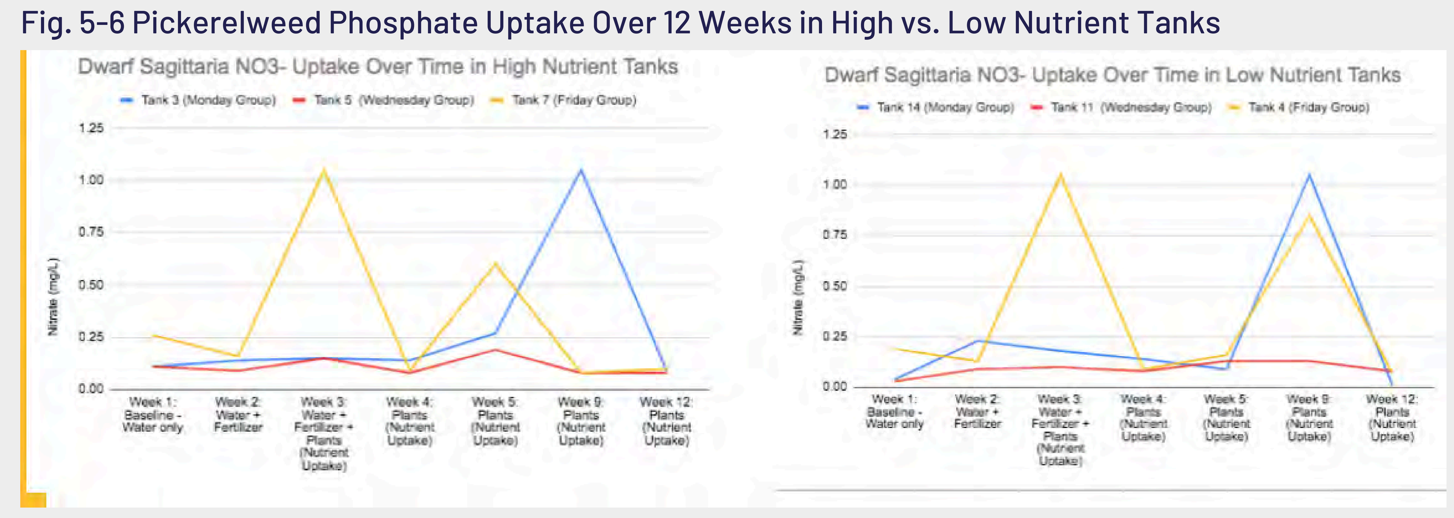


Fig. 7-8 Dwarf sagittaria Nitrate Uptake Over 12 Weeks in High vs. Low Nutrient Tanks

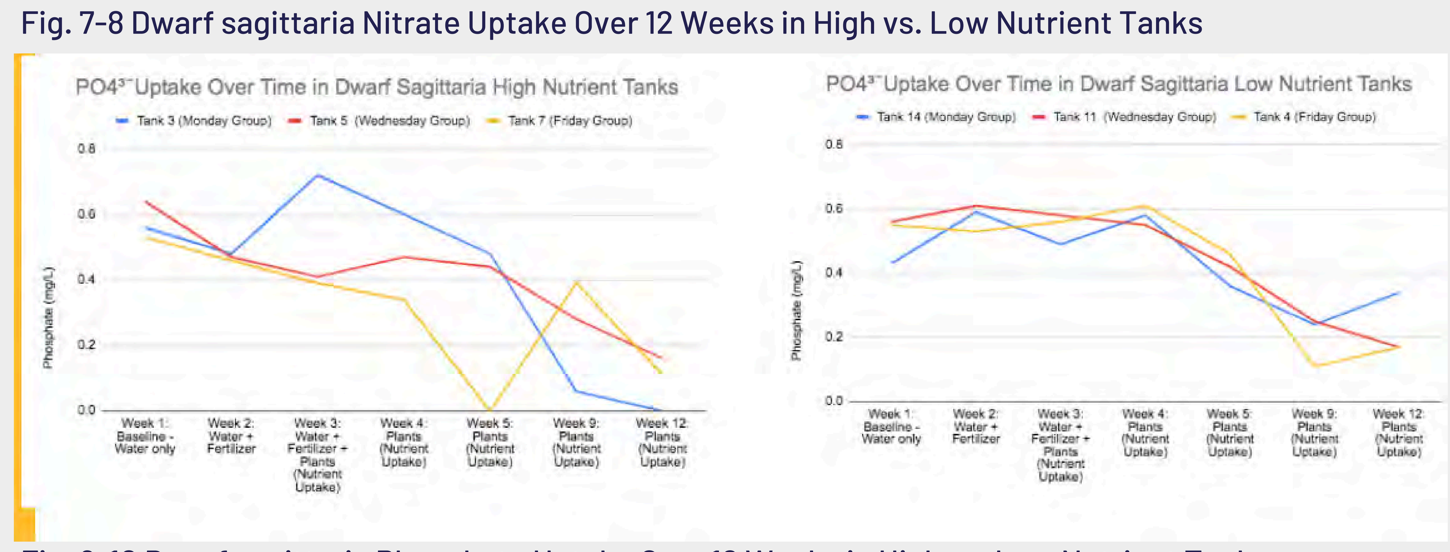


Fig. 9-10 Dwarf sagittaria Phosphate Uptake Over 12 Weeks in High vs. Low Nutrient Tanks

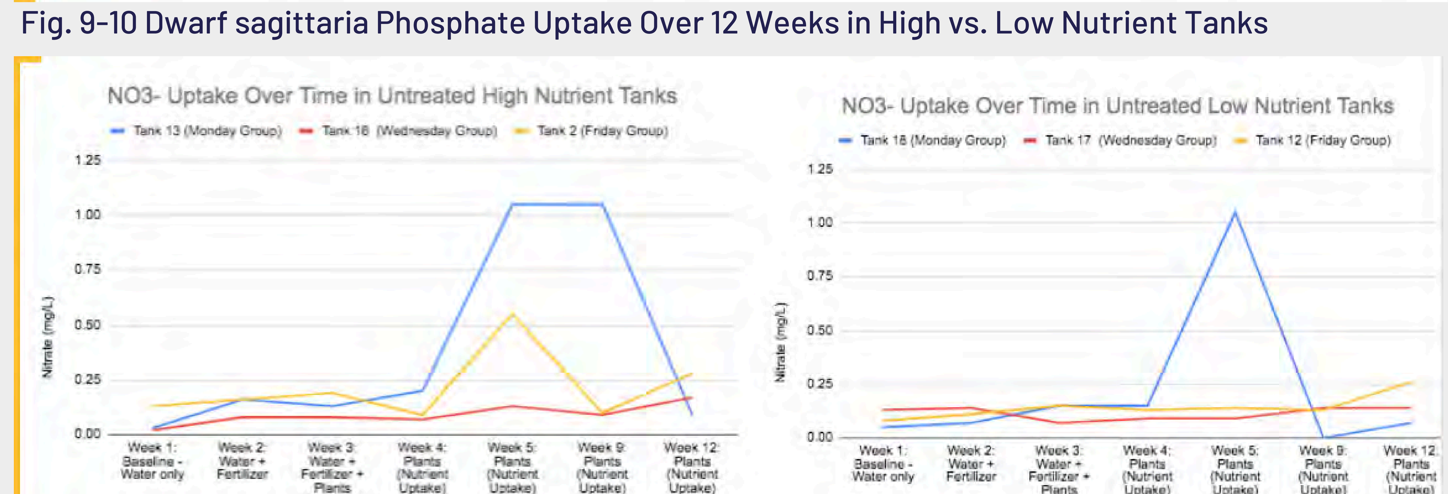


Fig. 10-11 Nitrate Uptake in Untreated Tanks Over 12 Weeks: High vs. Low Nutrient Levels

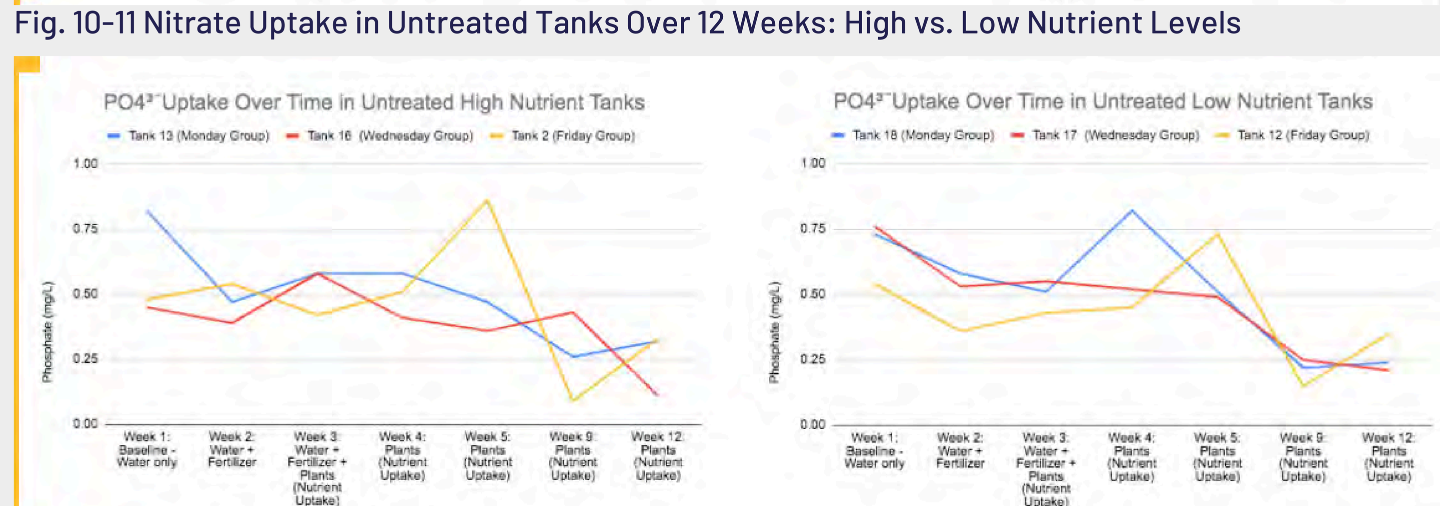


Fig. 12-13 Phosphate Uptake in Untreated Tanks Over 12 Weeks: High vs. Low Nutrient Levels

Results Cont.

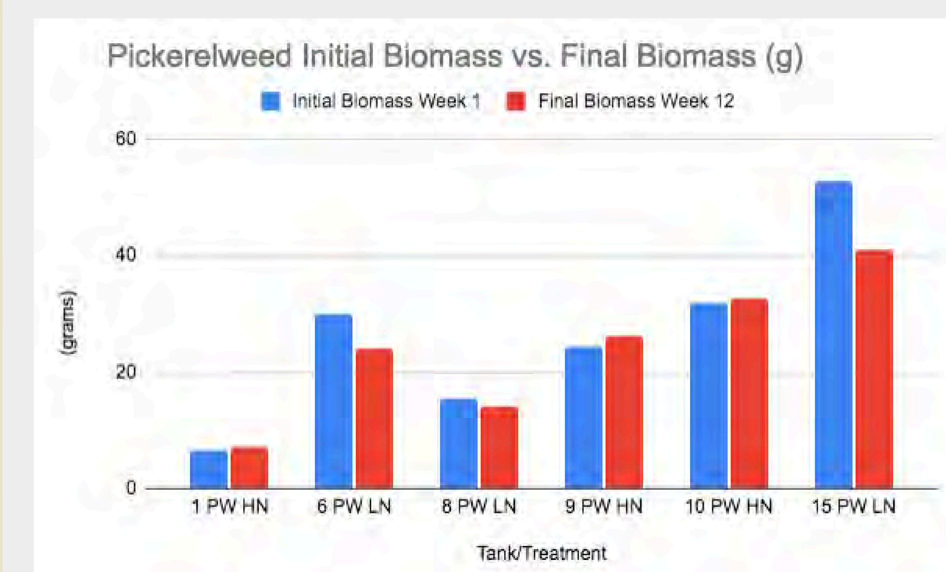


Fig. 14 Pickerelweed Initial Biomass (Week 1) vs. Final Biomass (Week 12)

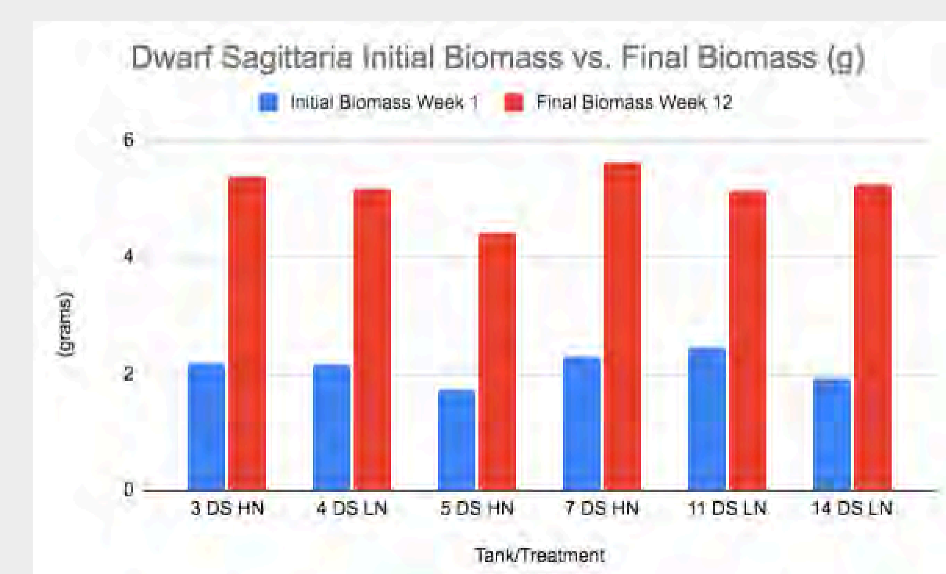
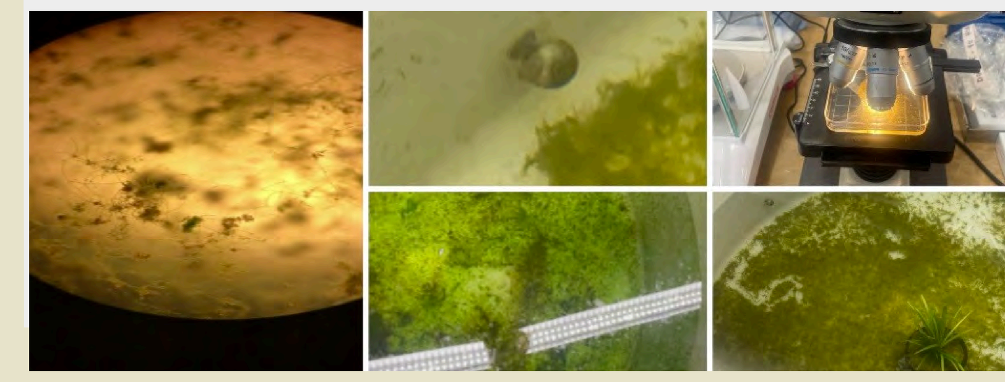


Fig. 15 Dwarf Sagittaria Initial Biomass (Week 1) vs. Final Biomass (Week 12)

Conclusion

- **Algae and Microorganisms Influence Nutrient Fluctuations:**
  - Abundant hair-like green algae and microorganisms like nematodes and flagella-like organisms were observed.
  - Algae rapidly uptake nitrogen and phosphorus for growth, affecting nutrient levels.
  - Microorganisms participate in nutrient cycling by decomposing organic matter.
- **Impact of Absent Plants:**
  - Absence of plants in NO Treatment tanks exacerbated effects of excess algae and microorganisms.
  - Plants regulate nutrient uptake unlike algae and microorganisms.
  - Unregulated microbial activity can lead to fluctuating nutrient dynamics.
- **Understanding Interactions for Management:**
  - Understanding interactions between algae, microorganisms, and nutrients is vital for effective aquatic ecosystem management.
  - Thorough studies are essential to investigate these interactions fully.
  - The insights gained from such studies can guide the development of strategies to manage nutrient fluctuations effectively and maintain the health of the ecosystem.



Conclusion Cont.

1. **Treatment Efficacy Variation:**
   - Different treatments showed varying efficacy in nutrient absorption and biomass dynamics.
2. **Plant Performance:**
   - Pickerelweed excelled in nitrate absorption in high-nutrient environments, while Dwarf Sagittaria showed robust nitrate uptake in such conditions.
   - Pickerelweed demonstrated notable phosphate absorption in low-nutrient conditions, whereas Dwarf Sagittaria showed effective phosphate absorption in similar conditions.
3. **Biomass Dynamics:**
   - Initial biomass was higher in Pickerelweed, but final biomass variability was pronounced, possibly due to prioritized leaf and stem development over root growth.
   - All Dwarf Sagittaria treatments showed increased final biomass, indicating consistent growth.
4. **Nutrient Cycling and Management:**
   - Excess algae and microorganisms influenced nutrient cycling in all treatments.
   - Understanding these interactions is crucial for effective aquatic ecosystem management, emphasizing the need for strategies to manage nutrient fluctuations and promote ecosystem health and resilience

Acknowledgements

I extend my sincere gratitude to my mentors, Grant Blank, Dr. Mingxin Guo, and Dr. Dennis McIntosh, for their invaluable support and guidance throughout this project. Additionally, I would like to express my appreciation to my project advisor, Dr. Gulnihal Ozbay, and the University of Delaware, as well as the Delaware Water Resources Center, for providing me with the opportunity to engage in this enriching experience and for their unwavering support. I want to acknowledge UD, DWRC, and Delaware EPSCoR for their generous funding, which made this project possible.

Consolidation of Delaware's Tier 1 Insects of Greatest Conservation Need and Associations with Non-Tidal Freshwater Wetlands

May 9, 2024

USGS science for a changing world

NIWR THE NATIONAL INSTITUTES FOR WATER RESOURCES

DSU College of Agriculture, Science and Technology

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Christopher M. Heckscher, Ph.D.
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Abstract

Using the Delaware Wildlife Action Plan as the primary guide, a dataset of Delaware's non-tidal wetlands and their associated Tier 1 insect species was developed. The dataset was used to create an online searchable database for easy viewing of species-habitat associations, as well as sources for each species confirming those associations. Non-tidal wetland ranges and species associations were mapped using the Northeastern Terrestrial Wildlife Habitat Classification System, but was not fully completed due to limited data.

Introduction

While state lists of rare Arthropods and associated habitats have been previously developed, there has been no previous effort to consolidate non-tidal wetlands and their species associations. While the majority of this information is contained in the Delaware Wildlife Action Plan (DWAP), it is outdated and scattered within the several hundred-page document. The goal of the project was to develop a publicly available dataset, searchable database, and mapping of non-tidal wetlands with species specific layers.

Methods

Database Development

- Non-tidal wetlands and associated Tier 1 (T1) insect species were sourced from the DWAP (DNREC 2015) for review
- Documentation for each species associating them with their habitats was sourced for citation
- Peer reviewed sources were taken primarily from publicly available resources (Google Scholar, ResearchGate, etc.) to minimize the usage of private or obscure articles
- DWAP Tier, Group, Subgroup, Scientific Name, Common Name, Primary Wetland and Supplemental Wetland Associations, and Associated Literature was collected in a spreadsheet
- Database was developed using the datatable package in RStudio and was published online using RPubs

ArcGIS Mapping

- Using ArcGIS, habitats were mapped using the Northeastern Terrestrial Wildlife Habitat Classification System (NETWHCS) (Fig. 1) Raster Dataset (Gawler 2008) as a framework
- Habitat codes for non-tidal wetlands were sourced from the DWAP which were used to isolate individual wetland types
- The isolated non-tidal wetland layers were then recombined to create individual layers for previously identified T1 species

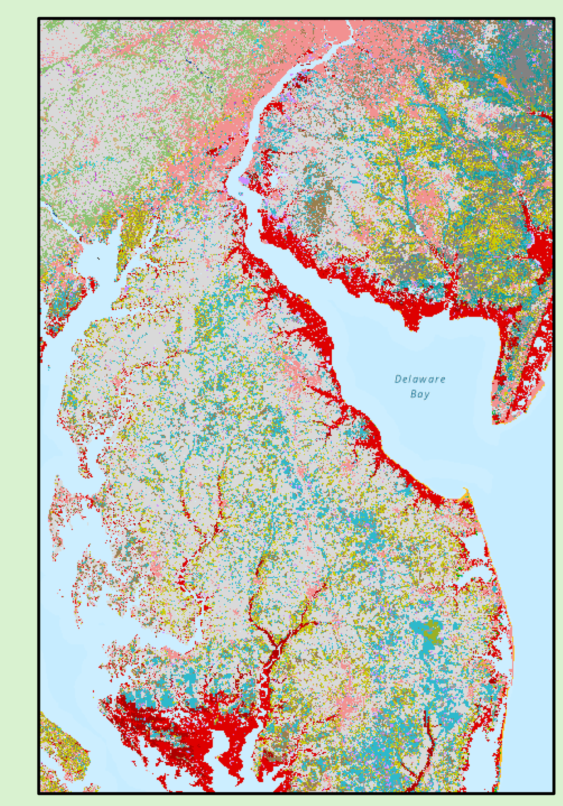

Figure 1. Image of habitats in Delaware and the surrounding area as determined by the NETWHCS

Results

- Searchable database was published on RPubs (Fig. 2) using the following link https://rpubs.com/polvozinho/t1dwap
- 15 Non-Tidal Wetlands with a collective 32 associated T1 insect species were identified (Fig. 3)
- Links to the completed project files were included in the description and comments of the RPubs page or at https://github.com/polvozinho/T1DWAP_ProjectFiles

Figure 2. QR Code linking to the developed RPubs database

Scientific Name	Cypress	CPFlt	CPPnd	CPFen	CPSwp	CPFld	CPCdr	EFM	FSS	IW	VP	SLF	PDMdw	PDSwp	PDFld
H. planatus			P								S				
H. spangleri			S								P				
P. mysticalampas					S	S	P								
P. bethaniensis										P					
B. fontana				S	S		S						S	S	
E. phaeton													P		S
E. conspicua													P		S
E. dion			S			S		S					S		S
P. m.chermocki				P	P	P									
P. m. massasoit													P	P	S
A. halesus					S	S	P		P						
C. hesseli							P								
S. kingi	P														
E. fax				P	S		S								
P. appassionata				P	P										
P. speciosissima					S	S		S	S	P					
P. nelita					S				S					S	
C. marmorata		S	P												
I. pergracilis	P														
O. detrita	S				S	S			S						
A. tuberculifera			S		S		S						P	S	
A. bipunctulata				P			S					P			
C. bilineata						S								P	P
C. erronea														P	P
E. dubium		P						P							
E. pallidum						S		S							
E. spinosa	P	S	S												
G. antilope	S	S					S								
L. eurinus			S												
N. bella				S								P			
R. mutata															
S.provocans		S				S									

Figure 3. Chart of Primary and Supplemental species-wetland associations

- 7/15 habitats were successfully mapped without complication using the NETWHCS
- 2/15 habitats were partially mapped due to discrepancies between the NETWHCS and the DWAP (Fig. 4)
- 2/15 habitats were not able to mapped due to lack of data in the NETWHCS
- 4/15 habitats were not able to be mapped with public data due to obscurity and rarity
- Species layers were constructed when substantial data was available

Conclusions

- All non-tidal wetland associated Tier 1 insects according to the DWAP were catalogued with sources confirming habitat association
- Mapping species-wetland associations in ArcGIS was partially successful within the timeframe
- Both the database and project files will be updated in the future, starting with complete habitat mapping, then Tier 2 and 3 associated insects

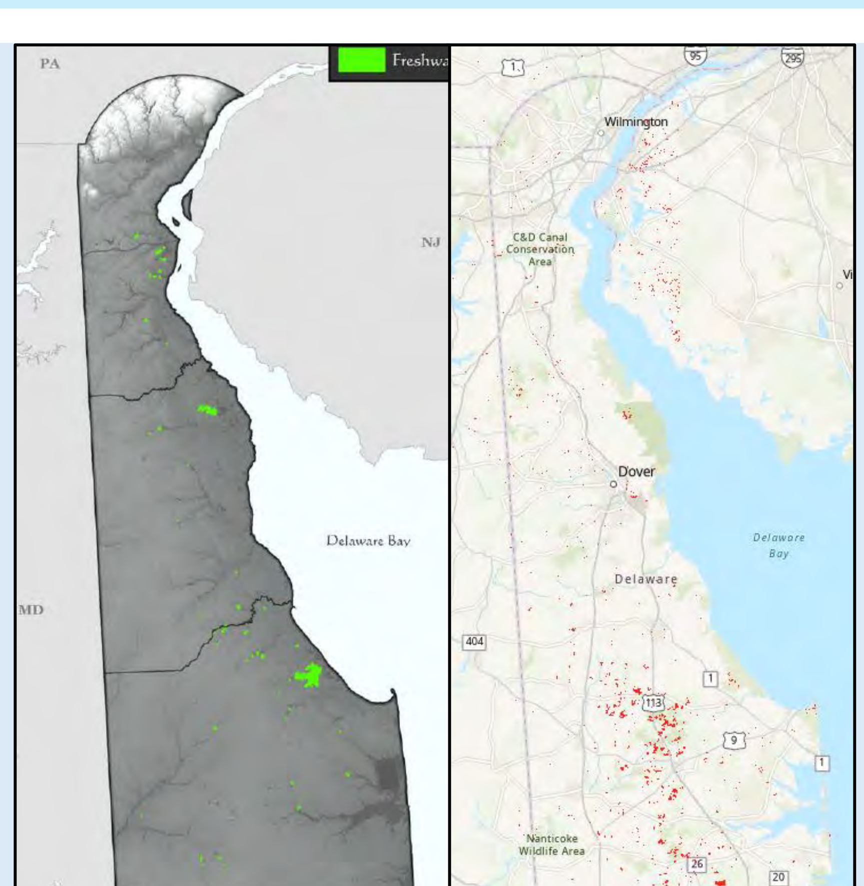

Figure 4. The differences in Freshwater Shrub Swamp habitat range between the DWAP (left) and the NETWHCS (right)

Citations

Delaware Department of Natural Resources and Environmental Control. 2015. 2015-2025 Delaware Wildlife Action Plan. Dover, Delaware, USA.

Gawler, S. C. 2008. Northeastern Terrestrial Wildlife Habitat Classification. Report to the Virginia Department of Game and Inland Fisheries on behalf of the Northeast Association of Fish and Wildlife Agencies and the National Fish and Wildlife Foundation. NatureServe, Boston, Massachusetts. 102 pp.

ACKOWLEDGEMENTS
Thank you to the USGS for making this project possible by way of funding from the US Department of Interior's Water Resources Acts of 1964 and 1984.

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Produced Water Remediation Through Advanced Evaporative Treatment Technologies

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Graduate Researcher : Jason Geiger (jkgeiger@udel.edu)
Overseeing Professor: Dr. Paul Imhoff (imhoff@udel.edu)

1. Abstract

The goal of my work is to find affordable techniques to remove contaminants from soils surrounding fracking sites, as well as clean up agricultural soils affected by high levels of salinity. Throughout my time in Dr.Imhoff's laboratory, working alongside graduate researcher Jason Geiger, the results of our many iterations of synthetically contaminated soil experiments have indicated that there is an observable positive correlation between selective application of capillary mat technology, and various methods of application for Potassium ferrocyanide (Prussian yellow), with the increase in Evaporative flux from a salt water solution, which acted as the "produced water" for our research purposes. Thus proving that we can accelerate the removal of pollutants within contaminated soils. This is an extremely promising conclusion, and as the need for produced water remediation techniques grow, so does the need to diversify and expand the approach, and I feel this research was an important step in that iterative process.

2. Background

Produced Water :

- High Salinity by-product of soil and natural gas hydraulic fracturing with low levels of organic contaminants
- Impacts plants, soils, and waterways when spilled

Treatment

- Traditionally: expensive, and destructive excavation, disposal, and backfill
- Proposed: low-impact enhanced evaporative flux with crystallization modifier, ferrocyanide
- In recent years, fracking has accounted for more than two-thirds of US oil production, a testament to a dire need of cost effective, efficient, and universally applicable remediation techniques

3. Research Objectives

- Test capillary mats as a means to distribute treatments and collect salts removed from soil and evaluate their influence on the evaporative process
- Evaluate water supply systems with ferrocyanide application to treat salt impacted soils
- Design large scale system for future evaluation of water supply and ferrocyanide treatment efficiency

4. Procedure

Experiment 1: Qualitative Investigation of capillary mat to transport salt water with ferrocyanide

- Filled beakers with salt water solution
- Cut and formed capillary mats to the top of the beaker, with a strip extended to the water itself
- The first two of the five beakers had their capillary mats filled with crystallized Prussian yellow, while the remaining set of two were sprinkled with the same amount of Prussian yellow in a solution. Finally we employed a control in order to compare evaporation rates

Experiment 2 : Treatment of Salt impacted soils using ferrocyanide and capillary mats in a water supply system

- Contaminated a Texas field soil and sand by saturating with 3.8 sodium chloride and drying and mixing cyclically
- Treated 3 cm of impacted soil in Marriott bottle water supply system setting the water table in the accompanying soil system

Analysis:

- Columns were separated into efflorescence revived and 1 cm segments of soil, dissolved in DI water
- Measurements of electrical conductivity and absorbance at 220 nm were used to analyze salt and ferrocyanide concentrations

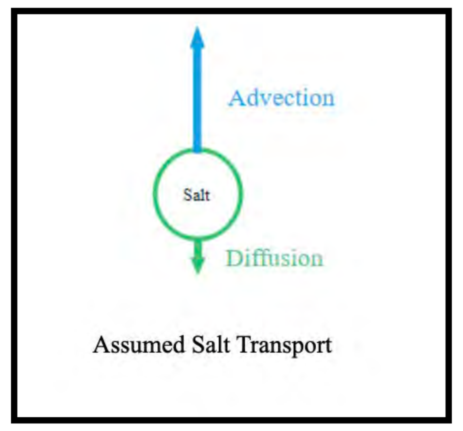


Figure 1 : generalization of what is taking place in experiment 2

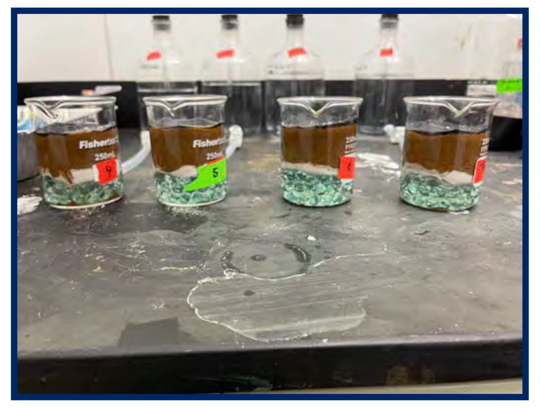


Figure 2 : Experiment 2 from left to Right
1, 2 - Prussian yellow crystallized,
3, 4 - Prussian yellow solution

5. Large Scale Pilot Systems

- Goal to to upscale Marriott systems to approximate field conditions
- Modified 55-gallon drums and PVC pipe to design system
- Plan to use for future pilot tests

Figure 3 : Overhead view

Figure 4 : Pilot system Post rock application

6. Results

Experiment 1 : Qualitatively, the results for both the Prussian yellow and capillary mat usage are promising. Despite a similarity in evaporation rates, the first four beakers clearly collect more efflorescence, a result of the process being more effective in transporting the sodium chloride (pollutant).

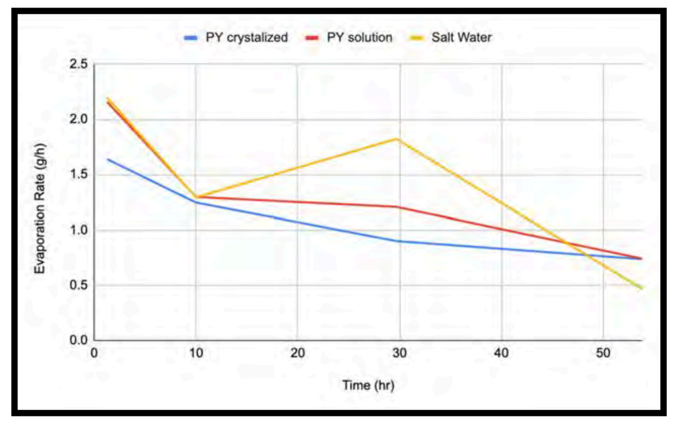


Figure 5 : Variations in evaporation rates were found to be largely inconclusive, although quantitatively, the similarities in evaporation rates indicate that capillary mats do not significantly reduce evaporation rates

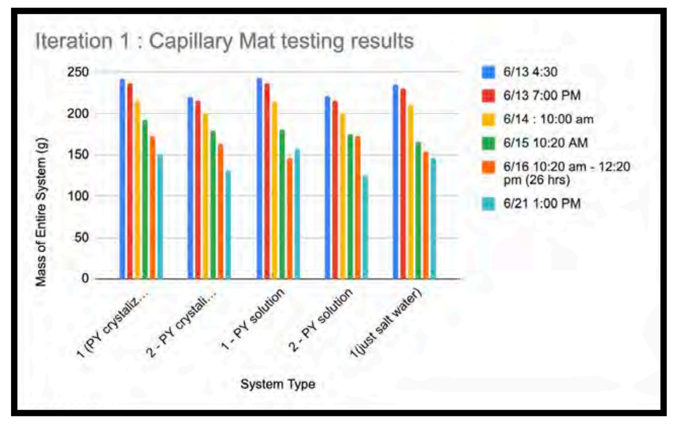


Figure 6 : System masses as a function of time, as testing began at 4:30pm on 6/13. There does not seem to be any stark contrast in loss of system mass via evaporation, yet at the right, there is a significant difference in efflorescence between the treated and untreated systems.

Figure 7 : Efflorescence with capillary mat And crystallized Prussian yellow application

Figure 8 : Efflorescence with capillary mat And Prussian yellow solution application

Figure 9 : Salt Water solution (Control)

Experiment 2 : Here, results for both the Prussian yellow and capillary mat usage are also promising. Diagrams represent a strong correlation between depth, and a decline in remaining sodium chloride and Prussian yellow.

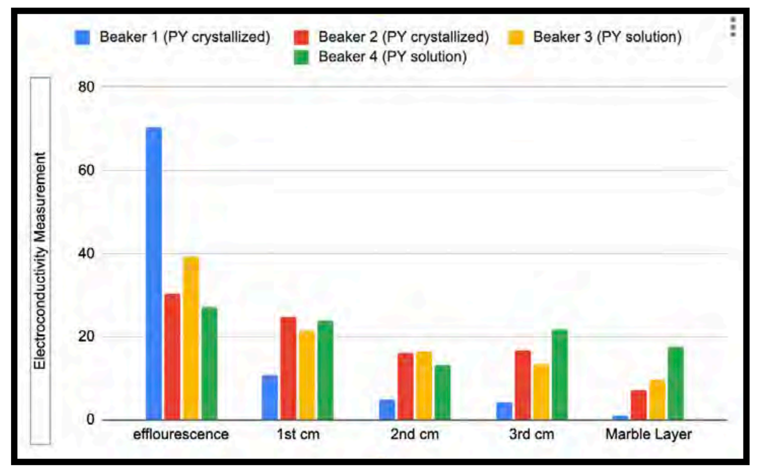


Figure 10 : Electrical conductivity measurements of each 1 cm Layer, takeaway being that the systems successfully moved the sodium chloride vertically

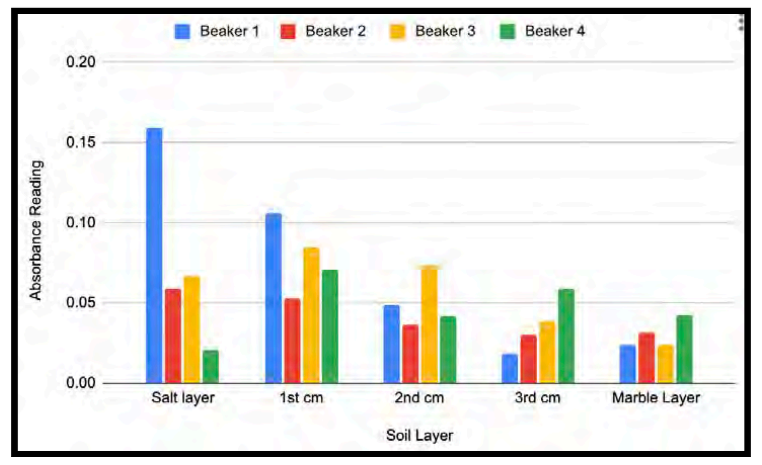


Figure 11 : absorbance values, showing how much Prussian yellow has reached the efflorescence layer, or remained in the soil

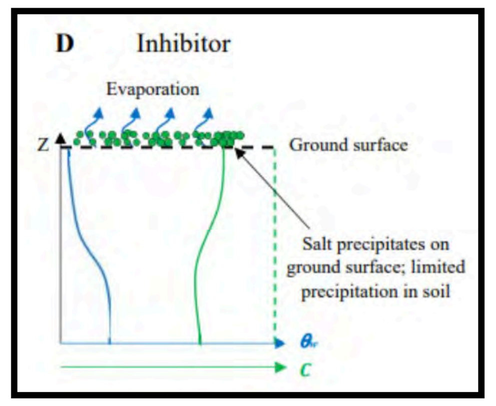
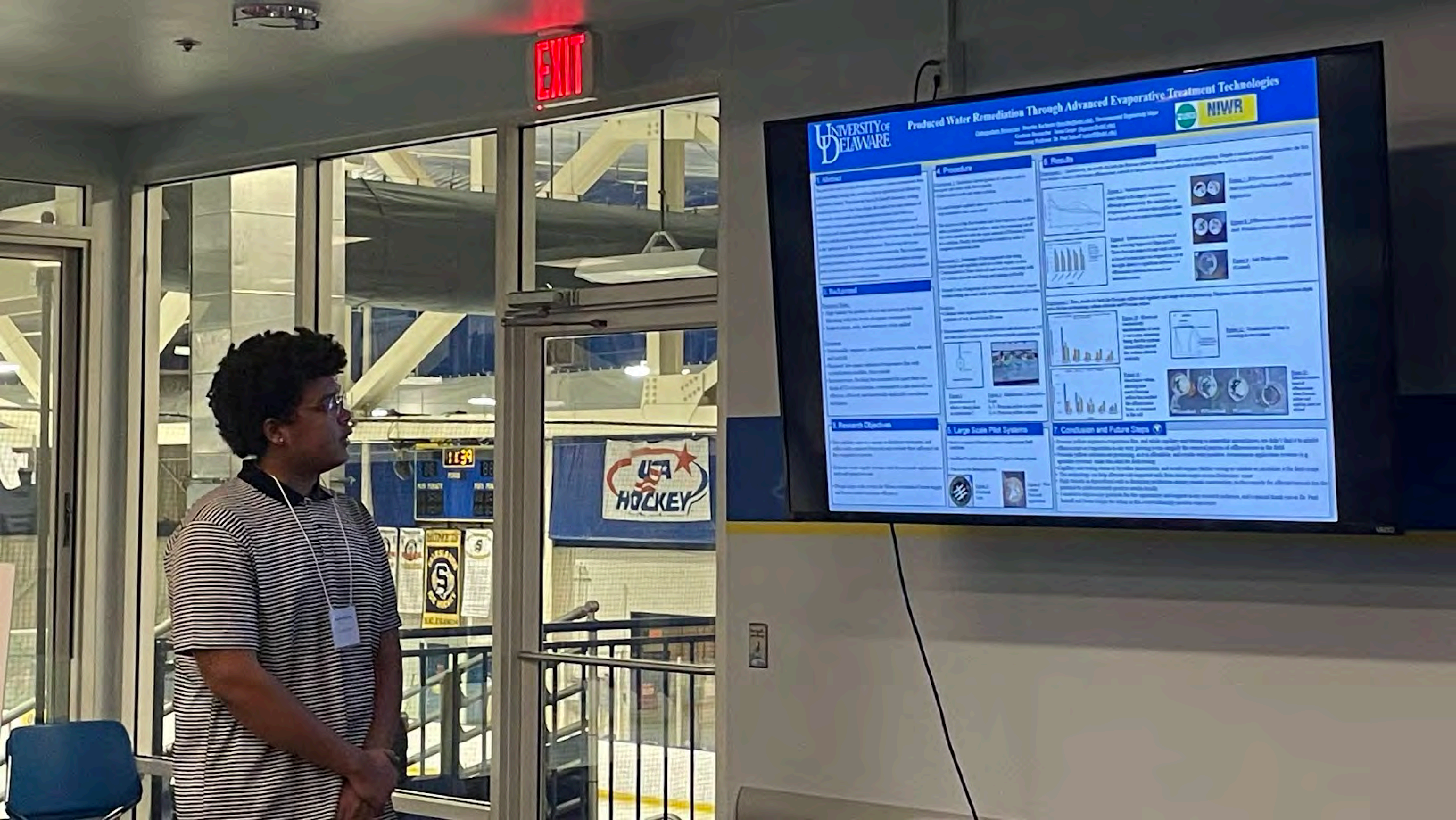


Figure 12 : Visualization of what is occurring in our systems

Figure 13 : Indicates positive trend of efflorescence when Prussian yellow and capillary mats are utilized

7. Conclusion and Future Steps

- Prussian yellow improves evaporative flux, and while capillary mat testing is somewhat inconclusive, we didn't find it to inhibit efflorescence or evaporation in any way, proving it can simplify the removal process of efflorescence in the field
- Prussian yellow solutions are promising, as it is affordable, and results were positive. Autonomous application systems (e.g. sprinkler systems) make this ideal for field testing
- Capillary mat testing seems to be rather inconsistent, and would require further testing to validate or invalidate it for field usage.
- This technology can help alleviate salt-impacted soils from storm surges across Delawares' coast
- High Salinity in Agricultural soils is disrupting production among coastal communities, so this remedy for affected topsoils has the potential to yield extremely positive results locally
- I wanted to express my gratitude for this opportunity and support in my research endeavor, and a special thank you to Dr. Paul Imhoff and Jason Geiger for aiding in this overwhelmingly positive experience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Produced Water Remediation Through Advanced Evaporative Treatment Technologies
NIWR
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5. Large Scale Pilot Systems
7. Conclusion and Future Steps
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Hydrostratigraphic chart of the Atlantic Coastal Plain

Evaluating the Feasibility of Using UIC Class I Injection

May 9th 2024

Jordan Rosales, University of Delaware Undergraduate Student, Geological Sciences Program

Lorrie Council, Ping Wang, Matthew T. Grabowski, Bob W. Scarborough

Abstract

In Delaware the wastewater generated by landfills and wastewater treatment plants (WWTP) is disposed directly into the environment subsequent to treatment. WWTPs dispose of treated wastewater through spray irrigation, rapid infiltration basins (RIBs), river and ocean outfalls. The option of subsurface injection is not utilized but its feasibility is examined in this report.Subsurface injection of wastewater would utilize an Underground Injection Control (UIC) Class I Injection Well. The EPA defines a UIC Class I Injection Well as a well injecting industrial or municipal waste that is either hazardous or non-hazardous, below the lowest Underground Source of Drinking Water (USDW) into a confined rock formation. The confined formation acts as a storage reservoir, preventing the migration of injected fluid into overlying USDWs with ongoing operational monitoring and testing. A favorable waste disposal formation is one that has saline groundwater, that is permeable, porous, and is vertically and laterally extensive to accommodate continuous injection over a period of 30 years or longer. Salinity conditions of groundwater exceeding 10,000 mg/L Total Dissolved Solids (TDS) constitutes a formation that is unsuitable for consumption, allowing it to be considered for injection.

Potential reservoirs identified within Delaware are the Mesozoic rift basins. The Queen Anne, Greenville, and Taylorsville Basins found throughout Delaware's Atlantic Coastal Plain, composed of successive lacustrine and fluvial sediments. Another potential disposal reservoir is the Waste Gate-Potomac Unit 1, the lowest Cretaceous coastal plain unit. Both types of reservoirs are suited for injection as they are confined units and are thought to occur below the lowest USDW.

Purpose

The overall goal of Phase 1 of this UIC Class I Project is to research and identify the preliminary steps needed to plan the potential use of Class I injection wells. The feasibility of implementation is dependent upon meeting the goals of Phase 1, which are identifying and characterizing:

- Potential deep geological storage resources.
- Potential waste that can be disposed.
- Sources of wastewater.
- The deepest wells or test holes in Delaware to examine the geology of potential deep geological storage resources.
- USDWs in each county to determine what aquifers are protected resources.

Methodology

This report was written as part of an undergraduate internship through the University of Delaware (UD) Water Resources Center (WRC) with the Department of Natural Resources and Environmental Control (DNREC) and Delaware Geological Survey (DGS) to evaluate the feasibility of using UIC Class I Injection Wells in Delaware for leachate and wastewater disposal. A syllabus was established with weekly tasks and deliverables that were presented at the end of each week at a meeting with DNREC, DGS, and GWPC contacts. These contacts served as mentors for the duration of the internship, providing resources and advice.

- GWPC- Provided Introductory webinars, UIC regulations, and actual well permit application and completion reports.
- DGS- Provided publications and information on Delaware's deep test borings and wells.
- DNREC- Provided the DNREC Open Data Portal, DNREC Well Viewer, and DNREC Delaware Environmental Navigator.
- DSWA- Leachate Quality and Quantity Reports summaries for the Cherry Island, Sandtown, and Jones Crossroads landfills.

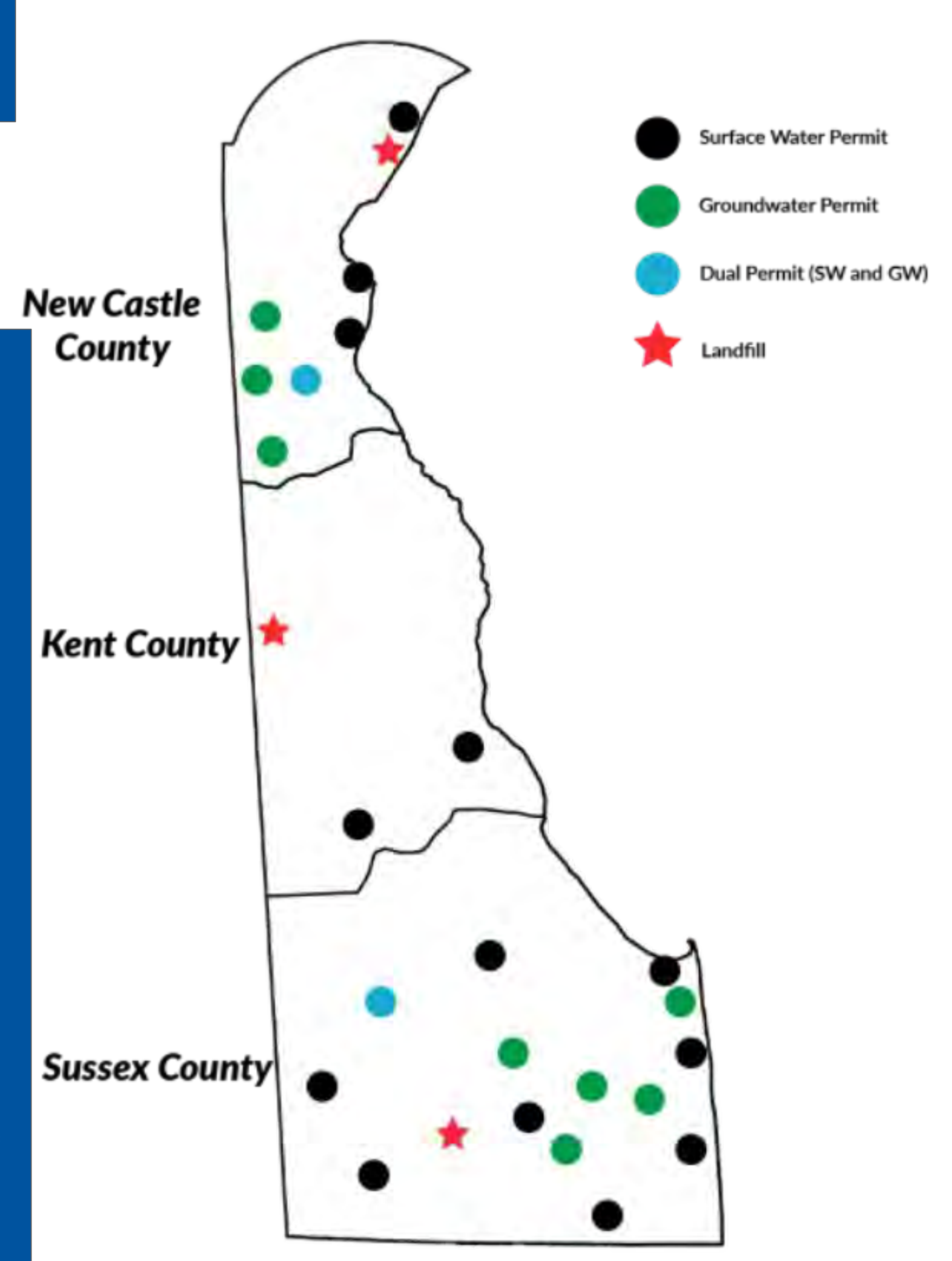

Figure 1- Map of wastewater treatment plants and landfills in Delaware.

Series	Geologic Units	Hydrogeologic Units	County
Pleistocene	Columbia	Columbia/unconfined aquifer	New Castle, Kent, Sussex
Pliocene			
Miocene	Bethany	Pocomoke aquifer	Sussex
	Cat Hill	Manokin aquifer	Sussex
	St. Mary's	Confining unit	
	Choptank	Upper Choptank aquifer	Kent, Sussex
		Milford aquifer	Kent, Sussex
	Calvert	Confining unit	
		Frederica aquifer	Kent, Sussex
		Confining unit	
		Federalsberg aquifer	Kent, Sussex
		Confining unit	
		Cheswold aquifer	Kent
		Confining unit	
Eocene	Piney Point	Piney Point aquifer	Kent
	Shark River	Confining unit	
	Deal		
	Manasquan	Rancocas aquifer	New Castle, Kent
Paleocene	Vincentown		
	Hornerstown	Confining units	
Cretaceous	Navesink		
	Mount Laurel	Mount Laurel aquifer	New Castle, Kent
	Marshalltown	Confining unit	
	Englishtown	Englishtown aquifer	New Castle
	Mercantville	Confining unit	
	Magothy	Magothy aquifer	New Castle
	Potomac	Potomac aquifer	New Castle

Table 2- Hydrostratigraphic chart of the Atlantic Coastal Plain.

Results

- The sands of the Atlantic Coastal Plain form fourteen aquifers, **Figure 2.**
- The Potomac Formation is the lowest USDW of Delaware's Coastal Plain.
- The Queen Anne and Bridgeville Basins are thought to be ideal potential confined reservoirs of Delaware, with a focus on the Queen Anne because of its extent and thickness.
- Delaware's landfills are identified as a potential waste source for a UIC Class I Injection Well.
- The leachate generated at each landfill is a continuous stream of wastewater that requires treatment and disposal.
- Due to the depth of the rift basins and Wastegate-Potomac Unit 1, no test hole or well has extended to their depth. Samples of these geologic resources would provide insight on their geochemistry hydrogeologic conditions.

Conclusions

This Phase 1 feasibility study identified the prospective deep confined geologic storage resources as the rift basins of the Atlantic Coastal Plain as well as the Wastegate-Potomac Unit I with the acknowledgement that these resources are lacking in geologic information. There exist multiple limitations on the feasibility of a UIC Class I injection well in Delaware on the basis of geologic unknowns. Seismic data and test holes drilled to the depth of the Wastegate-Potomac Unit I and rift basins are needed to assess the storage potential by clarifying the stratigraphic characterization, hydraulic characteristics, geochemistry, and structural geology.

Acknowledgements

I would like to acknowledge the entities of the Delaware Department of Natural Resources and Environmental Control, University of Delaware Water Resources Center, Delaware Geological Survey, Ground Water Protection Council, Delaware Solid Waste Authority, and the USGS for funding from the US Dept. of Interior by the Water Resources Research Act of 1964 and 1984. As well as the following individuals- Lorrie Council, Ping Wang, Matthew T. Grabowski, Bob W. Scarborough, Peter P. McLaughlin, John J. Rebar Jr., Gerald J. Kauffman Jr., Martha C. Narvaez, Pam Williamson, Jason Munyan, Adam F. Wallace, and John Madsen.


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Changes in Shoreline Conditions along the Delaware Inland Bays 2012 - 2022

Lydia Franks, M.S. Water Science and Policy and Andrew Homsey, UD Water Resources Center
Meghan Noe Fellows and Andrew McGowan, Delaware Center for the Inland Bays

Introduction

In support of the Living Shorelines Initiative, the University of Delaware Water Resources Center assessed and mapped shoreline conditions for Rehoboth, Indian River, and Little Assawoman Bays. Building off prior inventories completed for 2006 and 2012 in Rehoboth and Indian River Bays, shoreline conditions for 2022 were updated and included a 2012 and 2022 inventory for Little Assawoman Bay. The goals of this project were to update the 2012 inventories based on 2022 data, while completing a new inventory for Little Assawoman Bay and quantifying changes in shorelines for this period.

Methods

The previous shoreline inventories were assessed using GPS videography by the Virginia Institute of Marine Science and described land use, bank conditions and shoreline structures. A new method for this study, shown in Figure 1, was developed based on project needs and interests and 2012 data layers were altered to reflect this (Figure 1).

DNREC aerial imagery, flown in March 2022 at 0.5 ft. resolution, was used alongside the 2012 shoreline data to categorize shoreline conditions in ArcGIS Pro. A set of shoreline classes was chosen based on interest in the shoreline's physical composition. Segments of shoreline were grouped into the 9 classes based on the previous designation and characteristics observed from the imagery, as shown in the example in figure 3. A set of guidelines was established to aid in categorization and ensure quality assurance while quality control was assessed using an accuracy matrix for shoreline identification. Features were delineated at parcel level based on a minimum mapping unit of 30m inland. Classes were later grouped into 4 smaller categories for summary purposes.

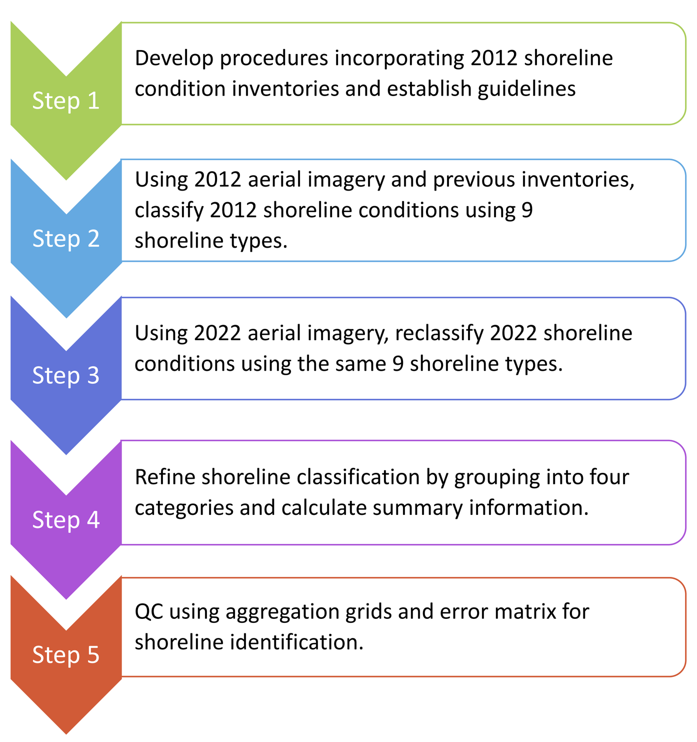

Figure 1. Steps to evaluate and update the 2022 shoreline inventory.

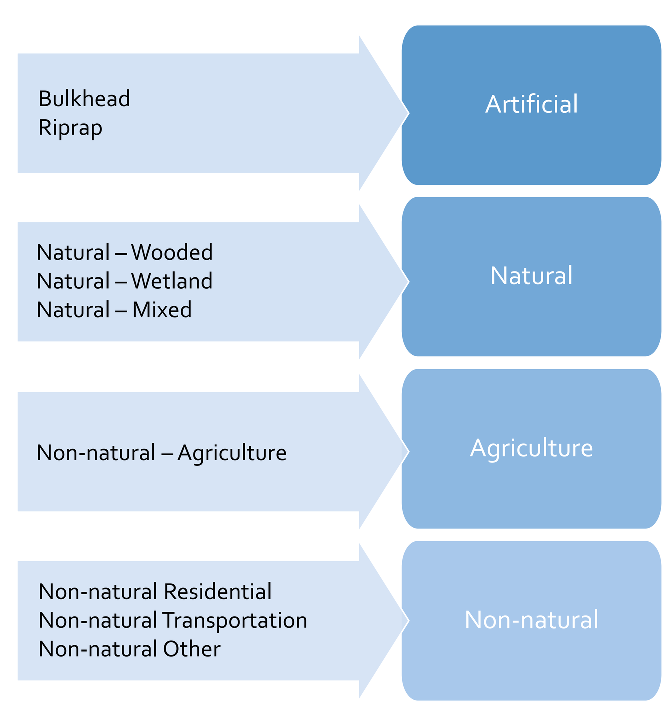

Figure 2. 9 shoreline classes (Cat 1) grouped into 4 categories for summary statistics (Cat2).

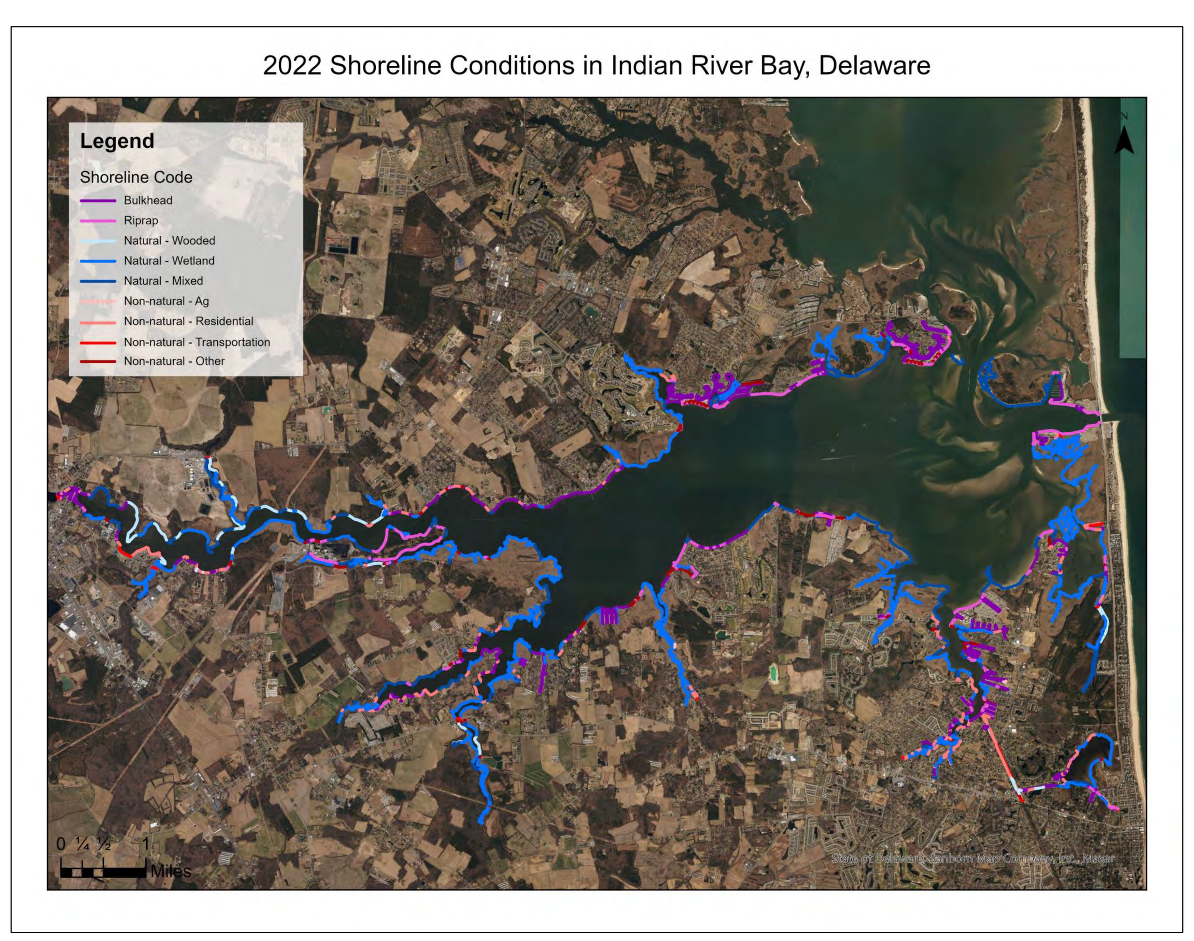

Figure 3. Example of the completed 2022 shoreline condition inventory (Indian River Bay) displaying shoreline conditions.

Results

Indian River Bay lost just over 1% of Natural shoreline from 2012 to 2022, while gaining 0.32% Non-natural and 0.87% Artificial shoreline. Agricultural shoreline only increased by 0.17% during this period (Table 1). Table 2 shows the breakdown of shoreline miles and percent of total shoreline for each category in 2012 and 2022. Figure 4 highlights locations of change in Natural shoreline conditions and Figure 5 shows Artificial and Natural shoreline for 2022.

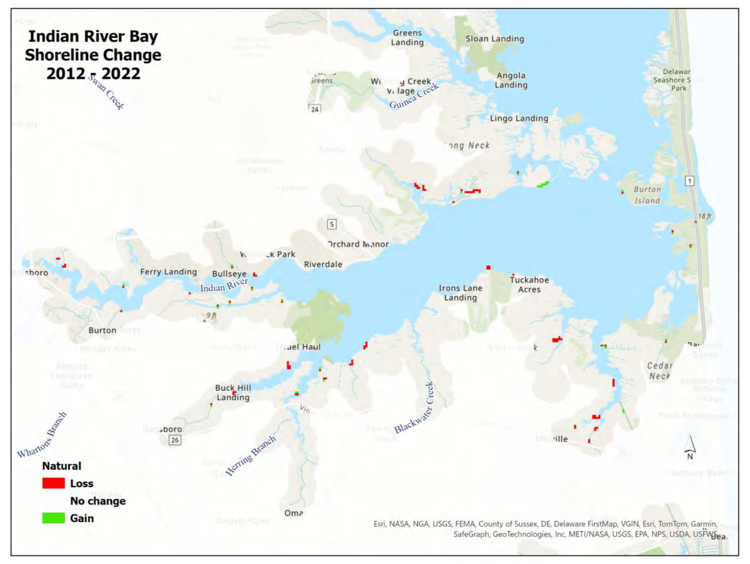

Figure 4. Map highlighting loss of Natural shoreline between 2012 and 2022 in Indian River Bay.

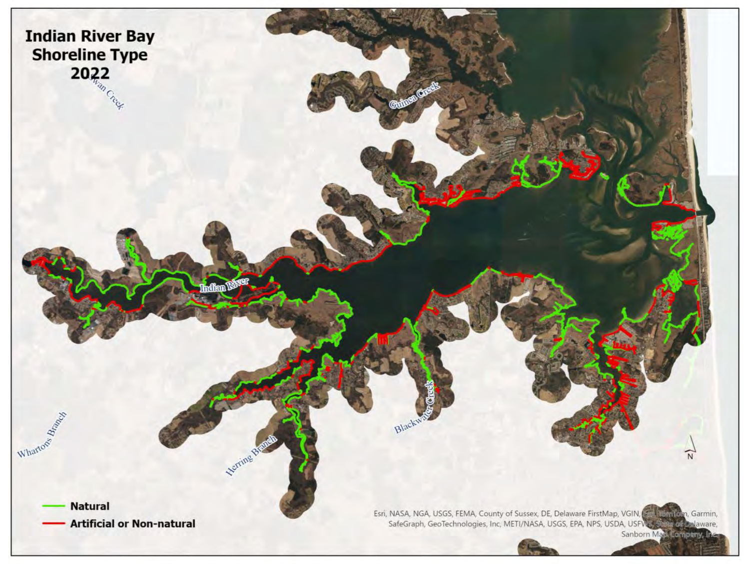

Figure 5. Map displaying 2022 shoreline as Artificial and Natural from Cat2 classes in Indian River Bay.

Cat2	Change in Length (mi) 2012-2022	% Change 2012-2022
Artificial	1.25	**0.87%**
Natural	-1.47	**-1.03%**
Agriculture	-0.25	-0.17%
Non-natural	0.46	0.32%

Table 1. Summary of change in length and percent for Indian River Bay based on four categories of shoreline type.

Cat2	2012 Length (mi)	2012 % Shoreline	2022 Length (mi)	2022 % Shoreline
Artificial	39.81	27.92%	41.05	28.80%
Natural	88.65	62.18%	87.17	61.15%
Agriculture	0.32	9.67%	0.08	0.06%
Non-natural	13.79	0.23%	14.25	10.00%

Table 2. Shoreline classes (Cat2) showing length in miles and percent of total shoreline for 2012 and 2022 in Indian River Bay.

Little Assawoman Bay shows relatively little shoreline change between 2012 and 2022, largely due to its existing protected land, losing only 0.56% of Natural shoreline while gaining 0.51% Non-natural and 0.04% Artificial, with Agricultural shoreline miles remaining unchanged (Table 3). Table 4 show the breakdown of shoreline miles and percent of total shoreline for each category in 2012 and 2022. Figure 6 shows locations of Natural shoreline loss and gain between 2012 and 2022 and Figure 7 shows Artificial and Natural shoreline in 2022.

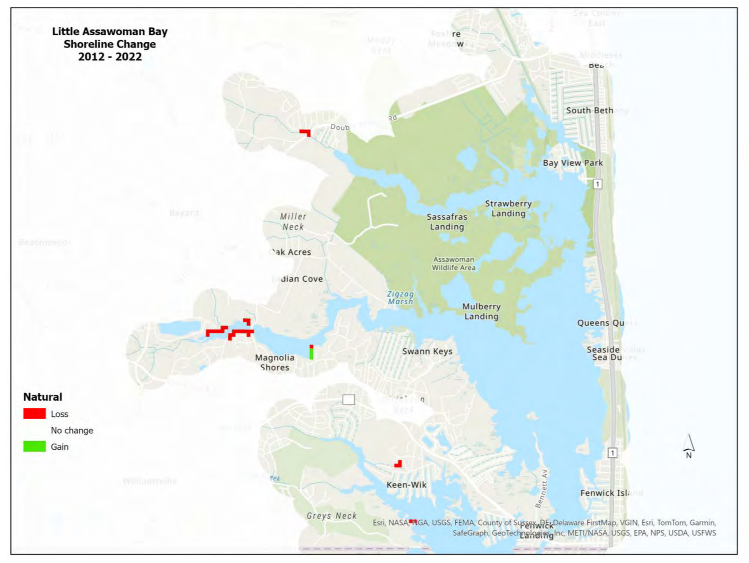

Figure 6. Map highlighting loss of Natural shoreline between 2012 and 2022 in Little Assawoman Bay.

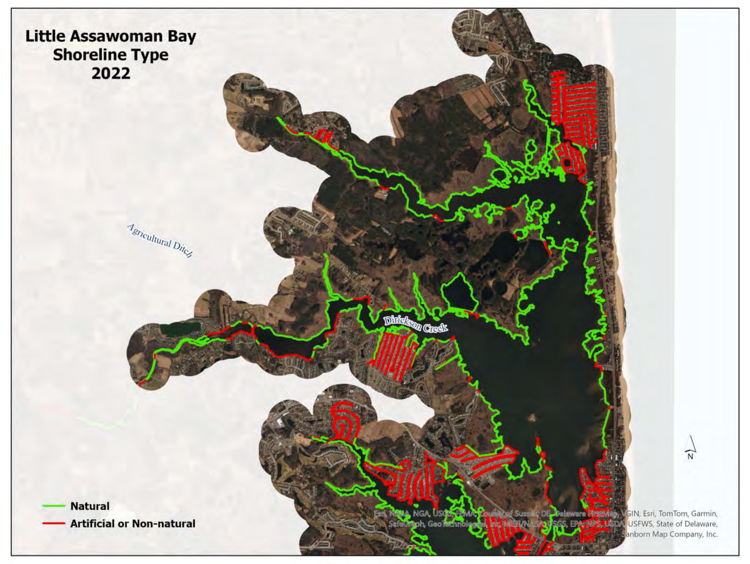

Figure 7. Map displaying 2022 shoreline as Artificial and Natural from Cat2 classes in Little Assawoman Bay.

Cat2	Change in Length (mi) 2012-2022	% Change 2012-2022
Artificial	0.05	0.04%
Natural	-0.66	-0.56%
Agriculture	–	0.00%
Non-natural	0.61	0.51%

Table 3. Summary of change in length and percent for Little Assawoman Bay based on four categories of shoreline type.

Cat2	2012 Length (mi)	2012 % Shoreline	2022 Length (mi)	2022 % Shoreline
Artificial	48.31	41.00%	48.36	41.05%
Natural	65.46	55.57%	64.81	55.01%
Agriculture	0.77	0.65%	0.77	0.65%
Non-natural	3.27	2.78%	3.88	3.29%

Table 4. Shoreline classes (Cat2) showing length in miles and percent of total shoreline for 2012 and 2022 in Little Assawoman Bay.

Rehoboth Bay lost 1.10% of Natural shoreline, the most of the three bays, between 2012 and 2022. The Bay gained 0.57% Artificial and only half a percent of Non-natural shoreline during the same period, while Agricultural shoreline did not change (Table 5). Table 6 shows the breakdown of shoreline miles and percent of total shoreline for each category in 2012 and 2022. Figure 8 highlights locations of Natural shoreline change between 2012 and 2022 and Figure 9 shows Artificial and Natural shoreline for 2022.

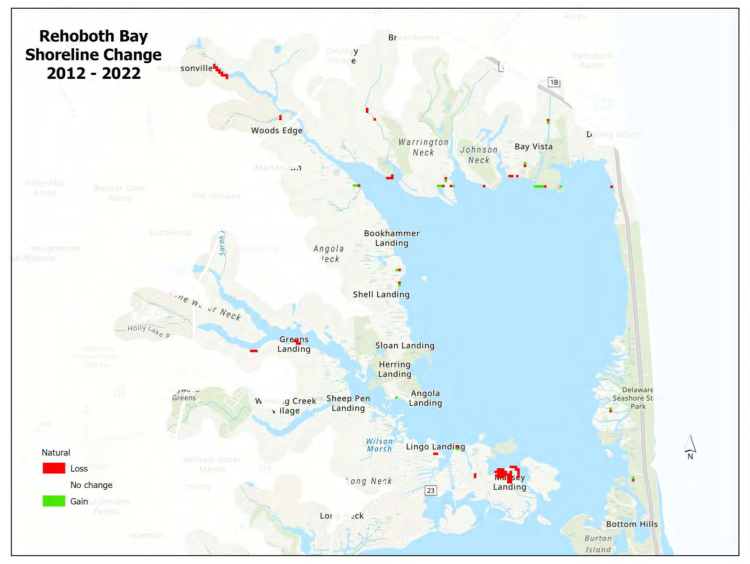

Figure 8. Map highlighting loss of Natural shoreline between 2012 and 2022 in Indian River

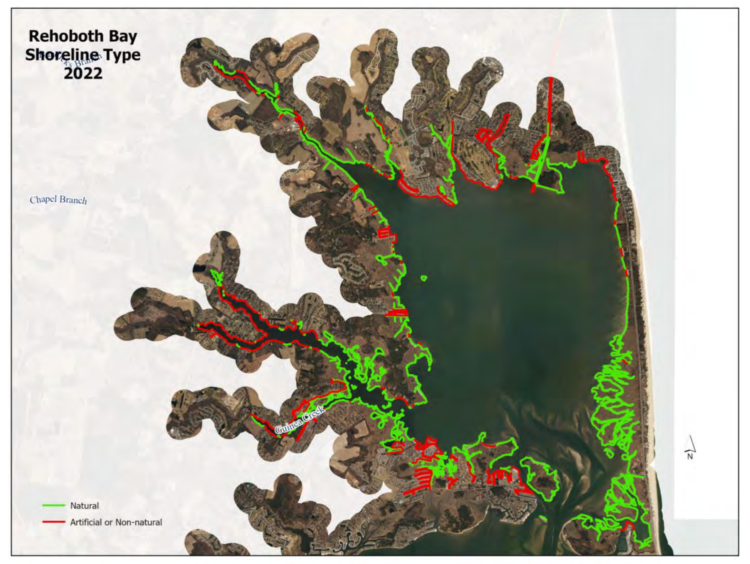

Figure 9. Map highlighting loss of Natural shoreline between 2012 and 2022 in Rehoboth Bay.

Cat2	Change in Length (mi) 2012-2022	% Change 2012-2022
Artificial	1.03	0.57%
Natural	-1.96	-1.10%
Agriculture	–	0.00%
Non-natural	0.90	0.50%

Table 5. Summary of change in length and percent for Rehoboth Bay based on four categories of shoreline type.

Cat2	2012 Length (mi)	2012 % Shoreline	2022 Length (mi)	2022 % Shoreline
Artificial	31.29	17.51%	32.31	18.09%
Natural	134.31	75.17%	132.35	74.08%
Agriculture	0.23	013%	0.23	0.13%
Non-natural	12.86	7.19%	13.76	7.70%

Table 6. Shoreline classes (Cat2) showing length in miles and percent of total shoreline for 2012 and 2022 in Rehoboth Bay.

Conclusions

Indian River, Little Assawoman, and Rehoboth Bays have seen minimal shoreline change between 2012 and 2022. The primary changes observed in this study were an increase in Artificial shoreline and a decrease in Natural shoreline. It was noted during reclassification that most land use change is occurring inland. An increase in newly built residential developments was seen >30m inland when comparing 2012 to 2022 aerials in Indian River Bay, but most Natural shoreline loss in Indian River Bay was still attributed to increased residential development.

Rehoboth Bay is larger and more densely populated than Indian River or Little Assawoman Bays, but Indian River Bay saw the greatest amount of change in shoreline conditions overall. Rehoboth Bay hosts a significant amount of Natural shoreline, primarily from protected natural areas such as state parks and preserves, and saw the largest overall change in Natural shoreline conditions. Agriculture comprised very little of the Inland Bays shorelines and Little Assawoman holds the highest amount of agricultural shoreline of the Bays, as it is primarily an agricultural watershed. Little Assawoman Bay also has the greatest amount of Artificial shoreline of the three Bays.

This inventory provides land and water managers of the Delaware Inland Bays with a blueprint to be further built upon and utilized for decision-making. Next steps for this project may include assessing inland land use and hot spots of development as they relate to planning and policy implications.

Acknowledgements

This research is a collaboration between the University of Delaware Water Resources Center and the Delaware Center for the Inland Bays. We would like to thank our CIB partners for their continued efforts, and the Virginia Institute of Marine Science for their initiative in completing the 2006 and 2012 shoreline inventories which served as the foundation to this study.


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CITY OF WILMINGTON GREEN JOBS PROGRAM IMPACT STUDY

PROJECT DESCRIPTION

The City of Wilmington Green Jobs Program is a summer internship program that provides City of Wilmington youth exposure to and experiences in natural spaces in their community, environmental topics, careers in the environmental field, outdoor hands-on activities, and professional development. The University of Delaware Water Resources Center (DWRC) and the City of Wilmington Department of Parks and Recreation have partnered on the implementation of this program since its inception in 2011. The program is a true partnership between the City of Wilmington and DWRC as well as the numerous organizations that host the youth throughout the six-week program.

This project, led by DWRC, in partnership with the City of Wilmington Department of Parks and Recreation, will provide the City, DWRC and program host organizations feedback on the program’s impact. This project employs a theoretical and methodological approach to collect data from Green Jobs Program Alumni and provides an overall assessment of the program. Program partners have requested program alumni feedback for several years and the feedback collected in this project will be valuable to the program’s growth, development and potential program refinement. This project is funded by the Wilmington Partnership Mini-Grants in the University of Delaware Community Engagement Initiative.

METHODS

The project is led by DWRC in partnership with the City of Wilmington Department of Parks and Recreation. The project team works together to ensure the project goals are achieved. DWRC tasks include developing IRB approved survey methods, distributing survey instruments, analyzing survey responses, and reporting results. The City has assisted in providing program participant information, contacting program participants, reviewing survey results, discussing program recommendations based on participant feedback and disseminating the project findings to City staff and leadership.

The survey tools developed included a structured online survey tool using Qualtrics and a semi-structured phone interview. Topics covered in the structured online survey and interviews include participant demographics, years participated in the program, overall satisfaction with the program, preparation for career readiness, development of professional skills, environmental awareness, appreciation for the outdoors and future career goals.

SURVEY RESULTS

The structured online survey portion of this project is completed. The IRB approved Qualtrics survey was sent to 105 Green Jobs Program alumni and resulted in 28 responses that provide insight into the Green Jobs Program experience. The survey consists of 25 questions that ask participants from the past 13 years of the program to provide feedback on what they learned about the environment, exposure to environmental careers and academic programs, and professional development during the six-week program. Analysis and reporting of the survey data is ongoing. Preliminary findings include the following participant responses:

- 100% recommend the Green Jobs Program to a friend.
- 60% are considering a job in the environmental field.
- 94% report that the Green Jobs Program improved their job/workplace readiness.
- 92% identified as Black/African American

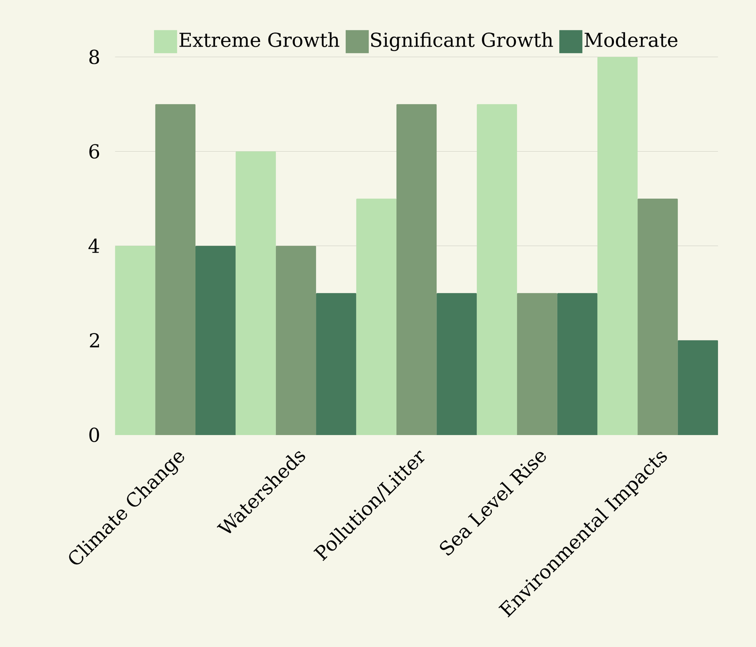
Program participants were almost evenly divided in terms of gender:
- 54% identified as male
- 46% identified as female

GREEN JOBS PROGRAM

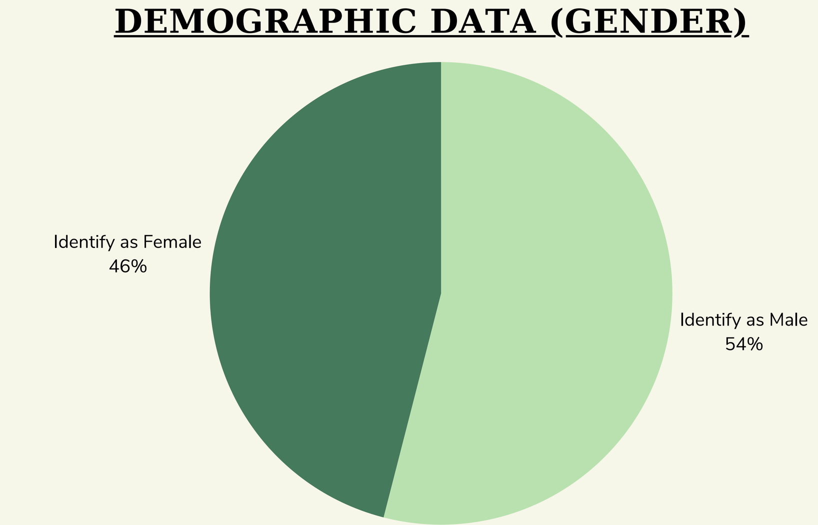
The Green Jobs Program is a paid six-week internship that serves City of Wilmington youth that are 14-18 years old. The key components of this program include environmental education, natural spaces in the City and State of Delaware, hands-on field work, and professional development. DWRC and the City of Wilmington Department of Parks and Recreation have partnered on the implementation of this program since its inception in 2011 and will be employing the 14th year of the program in 2024. The program is a true partnership between the City and DWRC as well as over 25 organizations that have hosted the youth throughout the thirteen years of programming. Key components of the program include:

- Program participants are City of Wilmington residents
- Internship program within the City of Wilmington Youth Career Development Program
- Participants chosen through an interview process
- 14 participants in the program
- 14-18 years old
- 6 weeks in the summer (mid-June-July)
- 25 hours/week
- Earn minimum wage
- Activities and program location vary with nonprofit, government, academic and private host organizations

AWARENESS IMPROVEMENT



DEMOGRAPHIC DATA (GENDER)



(Our survey shows that our participants were almost evenly split between students that identify as male and students that identify as female, showing that the program is a good program for all genders)

PROGRAM HOSTS & COMMUNITY PARTNERS

- Brandywine Red Clay Alliance
- City of Wilmington, Departments of Parks and Recreation and Public Works
- Delaware Center for Horticulture
- Delaware Department of Technology & Information
- Delaware Nature Society
- Delaware Sea Grant
- Delaware Solid Waste Authority
- Delaware State Cooperative Extension
- Delaware State University
- Eco Plastics Products of Delaware
- Food Bank of Delaware
- Junior Achievement of Delaware
- Lincoln University
- Partnership for the Delaware Estuary
- Straughan Environmental
- Stroud Water Research Center
- The Nature Conservancy, DE/PA
- The Village Tree, Inc.
- UD Water Resources Center
- UD Botanic Gardens
- UD Cooperative Extension

NEXT STEPS AND CONCLUSION

Results from this survey show that students who have gone through the Green Jobs Program have an increased awareness of environmental issues and are now willing to consider environmental careers, as well as feeling an increased level of job preparedness.

Following the data collection portion of this project DWRC is in the process of conducting analysis of the results, compiling a summary report, and providing feedback to the City of Wilmington and program partners. The DWRC will partner with the City of Wilmington to strengthen and update the program based on the results of the data and findings of this project.

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Observations
Recommendations
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