Purifying Wastewater for Rural Communities

Harrison Lowery, Lauren Hutchison, Tessa Shackelford

Project Summary

In 2016, Dr. McGrath, Professor of Biology at Sewanee, lobbied for the construction of three wetland basins at the Sewanee Utility District (SUD) in order to research the efficacy of wetland treatment for a small community setting. For the past few years, water quality measurements have been taken at the SUD's wetlands to better determine the outcomes of wetland treatment in rural communities like Sewanee. Our team's goal was to set up visualizations that allow our community partner, Dr. McGrath, to understand the water quality trends of the wetlands over time to push for sustainable development in the community.

Background

The goal of the Wetland Project is to analyze and visualize the constructed wetland data of Sewanee to show how it can be a viable option for wastewater treatment in smaller-scale, rural areas where traditional wastewater treatment plants are not economically feasible and they need a cheaper treatment option, or in areas with high environmental pollution and they need a solution.

The Sewanee Utility District (SUD) uses tertiary treatment, a combination of physical, biological, and chemical processes, to filter and treat wastewater, one of which is the constructed wetlands. Natural wetlands are bodies of water that cover soil for parts of the year. Wetlands can naturally clean wastewater by filtering out excess nutrients and pathogens through their aquatic plant life and microbial activity. Constructed wetlands mimic the filtering processes that natural wetlands have through careful engineering so that they can treat domestic wastewater.

Constructed wetlands are a more sustainable and cost-effective alternative to wastewater treatment in comparison to conventional municipal treatment plants. Through microbial activity, wetlands naturally treat contaminants and pollutants, providing a more biologically efficient method of wastewater treatment. Wetland treatment has worked successfully on a large-scale such as the systems in Clayton County, GA, and Orange County, CA. However, wetlands have not been used for wastewater treatment on a small-rural scale.

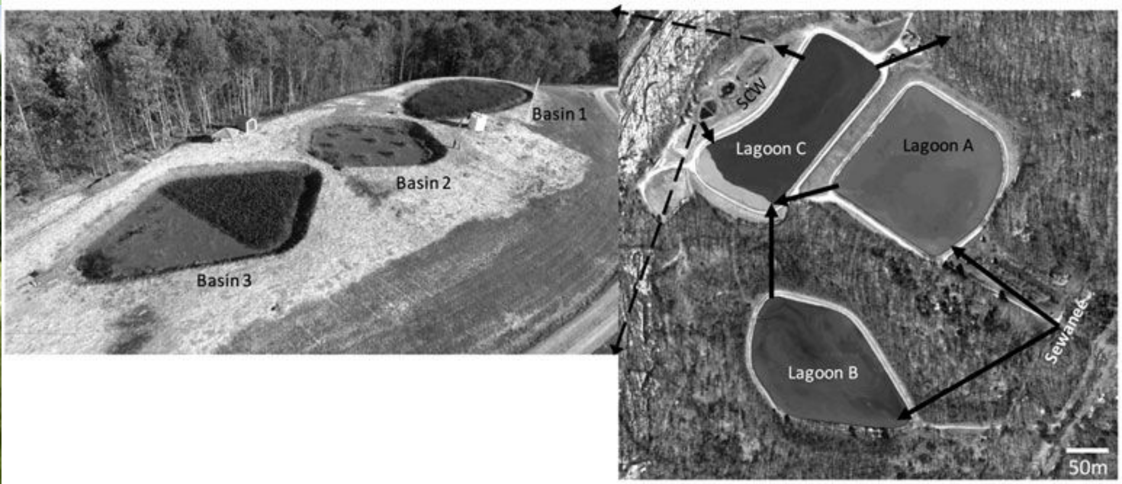
Client

Sewanee Wetlands Project-
Dr. Deborah McGrath

- Professor of Biology at Sewanee
- Project Manager of the Wetlands Project
- In collaboration with both the Sewanee Utility District and the University of Georgia

Location

Our project is centered around the Sewanee Utility District which is located on Sherwood Road in Sewanee. The Sewanee Utility District has 3 lagoons for wastewater treatment and a forest where spray fields deposit treated wastewater. It also has three constructed wetland basins that take wastewater from lagoon C. The wastewater flows through each basin and return to lagoon C where it is treated with chlorine and sprayed onto the forest.



Methods

Our dashboard has 7 different tabs. We originally thought we would have 4 tabs but we added three additional tabs

- The first tab is the overview and it has 3 individual tabs. The first shows the project summary, the second is the water quality variable definitions, and the third tab shows wetland photos.
- The second tab shows water quality comparisons between each site.
- The third tab shows trends in water quality variables monthly, daily, and hourly.
- The fourth tab shows boxplots of each variable by month and by site.
- The fifth tab shows the descriptive model for each variable by month and by site.
- The sixth tab shows weather data through bar plots. It shows each weather variable with the deviation of each variable per month.
- The seventh tab shows the aeration pre and post. It will allow our partner to continue to input data and see future trends by month.

Creating our dataset

- Look for any equipment malfunctions
- Remove any N/As or missing data
- Make all dates and times in the same format
- Combine datasets
- Choose the columns and variables needed for visualizations

Creating the Dashboard:

- Include important variables for water quality
  - utilize research
- Organize visualizations into tabs of interest
- Comment our code for community partner
- Make it easily accessible for future inputs of data

Data Description

Our data comes from the Sewanee Utility District and shows measurements of water quality parameters.

- **SONDE:** dataset shows the measurements of different water quality variables ~ 2017 - *December 2021*
    - We combined the SONDE Lagoon C and Wetland Basin 3 datasets into one dataset called "all_data"
- **SUD:** dataset shows weather data, like wind speed and air temperature ~ *October 2020 - December 2021*
    - We used the SUD daily dataset which shows daily measurements and the SUD hourly dataset which shows hourly measurements
- **OESS:** dataset shows temperature and rainfall measurements collected from the Office of Environmental Stewardship and Sustainability (OESS). ~ *January 2021 - January 2022*

The water quality data were collected using electronic sensors that constantly take measurements every hour

Variables:

- **Turbidity:** Relative clarity of water; the amount of light scattered by materials in the water (clay, silt, (in)organic matter, algae, living organisms)

- **pH:** Acidic or basic; pH influences solubility; low pH = high solubility = toxicity of heavy metals in water
- **Conductivity:** Measured in microsiemens per centimeter; water's capability to pass through an electric current; increased conductivity indicates pollution (untreated wastewater, stormwater runoff)
- **Ammonia*:** Product of microbiological decay of nitrogenous matter; excessive harmful to vegetation and toxic to aquatic life
- **Ammonium*:** Ammonia nitrogen includes the ionized form (ammonium, NH_4^+). A decrease in pH favors the ionized (NH_4^+) form.
- **Temperature:** Hourly water temperature in Wetland Basin 3 & Lagoon
- **Nitrate:** Occurs naturally at safe levels (< 3 mg/L); however, concerns with levels over 10 mg/L (runoff, leakage, fertilizer)
- **Oxygen Reduction Potential:** Oxidation Reduction Potential; measured in millivolts; determines how effective disinfection is; measurement of sanitation
- **Dissolved Oxygen:** Measures percent of dissolved oxygen saturation and dissolved oxygen levels; important for aquatic organisms survival, DO decreases as organic matter decays (eutrophication)
- **Vapor Pressure Deficit:** is the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated.

Product/Outcome

We want to use the Sewanee Utility District data to create an interactive dashboard that will show water quality comparisons between two wastewater treatment methods: the conventional lagoon treatment and the experimental wetland treatment. Additionally, our dashboard shows yearly, monthly, daily, and hourly trends for both water quality parameters and weather conditions like air temperature and precipitation.

We interpreted and organized the data so that it can be used to collect future results of wetland wastewater treatment. Furthermore, we visualized trends of water quality variables, so that Dr. McGrath can evaluate the difference in water quality pre and post-aerator. With the recent installation of an aerator, the incoming wetland data is going to be crucial in understanding the impact that wetlands could truly have on our wastewater treatment systems. This makes the data pre-aerator even more important in determining the effectiveness of the wetlands post-aerator. With our dashboard being dynamic and updatable, this will allow for easy comparisons moving forward.

Our original goal was to show that the Sewanee wetlands could further improve wastewater treatment compared to the lagoon and spray field system alone; however, as we learned about our project, we discovered that the wetlands were not producing the results we wanted due to the decrease in oxygen levels.

Significant Findings

We found that the data changed the most between warmer and colder months as temperature impacts many water quality parameters. As temperature increases so does conductivity; however, an increase in temperature decreases dissolved oxygen and oxidation-reduction potential, leading to a more anoxic water body. This is a crucial fix to monitor in order to successfully provide the possibility of releasing cleaned wastewater back into local streams.

We also discovered more about the difference in water quality variables between each site, Wetland Basin 3 and Lagoon C. In Wetland Basin 3, turbidity and ORP levels had higher quality standards than in Lagoon C; however, over time the difference between the two sites became smaller. This is because the wetlands are small and have been taken over by invasive species. As a result, dissolved oxygen levels have dropped in the wetland. In order to improve oxygen levels, Dr. McGrath installed an aerator. While all of our data is pre-aerator, Dr. McGrath will continue to input data over time, so she can see the improvements post-aerator.

From these results, we are hopeful that our dashboard will allow Dr. McGrath to make appropriate decisions in order to improve the water quality in the wetlands. Furthermore, we are excited to see how water quality will change over this year after the implementation of the aerator.

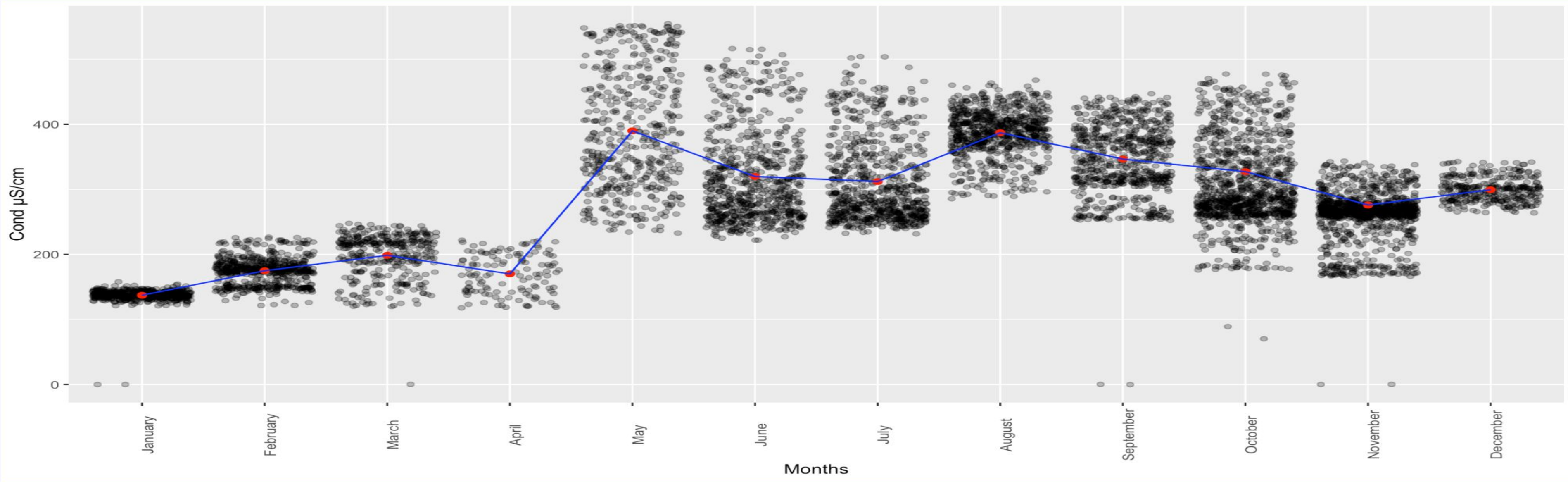
Product Continued…

- Figure 1 is a descriptive model that shows the means of each variable compared to all of the data for each month. The red dots are the means, the blue line connects the means, and each black point represents a collected data point for that variable for that month. It is also separated by site location.
- Figure 2 shows each variable grouped by site. The colors of each bar show if they are meeting EPA standards or not. Blue means it meets standards and green means it does not meet EPA standards.
- Figure 3 shows water quality variable averages by month, day, and hour. It also shows each site graphed together, each variable, and the weather variables of temperature, rainfall, and solar energy total.
- Figure 4 shows rainfall totals according to SUD and OESS collections. The blue is the SUD and the green is the OESS rainfall totals.
- Figure 5 shows each variable pre-aeration. The aeration adds oxygen to the wetlands. The graph will also allow our partner to continue to input data to show trends by month and year post-aeration, by site, and by variable.

We also wanted our partner to see ANOVA tests for each water quality variable so we included this in the final package for her.

Figure 1

Descriptive Models Using 2021 Data



Select:

Site

Wetland Basin 3

Variable

Cond µS/cm

Figure 2

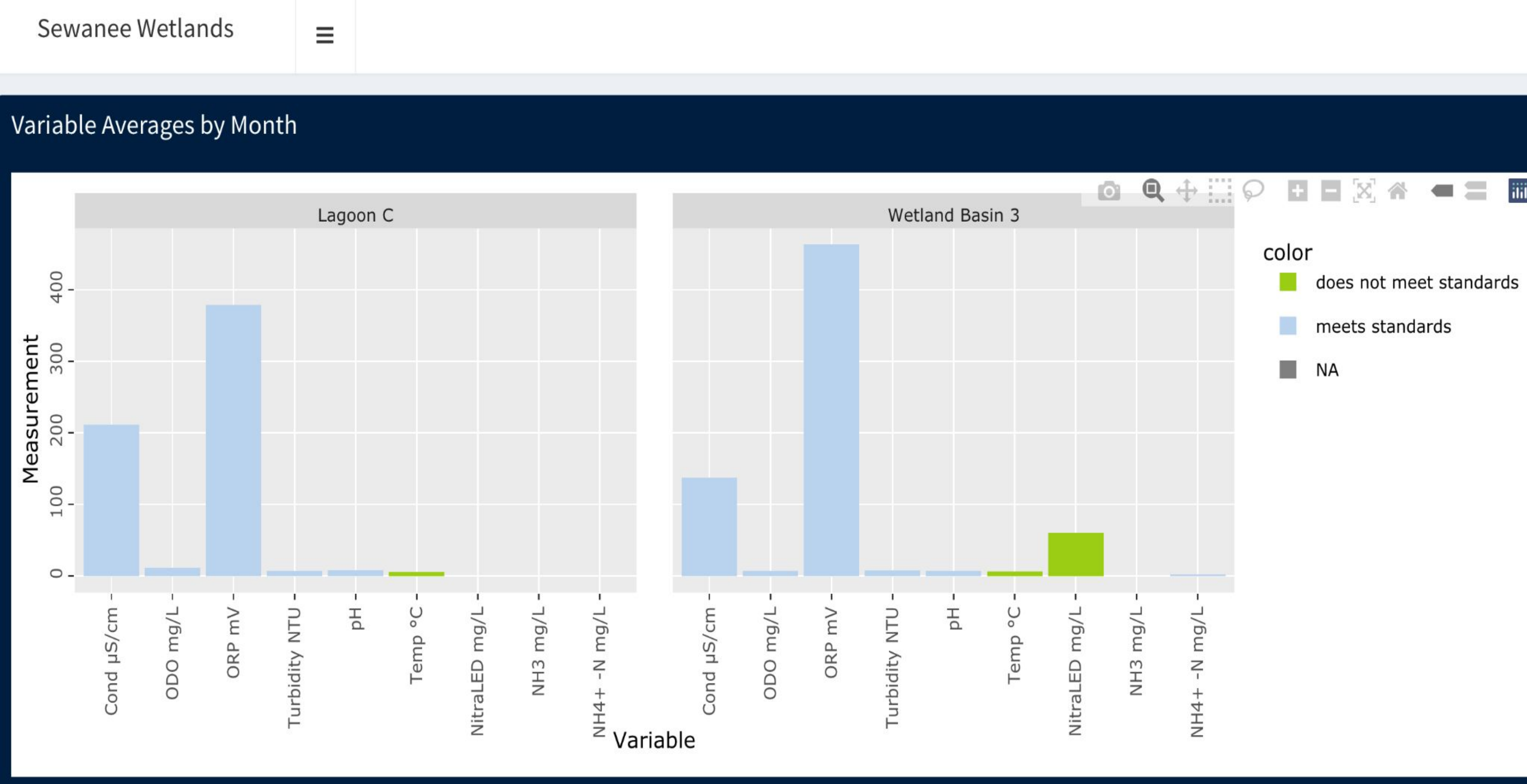

Sewanee Wetlands
Variable Averages by Month
Lagoon C
Wetland Basin 3
Measurement
0
100
200
300
400
Cond µS/cm
ODO mg/L
ORP mV
Turbidity NTU
pH
Temp °C
NitraLED mg/L
NH3 mg/L
NH4+ -N mg/L
Variable
color
does not meet standards
meets standards
NA

Figure 3

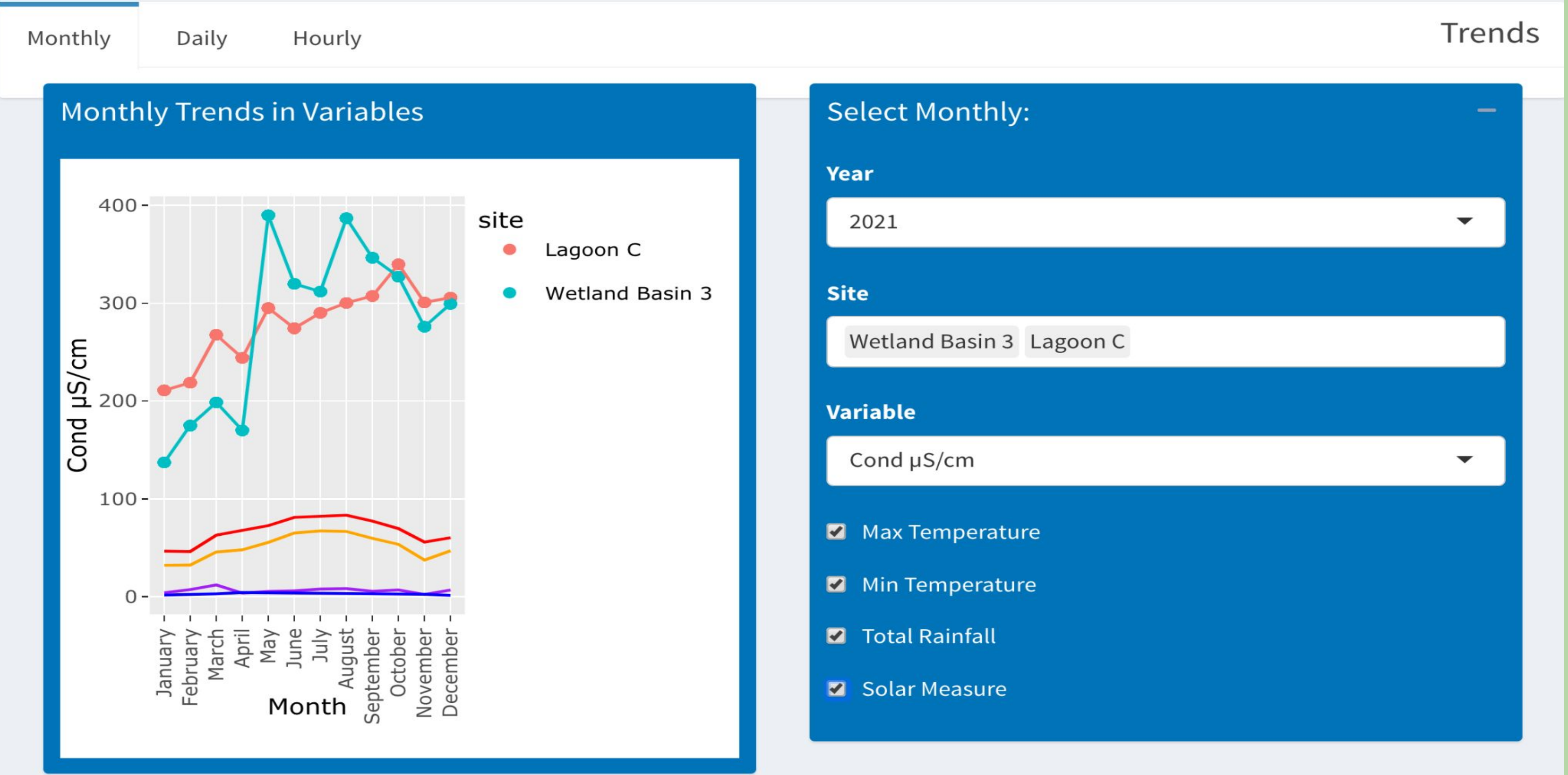
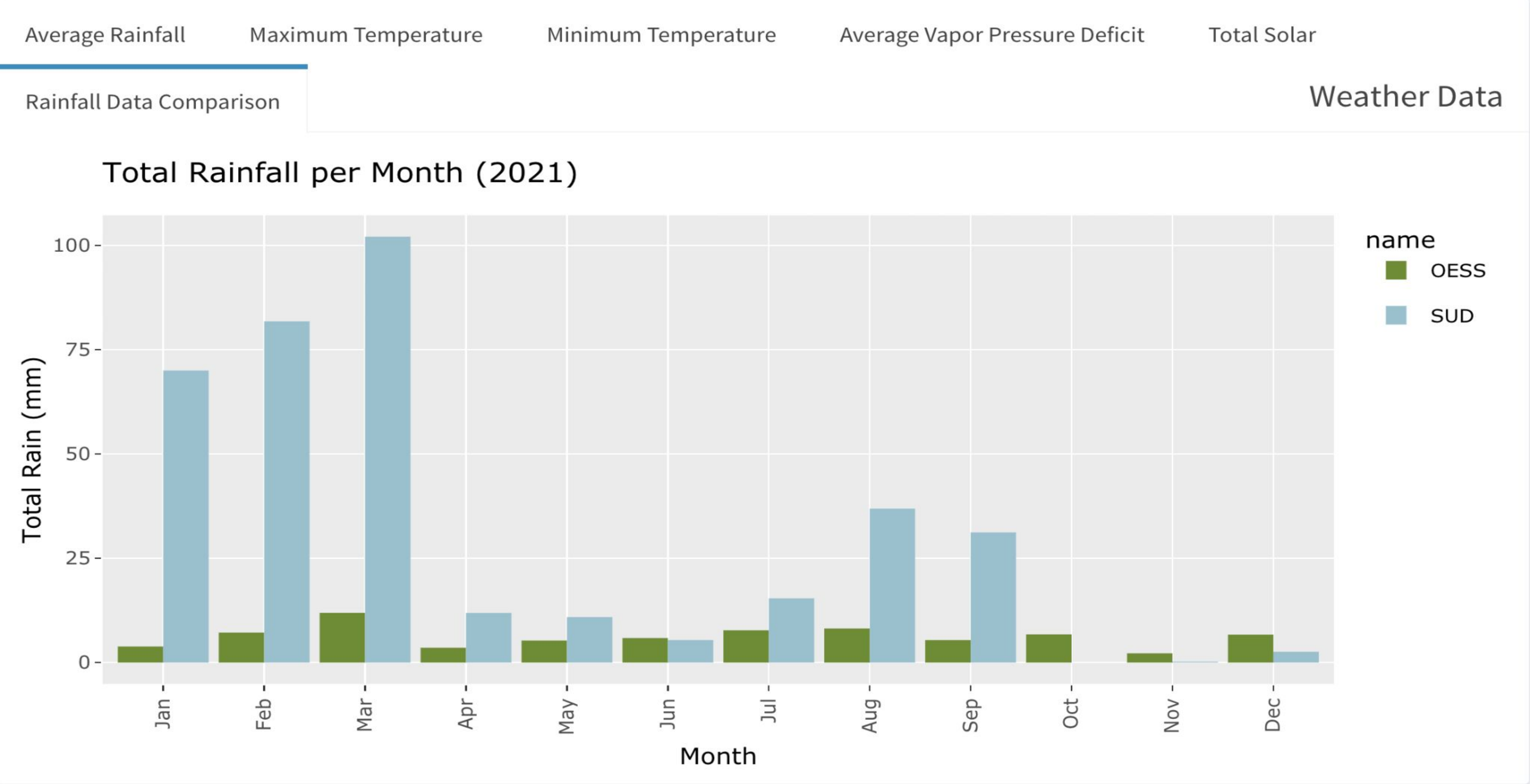
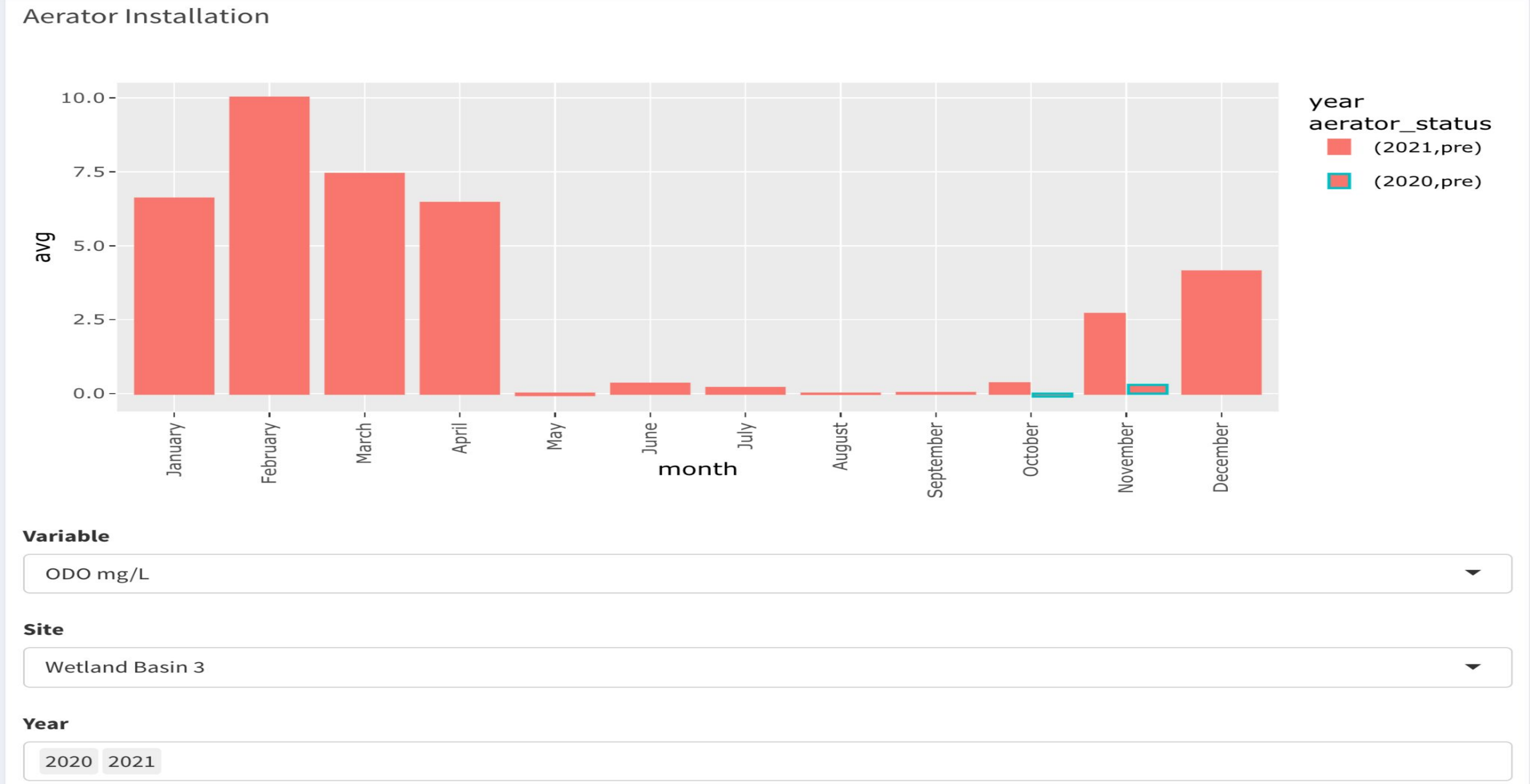

Monthly
Daily
Hourly
Trends
Monthly Trends in Variables
400
300
200
100
0
Cond µS/cm
site
Lagoon C
Wetland Basin 3
January
February
March
April
May
June
July
August
September
October
November
December
Month
Select Monthly:
Year
2021
Site
Wetland Basin 3
Lagoon C
Variable
Cond µS/cm
Max Temperature
Min Temperature
Total Rainfall
Solar Measure

Figure 4



Average Rainfall
Maximum Temperature
Minimum Temperature
Average Vapor Pressure Deficit
Total Solar
Rainfall Data Comparison
Weather Data
Total Rainfall per Month (2021)
100
75
50
25
0
Total Rain (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
name
OESS
SUD

Figure 5


Aerator Installation
avg
10.0
7.5
5.0
2.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December
month
year
aerator_status
(2021,pre)
(2020,pre)
Variable
ODO mg/L
Site
Wetland Basin 3
Year
2020
2021

Impact and Next Steps

We interpreted and organized the data so that it can be used to collect future results of wetland wastewater treatment. Furthermore, we visualized trends of water quality variables, so that Dr. McGrath can evaluate the difference in water quality pre and post-aerator. With the recent installation of an aerator, the incoming wetland data is going to be crucial in understanding the impact that wetlands could truly have on our wastewater treatment systems. This makes the data pre-aerator even more important in determining the effectiveness of the wetlands post-aerator. With our dashboard being dynamic and updatable, this will allow for easy comparisons moving forward.

From these results, we are hopeful that our dashboard will allow Dr. McGrath to make appropriate decisions in order to improve the water quality in the wetlands. Furthermore, we are excited to see how water quality will change over this year after the implementation of the aerator.

If we were able to continue this work further, our team would recommend continuing working with the updated data and considering the post aerator factor. The aerator is predicted to improve the functionality of the wetlands and produce much more desirable results. Using the future post aerator data, it would be important to confirm or deny this prediction and create visualizations that can help to analyze the results more in depth.

Our Team

Harrison Lowery C '24

Harrison Lowery is from Homewood, AL and is an English major at Sewanee: The University of the South. Harrison is a member of the Sewanee-Monteagle Rotary Club and a member of Phi Gamma Delta.

Tessa Shackelford C '24

Tessa Shackelford is from Sewanee, TN and is an Environment & Sustainability major at Sewanee: The University of the South. She is a member of the Order of the Gown, a site leader for the Bonner/Canale program at the university farm, a member of Theta Kappa Phi, and plays for the women's tennis team.

Lauren Hutchison C '22

Lauren Hutchison is from Aldie, VA and is an Environment & Sustainability major at Sewanee: The University of the South. She is a member of the Order of the Gown and played for the women's soccer team.