CPLN680 Capstone

Waterfront Recreation Sites in Philadelphia

A Dashboard Developed for Residents and Visitors

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Background and Motivation:

Although the Delaware River was named River of the Year for 2020 and serves fifteen million people for drinking, fishing, kayaking, and other recreation, there is still a 27-mile stretch of the river between Philadelphia, PA, Camden, NJ, and Chester, PA that needs improvement. This stretch is considered safe for only secondary contact recreation, which means immersion and ingestion, and any high degree of body contact with the water, might be dangerous for people. Many projects are currently working on improving this. By finding the relations between CSOs, precipitation, and water quality, this project aims to find the potential for waterfront recreation under the current situation and help adjacent communities to be informed on the fairest opportunities for each resident to access recreational activities in the safest possible way.

Research Question:

Which waterfront recreation sites should people visit, and what activities are available and safe depending on weather conditions and water quality?

Literature Review:

River Network brings people and communities together to protect and restore rivers and other bodies of water that sustain all life. Gayle Killam and Ellen Kohler wrote *Recreational Uses in the Delaware River - Laying the Foundation* in 2006. Besides normal bacteria such as E. coli and Enterococci, they mention that additional pollutants, such as nitrogen and phosphorus loads that encourage nuisance or harmful algae outbreaks, and various toxic chemicals present in the Delaware River Basin due to industrial activity and agricultural practices, must be addressed in order to fully support swimming and boating.

In 2021, Francisco Duran Vian and the team classified riverfront parks and walks based on two criteria: 1) the position of the open space within the river corridor, and 2) the access possibilities from the open space to the water. They also determined how necessary it is to assume and respect the presence of the river in development processes when planning riverfronts.

Waterfronts really influence how people choose recreational sites. So, water qualities and weather conditions that have effects on waterfronts is essential information for people to have access to. The next steps of previous studies should include an examination of how to provide concise and real-time information to residents and visitors.

Data:

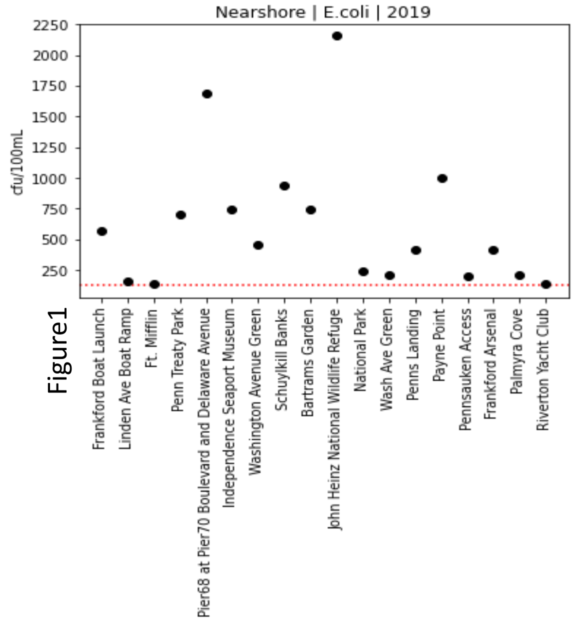
Table 1. Data used for the analysis of relation between the CSO, precipitation, and water quality.

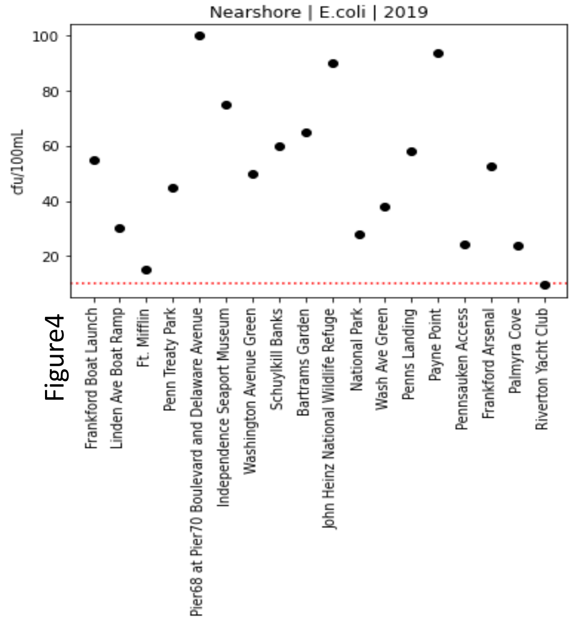
Data	Source	Notes
Water quality	DRBC	2019, 2020, 2021
	PWD	2019
	The Water Center at Penn	2021 summer
Precipitation	PWD	
CSO info	OpenDataPhilly	Location shapefile
Recreation location and use		Collected and cleaned up by the Water Center at Penn and Michael Baker International

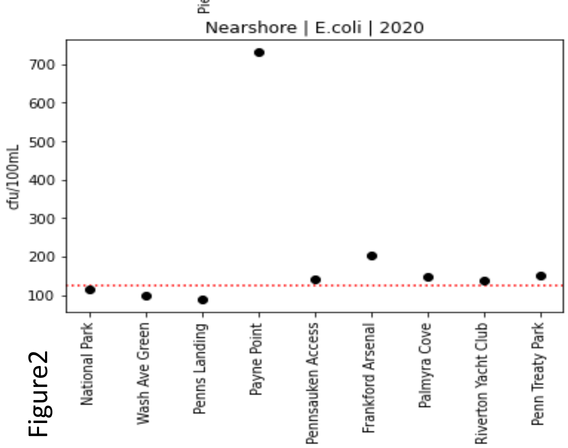
In this table, water quality refers to bacteria levels collected by DRBC, PWD, and the Water Center at Penn. I participated in the sample collecting process last summer for the water center. PWD provides precipitation data. The CSO shapefile was downloaded from OpenDataPhilly. Recreation locations and their use were collected and completed by Michael Backer International and myself as a research assistant at the Water Center. The recreation-related part was given up by the Delaware River Roadmap team at the Water Center at Penn. However, I still find that it should be attractive to the public. This report proposes that the data be reused and provided to people who need it when planning visits to waterfront recreation locations.

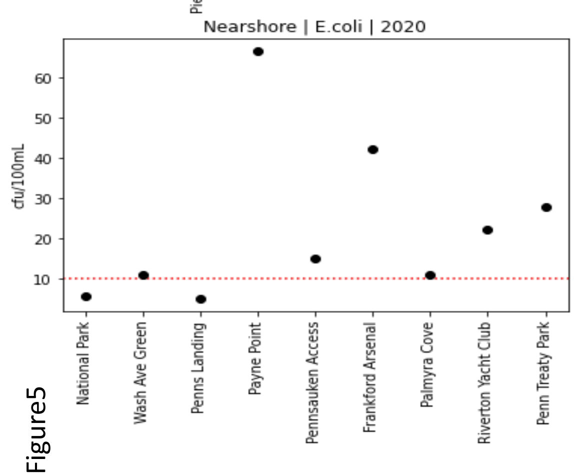
Methodology and Results:

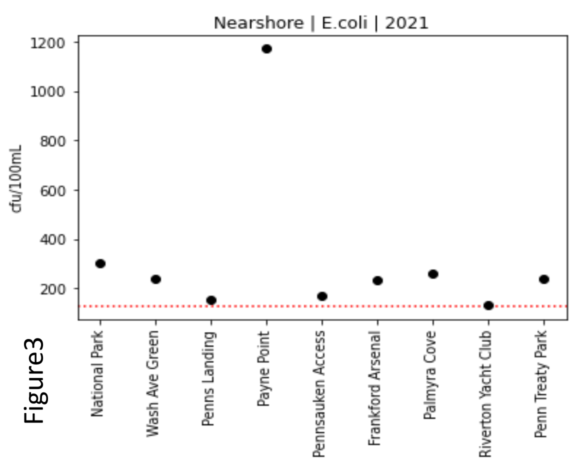
As mentioned in the literature review section, E. coli and Enterococci are usually good water quality indicators for freshwater recreation sites. In the EPA's recommendation, which can be found in their report *Rationale for the Development of Ambient Water Quality Criteria for Bacteria Protection of Recreational Use*, to meet the EPA's Recommendation 1 criteria for primary contact recreation, the average E. coli level in a 30-day period does not exceed 126 CFU/100mL (where the average is calculated as the geometric mean or GM), and there is no more than a 10% excursion frequency of the Statistical Value Threshold (STV) of 410 CFU/100mL in the same 30-day period. For Enterococci, the GM should not exceed 35 CFU/100mL, and the STV is 130 CFU/100mL.











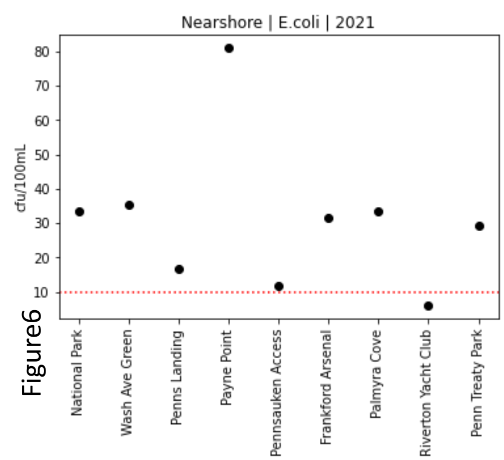


Figure 1, 2, &3. The average E. coli level in 2019, 2020, 2021 (where the average is calculated as GM in 2019, 2020, 2021; red line is 126 CFU/100mL)

Figure 4, 5, &6. Percent Exceedance E. coli in 2019, 2020, 2021 (red line is EPA-recommended Statistical Value Threshold of 410 CFU/100 mL)

All of the nearshore E. coli data collected by each monitoring program was aggregated, and the percent of samples with E. coli levels exceeding the EPA-recommended criterion was calculated for each monitoring program. These figures show the yearly water quality situation of these waterfront recreation sites.

The factors that may influence the water quality levels were also studied, the first being wet weather pollution. The percent exceedance was calculated for the subset of samples collected during wet weather conditions, and for the subset of samples collected during dry weather conditions.

Table 2. Summary of nearshore E. coli levels measured by DRBC and PWD, showing the percent of samples exceeding the EPA-recommended geometric mean threshold of 126 CFU/100 mL.

MONITORING PROGRAM	TOTAL PERCENT EXCEEDANCE	WET WEATHER PERCENT EXCEEDANCE	DRY WEATHER PERCENT EXCEEDANCE
DRBC, 2019	70%	78%	65%
DRBC, 2020	54%	78%	49%
PWD, 2019	80%	89%	67%

As shown in TABLE 2, E. coli levels were observed to exceed the EPA-recommended geometric mean threshold most frequently in the PWD 2019 monitoring program (80% of samples) and least frequently in the DRBC 2020 monitoring program (54% of samples). E. coli levels were observed to exceed the threshold more frequently during wet weather conditions than dry weather conditions. This suggests that nearshore water quality conditions are generally less safe for swimming during wet weather conditions. Even during dry weather conditions, however, the percent exceedance of the EPA-recommended geometric mean value was relatively high. About two thirds of samples collected by the 2019 programs had E. coli levels exceeding the 126 cfu/100 mL threshold.

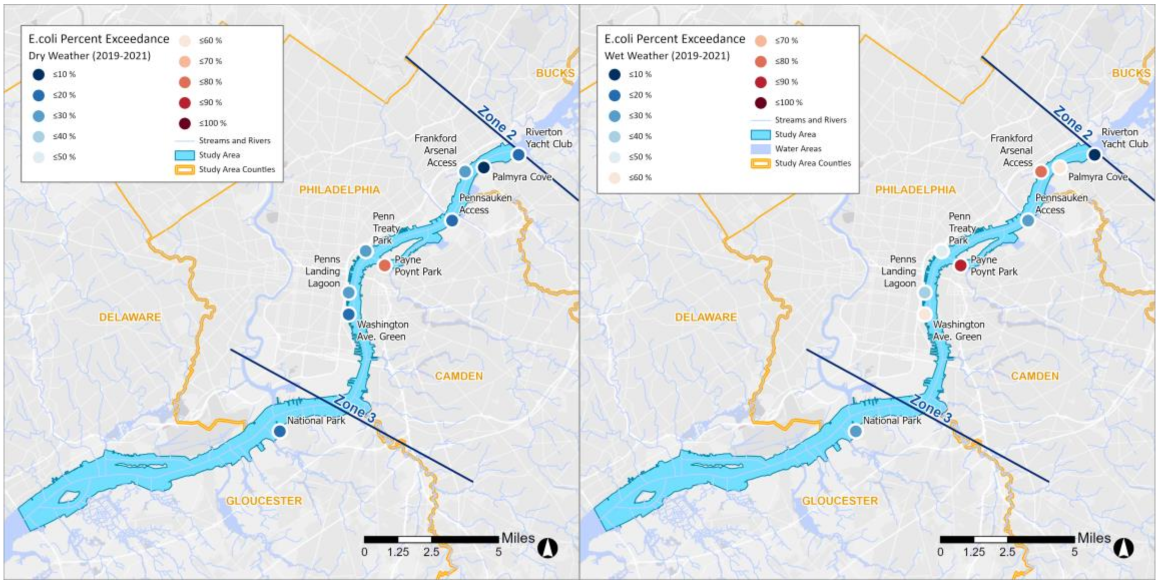


Figure 7. Percent exceedance of Statistical Value Threshold of wet and dry weather of E. coli in 2019 - 2021

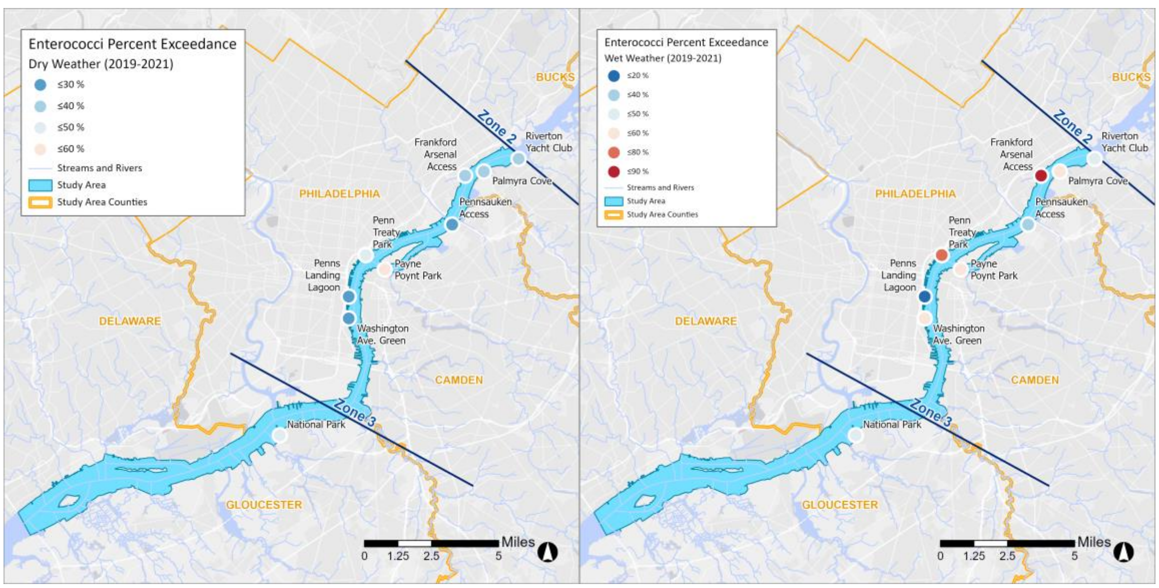


Figure 8. Percent exceedance of Statistical Value Threshold of wet and dry weather of Enterococci in 2019 - 2021

These maps are a data visualization of wet and dry weather influences water quality. A qualitative assessment was supplemented with a statistical hypothesis test. Student’s t-test was used to assess whether the differences in geometric mean concentrations between dry weather and wet weather conditions were statistically significant.

Table 3. P values resulting from Student's t-test for E. coli concentrations during wet and dry conditions

Site (Program, River Mile)	**P value**
Linden Avenue Boat Launch, PA (PWD, 110.3)	0.163
Riverton Yacht Club, NJ (DRBC, 108.1)	*0.0459
Palmyra Cove, NJ (DRBC, 106.7)	*<0.0001
Frankford Arsenal, PA (PWD, 106.1)	0.06
Frankford Boat Launch, PA (DRBC, 106.1)	*0.0002
Pennsauken Access, NJ (DRBC, 104.3)	*0.0323
Pyne Poynt Park, NJ (DRBC, 101.3)	0.3067
Penn Treaty Park, PA (PWD, 101)	0.0681
Penn Treaty Park, PA (DRBC, 101)	*0.0081
Independence Seaport Museum, PA (PWD, 99.5)	*0.0406
Penn's Landing Lagoon, PA (DRBC, 99.5)	*0.0083
Washington Avenue Green, PA (PWD, 98.7)	*0.0222
Washington Avenue Green, PA (DRBC, 98.7)	*0.0002
National Park, NJ (DRBC, 92.03)	0.6902
Ft. Mifflin, PA (PWD, 91.54)	*0.0167
Schuylkill Banks, PA (PWD, 92.4)	0.1363
Bartram's Garden, PA (PWD, 92.4)	0.1052
John Heinz Wildlife Refuge, PA (PWD, 85.5)	*0.003

Table 4 shows the P values for rejecting the null hypothesis. The data suggests that wet weather is a significant driver of water quality for monitoring sites with P values less than 0.05. It is notable that P values were greater than 0.05 for seven of the monitoring sites. Wet weather pollution may not be the primary determinant of fecal pollution levels at these seven monitoring sites.

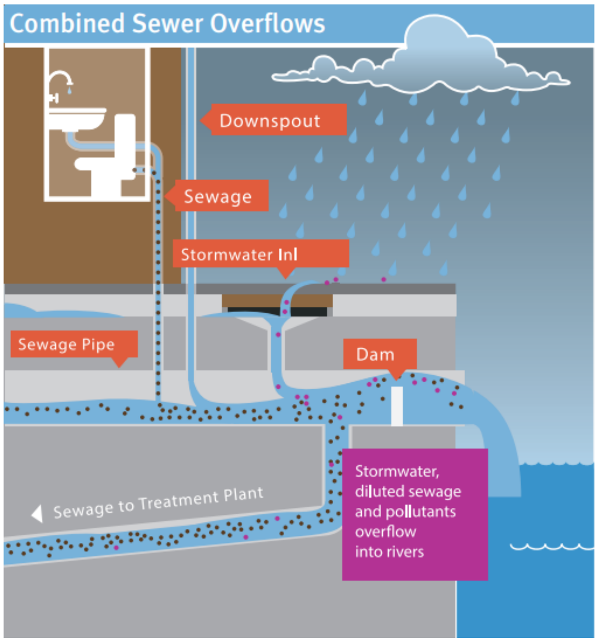


Figure 9. The system of combined sewer overflows.

Before talking about other aspects, it is important to understand that the presence of precipitation is not the only factor; the intensity of rainfall in a certain time is also important. In a combined sewer system, only wastewater from homes flows into our combined sewers and then to the treatment plant during dry weather. However, in wet, stormy weather, these combined sewers cannot always handle the additional water. Sewage from homes, along with dirty water from the streets, can easily overflow into waterways in these conditions. This situation could be eliminated by adding green tools, but the overflow issue has not been fully solved so far.

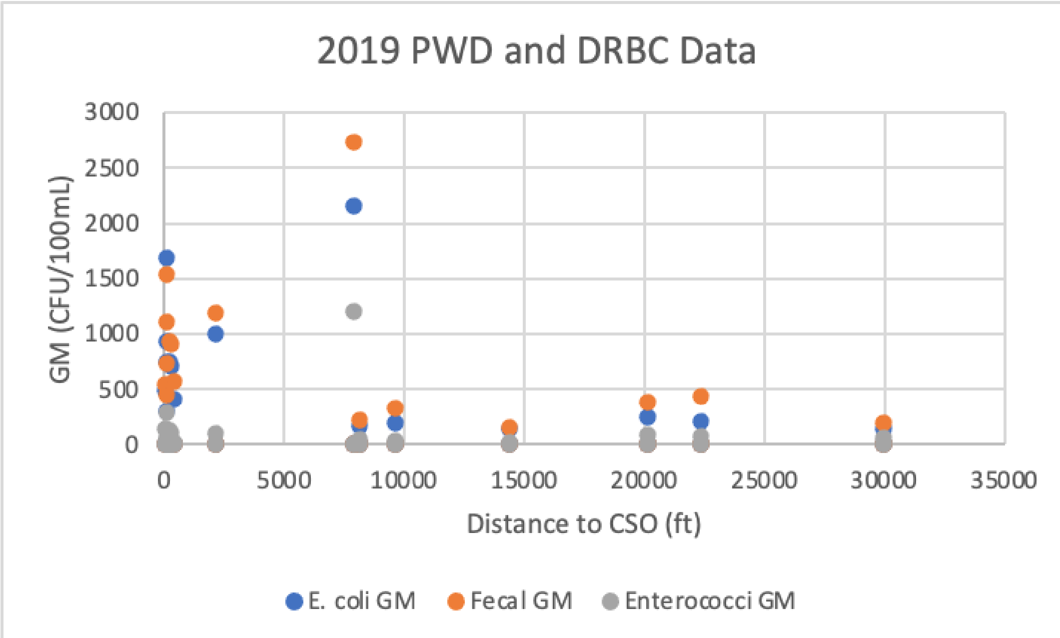


Figure 10. The geometric mean E. coli concentration at both DRBC and PWD monitoring sites against the distance from the monitoring site to the nearest combined sewer outfall

Combined sewer overflows (CSOs) are one of the ways that human sewage can be released into urban rivers. Other ways that human sewage can enter urban rivers include sanitary sewer overflows and leaks and illegal connections between sanitary sewers and separate storm sewers. Based on the large areas served by combined sewer systems in Philadelphia, Camden, and Chester, CSOs are assumed to be one of the most significant contributors to wet weather fecal pollution within the study area. As shown in Figure 10, the highest geometric mean concentrations are observed for monitoring sites within 9,000 feet of a combined sewer outfall. Lower geometric mean concentrations are observed for monitoring sites greater than 9,000 feet from a combined sewer outfall. While the DRBC and PWD data are consistent with the hypothesis that CSOs are a large contributor to bacterial concentrations, other environmental parameters, such as tidal range and sediment resuspension, may influence the bacterial concentration and persistence that are correlated with proximity to CSOs.

Application:

A web application can help increase notification, response, and prediction of environmental events of significance. The knowledge of environmental conditions or the ability to forecast them can facilitate increased tourism and recreation. To make a dashboard for visitors to use, it is first necessary to simply forecast river water quality by providing bacteria levels. However, sample results sent to the laboratory take at least 48 hours, which is not very helpful to visitors who wish to know if it is safe to swim that day and in case of forecasting.

The forecast web app for Schuylkill River was then considered. Samplings of the Schuylkill River and its tributaries show that fecal coliform concentration can increase by over 100 during a storm event. Fecal coliform contamination presents a problem for real-time systems because there is no fast and straightforward method to determine fecal coliform counts continuously. The study's available real-time data included flow, turbidity, and rainfall, which were related to stormwater discharges and combined sewer overflows.

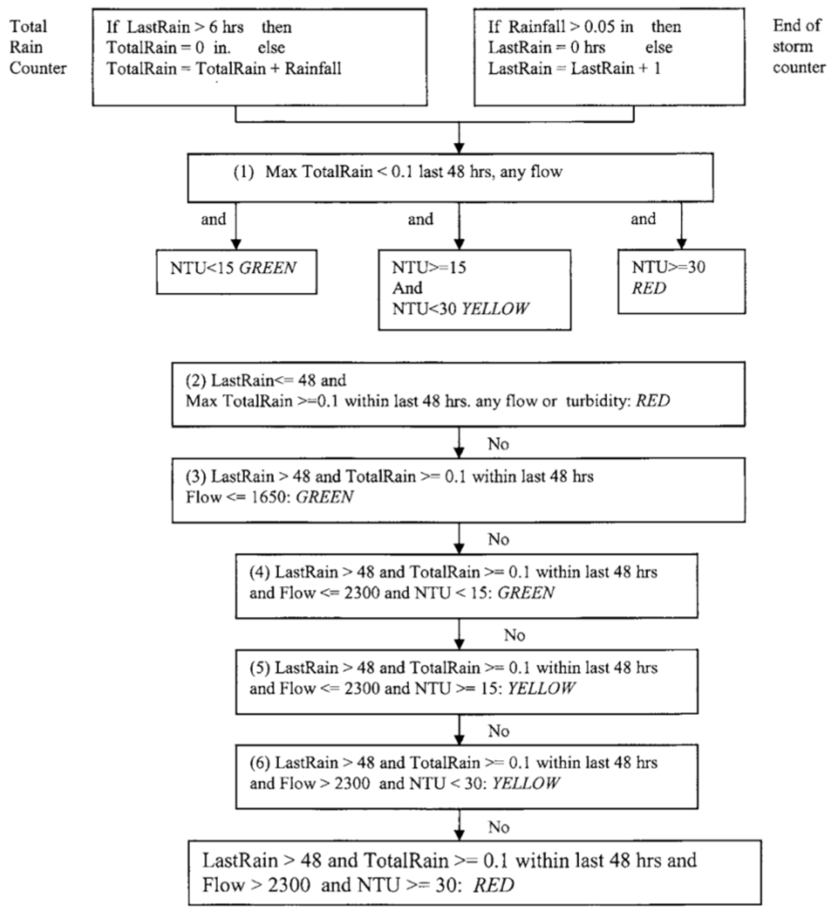


Figure 12. Philly RiverCast algorithm diagram

Maimone et al. 2007 note that Christensen et al. (2000, 2005) have published research correlating fecal coliform density to real-time data on several rivers in Kansas. One conclusion based on their work suggests that statistical patterns predicting fecal coliform density will vary depending on sources, climate, and flow patterns.

Because the statistical models are specific to each beach, the best model for each beach is based on a unique combination of environmental and water quality variables as explanatory factors. Even though it is not feasible to make models for each recreation site listed previously, it is still possible to provide related information to the public, and with a straightforward explanation of how these factors influence the fecal coliform level, residents or visitors could use this web app to have a general sense about the water quality for each waterfront recreation sites and decide which sites to visit. The concise information will be provided in the understanding factors tab, and other real-time information will be provided in the plan your visit tab. In the future, more studies based on each waterfront recreation location will take place, and algorithm diagrams could be developed for each site.

References

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