# Stormwater Monitoring at Beachwood Beach West and West Beach of Pine Beach

A Closer Look at Water Quality within Barnegat Bay

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## Abstract

This study examined the issue of poor water quality of Beachwood Beach West and West Beach at Avon Road of Pine Beach to determine possible bacteria sources and make recommendations for local municipalities to enforce. From June 27$^{th}$ to August 1$^{st}$, samples were collected in dry weather once every week and within the first and second flushes of storms delivering 0.10 inches of precipitation or greater. Samples were then analyzed for *E. coli* and *Enterococcus*, and supplemented with optical brightener readings to test for a human signature. Results demonstrated significant increases of *E. coli* and *Enterococcus* levels between first and second flushes, which points to possible evidence of storm drain blockages or infrastructure cross-connections. A linear regression between optical brighteners and *Enterococcus* yielded a low $R^2$ value of 0.00009, indicating no correlation. The combination of high optical brightener and bacteria levels detected within the storm pipes seem to suggest a sewage leak as a source since optical brighteners are found in laundry effluent, denoting human influence. Excessive levels of *E. coli* present in dry weather may be caused by sources of pet waste, boat pump-out waste, and other pollution washing into the water.


## Introduction

The Toms River section of the Barnegat Bay has long been known to have poor water quality ever since the NJ Department of Environmental Protection began the Coastal Cooperative Monitoring Program (CCMP) in 1985 (Rogers, Golden & Halpern). Through the CCMP, recreational waters are monitored for bacteria levels on a weekly basis. In 2004, New Jersey adopted the BEACH Act which calls for the single sample enterococcus standard of 104 colonies per 100 ml of water, replacing the former standard of 200 fecal coliforms per 100 ml water (*Testing the Waters 2006*). If samples demonstrate bacteria levels higher than the standard, beaches are closed and the waters must undergo retesting until the samples fall below the standard. During this retesting period "bracket sampling" may be utilized, which calls for sampling in multiple areas along the beach to determine the magnitude of the problem.

Since 2005, the Natural Resources Defense Council (NRDC) has identified Beachwood Beach West as a repeat offender on their Beach Bum list every year for violating the daily maximum bacterial standard numerous times (*Testing the Waters 2011: NJ*). The NRDC's most recent *Testing the Waters* report of 2011 states that Pine Beach's West Beach at Avon Road has been added to the Beach Bum list for exceeding the bacterial standard with 15% of its total samples.

This background information prompted a study to be conducted on the water quality of both Beachwood Beach West and West Beach at Avon Road in hopes to gain better perspective of the bacteria sources and offer suggestions to facilitate the situation.

According to the NRDC, the most common causes for poor water quality are pollution from stormwater runoff and sewage. The source of pollution at these beaches has not officially been concluded; however, many reports point to the stormwater outfall pipes that drain directly onto Beachwood Beach West and Pine Beach's West Beach as likely sources. During rainfall events, water flushes out storm drains connected to nearby roadways which carry domestic and industrial runoff containing fertilizers, pesticides, animal wastes, carrion, automotive oils, and other pollutants into the outfall pipes that empty into bathing beach waters (Kirwan 2005). Within the first 30 minutes of a storm, or "first flush," bacteria levels in the water are usually at their peak because this stormwater discharge tends to carry the most pollutants (*NPDES Storm Water Sampling Guidance Document*, 1992). In some cases, the second flush of a storm pipe may contain more bacteria than in the first flush, which creates a case for investigation. Thus, a stormwater monitoring plan was prepared in order to capture samples at peak flow levels from storm pipe outfalls and determine the magnitude of the problem at the proposed locations of study.

To identify the source of contamination, sampling is conducted before, during, and after rainfall events (Kirwan, 2005). In order to determine whether the pollution source is of human or animal origin, many studies now employ testing of optical brighteners. Optical brighteners are whitening agents added to laundry detergents, paper, and plastic materials to enhance their white appearance (Floresguerra, 2003). The occurrence of optical brighteners indicates a human signature, such that stormwater discharge containing laundry effluent may support evidence of sewage in recreational waters. This study incorporated the detection of optical brighteners in essence to track the source of the bacteria found in the water.

Due to a lack of rainfall in 2010, stormwater outfalls did not flush often; therefore, Beachwood Beach West closed for only 2 consecutive days after a single storm for high bacteria counts (*Testing the Waters 2011: NJ*). In that same year, Beachwood Beach West tested over the marine water standard on 7 other occasions, as did West Beach in Pine Beach on 4 counts, but neither closed. Beach closings are made according to data collected by the NJDEP under the CCMP in efforts to alleviate public health risks. When swimming, water containing bacteria may be accidentally swallowed and can cause a list of health afflictions including: pink eye, sore throat, ear infections, dysentery, hepatitis, and gastroenteritis (*Testing the Waters 2004*). Although the amount of precipitation seems to control the decision on beach closings, there is a great deal of concern when unaware swimmers dive into bathing beach waters that have remained open after testing for abnormally high bacteria levels. For this reason, the results of this study are crucial in making recommendations for beach closings so that public well-being is not compromised.

With the focus on the health of the Barnegat Bay, it is crucial to continue monitoring bathing beach waters. New Jersey beaches must be maintained to the best conditions so that the vitality of the shore environment is not lost.

## Locations

Prior to this project, the NJDEP identified hot spots along the Toms River with known water quality issues. Beachwood Beach West and West Beach near Avon Road of Pine Beach were selected from this list because they were located close to one another and thus would provide the most feasibility for stormwater monitoring. After touring both locations, the sites were chosen. Four sites were set at Beachwood Beach West (See Fig. 1), known as Location 1, including: Site 1 by a walkway near boat slips, Site 2 at an outfall pipe, Site 3 near the dock, and Site 4 at another outfall pipe. To note, during storm events samples were also taken within the storm outfall pipes at Sites 2 and 4 (See Figs. 2 and 3).


Figure 1. Sites at Beachwood Beach West. From left to right: Site 1(39°56'31.69"N, 74°11'8.12"W), Site 2 (39°56'32.26"N, 74°11'6.30"W), Site 3 (39°56'34.63"N, 74°11'3.26"W), and Site 4 (39°56'29.28"N, 74°10'56.53"W).

Figure 2. Storm pipe at Site 2 of Beachwood Beach West.

Figure 3. Storm pipe at Site 4 of Beachwood Beach West.

Three sites were also selected at West Beach of Pine Beach (See Fig. 4), known as Location 2, including: Site 1 near boat slips, Site 2 at an outfall pipe, and Site 3 off the dock. Additional samples were taken within the storm outfall pipe at Site 2, as well.


Figure 4. Sites at Location 2, West Beach, Avon Road in Pine Beach. From left to right: Site 1 (39°56'27.47"N, 74°10'22.82"W), Site 2 (39°56'28.46"N, 74°10'17.09"W), and Site 3 (39°56'26.62"N, 74°10'8.61"W).

## Methods

As requested by the NJDEP, a Quality Assurance plan was formulated to ensure that the samples would be collected properly, safely, and accurately. The NJDEP categorized the Quality Assurance plan for this study into Tier B of the Watershed Watch Network of New Jersey. Tier B qualifies volunteers as stewards who, with informal to formal training, can identify water quality issues for investigation and provide data for local decision makers to utilize (Donkersloot, 2008). With a plan in place, all measures taken had to be within protocol of the NJDEPE Field Sampling Procedures Manual for Public Recreational Bathing waters. The Quality Assurance plan along with the methodology and the sampling parameters list can be found in the Appendix at the end of this report.

The Coliscan Easygel® (Micrology Laboratories) and IDEXX Enterolert®

(IDEXX) methods were used to identify counts of *E. coli* and *Enterococcus* bacteria, respectively. The YSI® 85 Handheld Instrument functioned to measure temperature, salinity, percent saturation dissolved oxygen, concentration of dissolved oxygen, and conductivity. Rutgers Cooperative Extension of Ocean County provided the Aquaflor® Handheld Fluorometer (Turner Designs) to analyze levels of turbidity and optical brighteners in the samples. In addition, prior to equipment failure a portion of the samples were tested for pH using the Oyster meter.

A dry weather sampling session was conducted every Monday morning to set a baseline of data for our samples. During baseline sampling, one sample was collected from each site at both locations. Stormwater sampling, on the other hand, required more patience and planning. For stormwater sampling, close attention was paid to the Doppler radar on NOAA's weather.gov station and the Weather Channel in order to effectively track storms with. Precipitation of 0.10 inches or more qualified as a storm event. When a storm proved worthy of sampling, alerts were sent out via phone calls and the team went out to sample. In a storm event, samples were collected during the first 30 minutes, or first flush, and the second 30 minutes, or second flush.

Samples were collected in Sodium thiosulfate-treated Whirlpaks®, to prevent any chlorine in the water from interfering with water quality readings, and then transported to the lab on ice. At the lab (See Fig. 5), samples were tested for physical and chemical water quality parameters with the YSI-85®, Aquaflor® Handheld Fluorometer, and Oyster meter. When using the YSI-85®, the probe was inserted into the individual WhirlPaks to determine the readings of the aforementioned parameters. The oyster meter was used in the same manner as the YSI-85® to test pH. To determine optical brightener and turbidity levels, a few drops of sample water was put into a cuvette that was inserted into the Aquaflor® Fluorometer, covered, and read. Additionally, the NJDEP provided a jar of a 5% Tide laundry detergent concentration equivalent to 50 relative fluorescence to use as the optical brightener standard for the Aquaflor® Fluorometer. For comparison, samples were also taken at the Ocean County Utilities Authority to test optical brightener levels in the secondary treatment effluent and the primary clarifier. All equipment was carefully triple rinsed with deionized water after testing each sample in the experiment.

Samples were plated with ECA Check Easygel media using 1 mL of sample water with the Coliscan Easygel® method (Micrology Labs). Samples were also plated with the IDEXX Enterolert® method (IDEXX) using the marine water standard of 10 mL sample water to 90 mL deionized water. Baseline samples were plated in the IDEXX Quanti-Tray wells and stormwater samples were plated in the IDEXX Quanti-Tray 2000 wells. After plating both methods, the samples incubated in separate incubators for a 24-hour period and were analyzed for bacteria colonies the following day. Petri dishes containing dark blue or purple colonies (See Fig. 5) indicated *E. coli*, which were counted and multiplied by 100 to obtain the number of colonies per 100 mL water. The IDEXX trays were analyzed underneath a UV light because wells will glow if containing *Enterococcus* (See Fig. 7). According to which specific tray was used, the Quanti-Tray and Quanti-Tray 2000 Most Probable Number (MPN) tables were referred to when determining the MPN corresponding with the number of positively glowing wells for each sample. The actual MPN was then multiplied by a dilution factor of 10 to keep within marine water standards (IDEXX).


Figure 5. Lab station. Incubator, IDEXX sealer, and cooler.

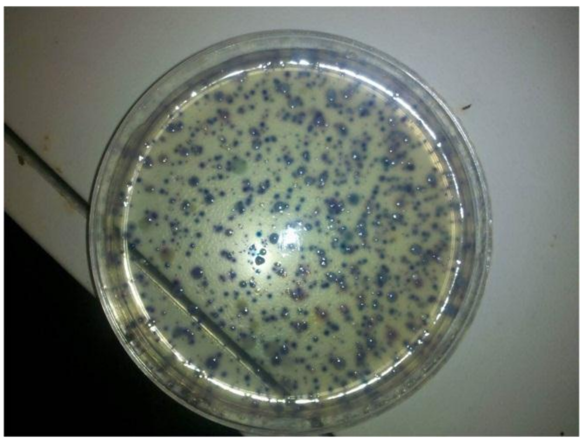

Figure 6. Coliscan Easygel plate containing *E. coli* indicated by dark blue colonies in a sample collected from a problematic storm pipe at Beachwood Beach West on July 8, 2011.

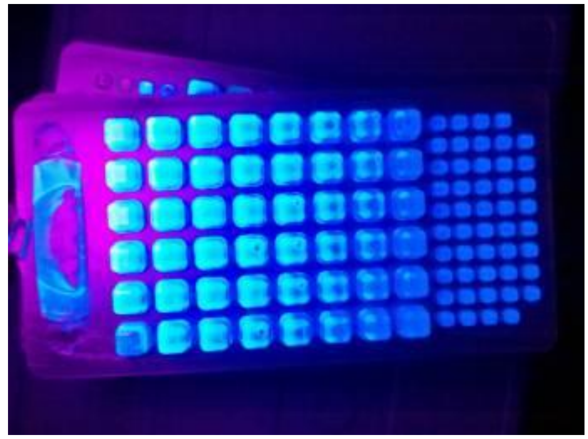

Figure 7. IDEXX Quanti-Tray 2000. IDEXX Quanti-Tray 2000 containing *Enterococcus* indicated by many fluorescing wells of a sample collected from Beachwood Beach West on July 29, 2011.

## Results

Baseline sampling was conducted for a total of 5 sampling sessions from June 27 to August 1. A total of 4 storm events were captured between the two locations of study on the following dates: July 3, July 8, July 25, and July 29. As a disclaimer, any site illustrated on a graph containing the letter 'i' next to it indicates that a sample was taken inside of the storm pipe at that site.

The figure shown below (See Fig. 8) illustrates the average *E. coli* levels found at Beachwood Beach West during dry (baseline) weather, and the first and second flushes. On average, all samples tested well over the freshwater standard of 200 colonies per 100 mL at levels of approximately 650 - 18,725 colonies per 100mL.

Figure 9 displays the average *E. coli* levels at West Beach of Pine Beach. Similarly, averages of all of the samples taken at this location tested over the freshwater bacteria standard with results between 260 - 8333.3 colonies per 100mL. At both locations, the highest levels of *E. coli* occurred during the second flush of a storm.

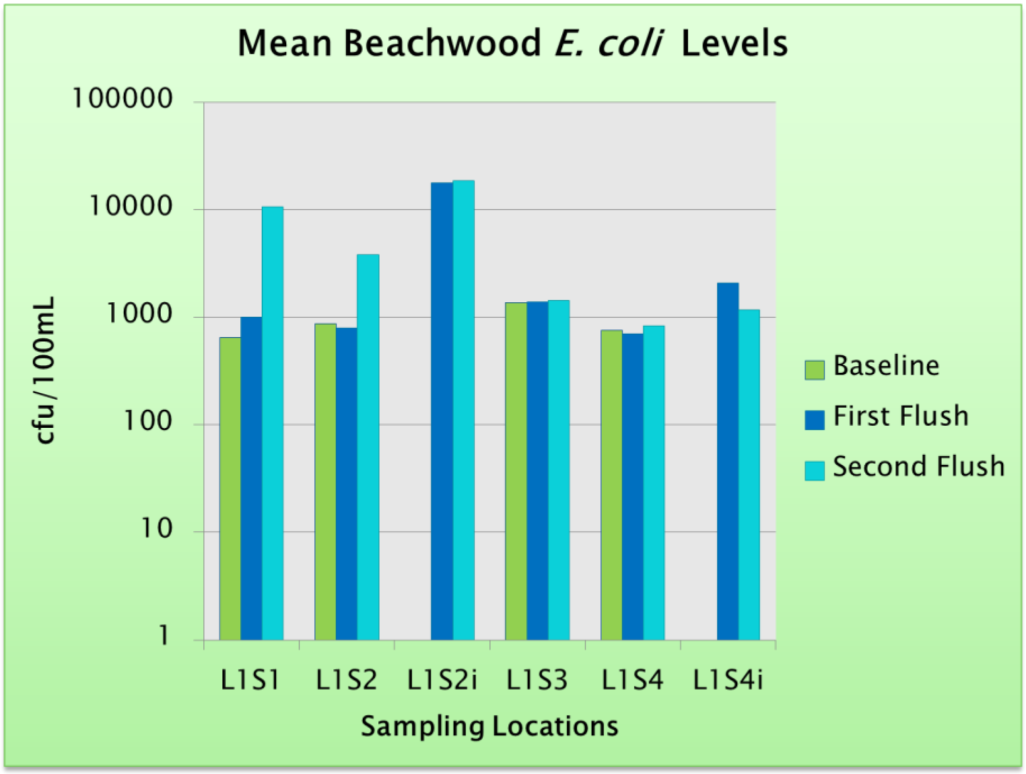


Figure 8. Average *E. coli* levels at Beachwood Beach West.

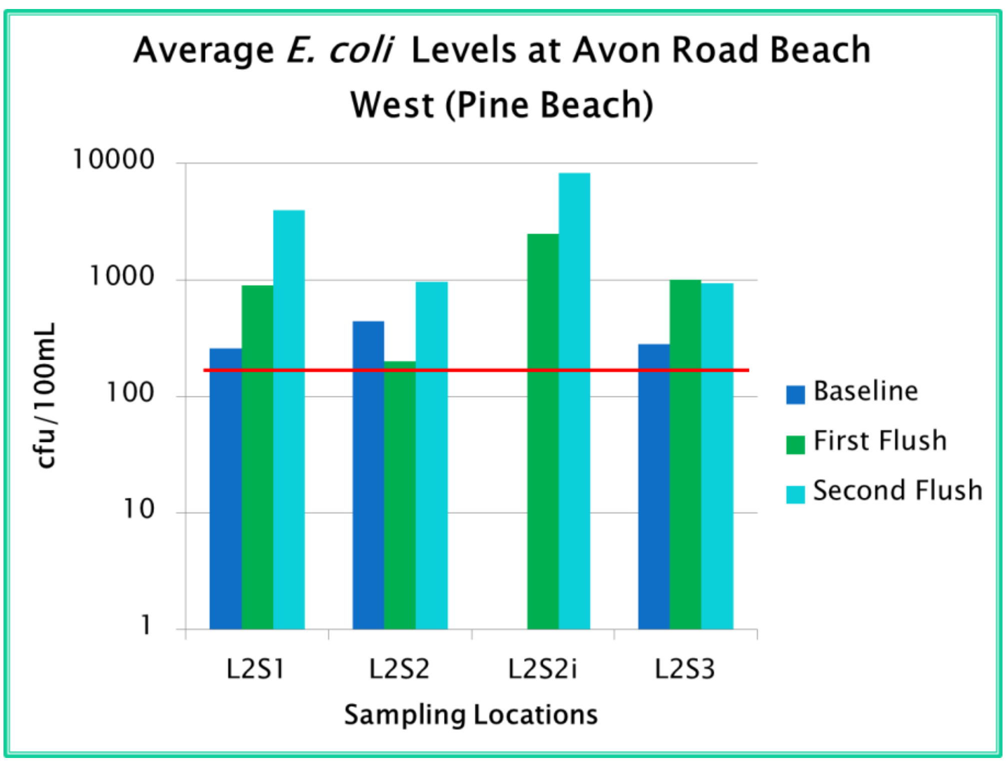


Figure 9. Average *E. coli* levels at West Beach of Pine Beach.

During storms, samples taken within storm pipes at Beachwood Beach West and West Beach of Pine Beach on average demonstrated extremely high levels of *E. coli* (See Fig. 10). In both cases, the first and second flush contained counts of *E.* coli of magnitudes more than the standard. The highest reading occurred inside the storm pipe at Site 2 of Beachwood Beach West during the second flush on July 8th with 41, 900 colonies *E. coli* per 100mL of water. This sample also read at 236 for optical brighteners. Furthermore, counts of *E. coli* generally increased in the second flush compared to the first flush.

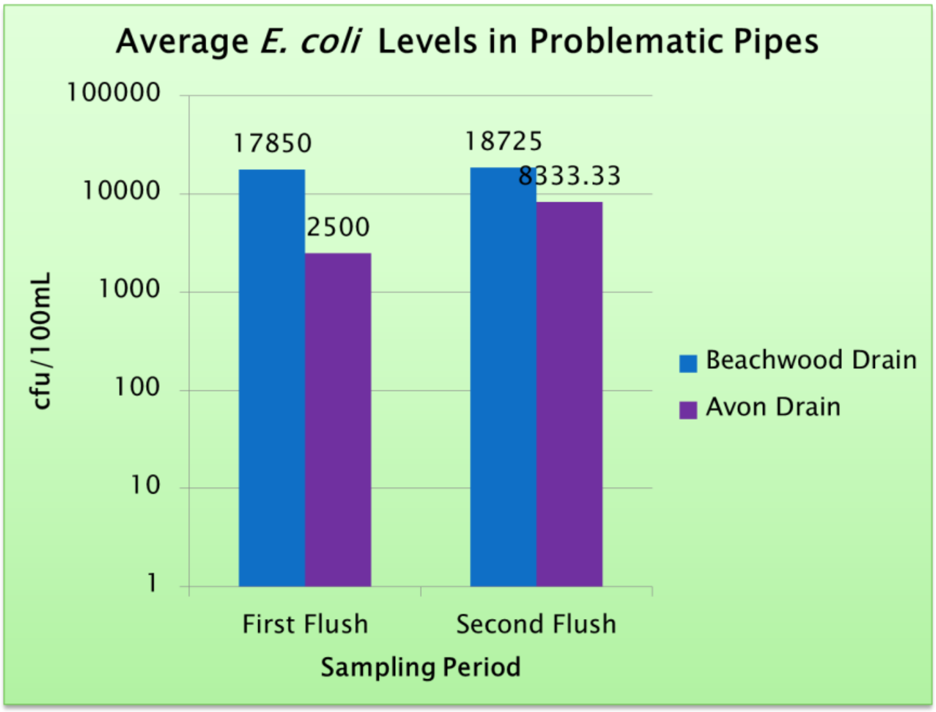


Figure 10. Average *E. coli* Levels in Storm Pipes of Beachwood Beach West and West Beach of Pine Beach.

Due to incubation error in the early stages of sampling, the NJ DEP's *Enterococcus* data (*Ocean County Ocean Monitoring Results*) was used for all dates prior to July 25. This data was incorporated with the study's data from later dates and averaged together for all sites at both locations.

Below, Figure 11 shows the average *Enterococcus* levels at each site of Beachwood Beach West. Average levels of *Enterococcus* ranged between 20 - 24.2 MPN for baseline sampling. Levels of *Enterococcus* in the first flush read at 77.5 – 88 MPN and increased during the second flush to levels of 264.4 – 4937.8 MPN.

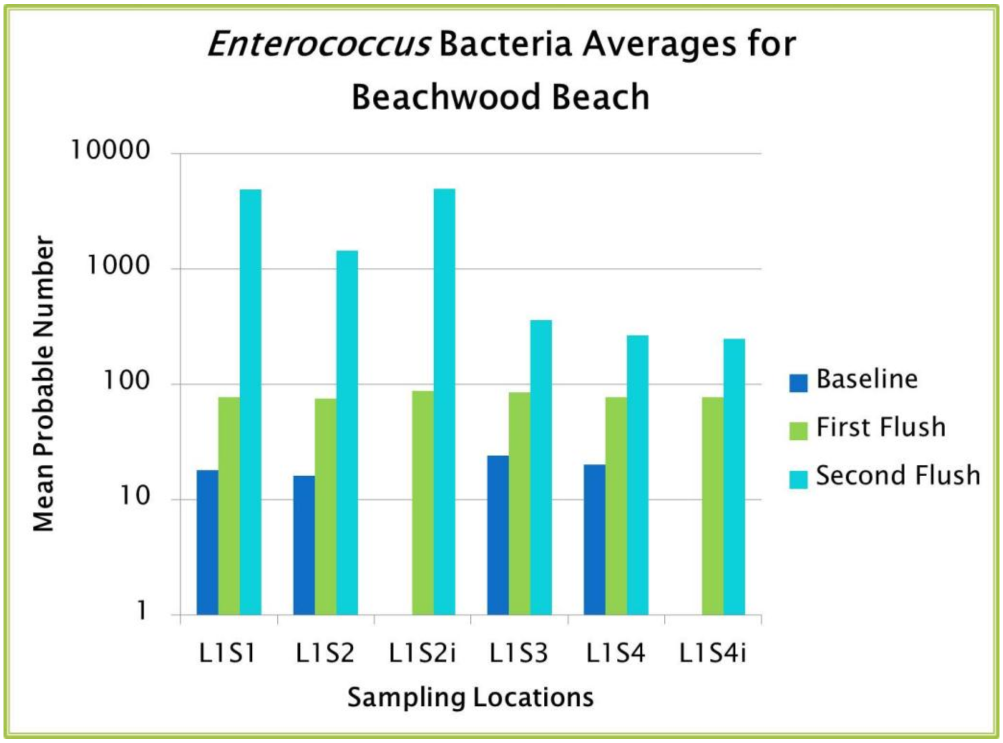


Figure 11. Average *Enterococcus* Levels at Beachwood Beach West.

Figure 12 displays the average *Enterococcus* readings for baseline, first flush, and second flush samples taken at West Beach of Pine Beach. The average *Enterococcus* levels for baseline samples taken at West Beach were between 18 - 28.8 MPN. Readings increased during the first flush to levels of 35 - 72 MPN and subsequently during the second flush up to 230.6 - 3415.6 MPN.

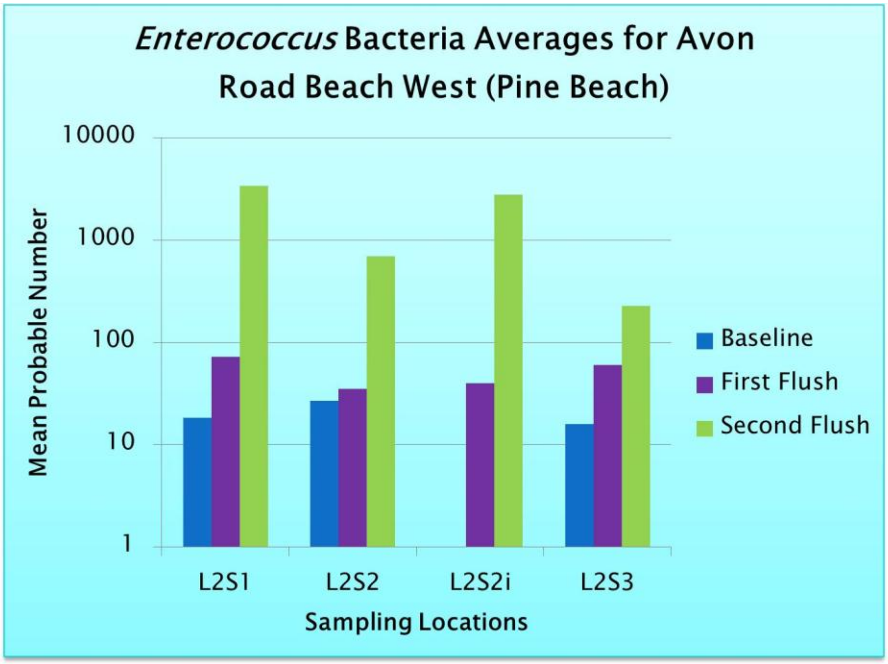


Figure 12. Average *Enterococcus* Levels at West Beach of Pine Beach.

The highest counts of *Enterococcus* were measured in samples taken inside the storm pipes at both Beachwood Beach West and West Beach of Pine Beach (See Fig. 13). The average readings in the storm pipe at Beachwood Beach West and West Beach of Pine Beach increased significantly between the first and second flush.

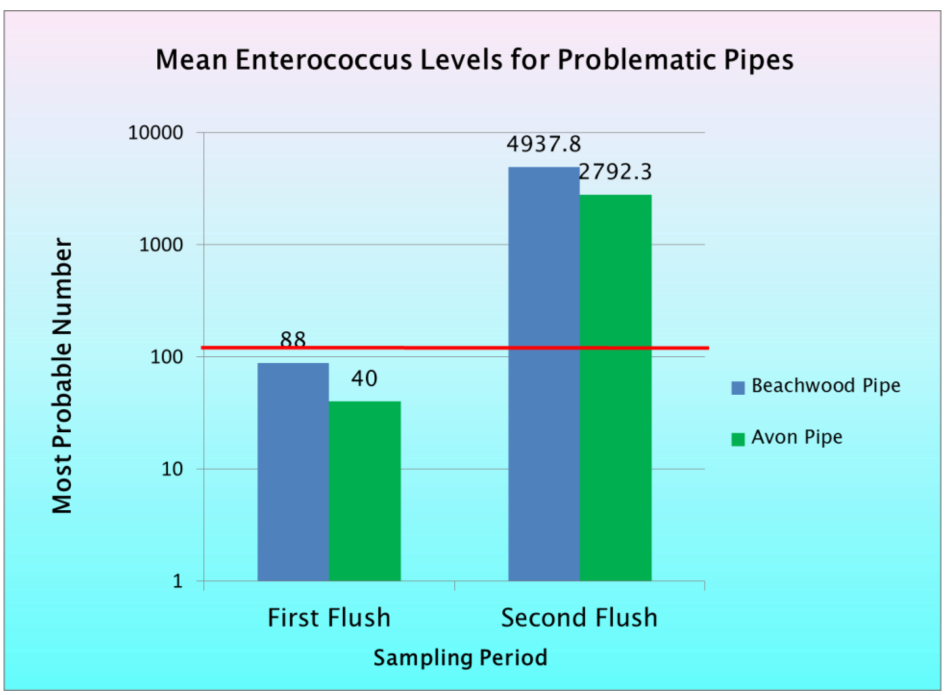


Figure 13. Average *Enterococcus* Levels in Storm Pipes of Beachwood Beach West and West Beach.

The mean optical brightener readings were graphed according to their sampling interval to determine when significant readings occurred at both Beachwood Beach West and West Beach of Pine Beach (See Figs. 14 and 15). On average, levels ranged as low as 56.45 at Site 4 of Beachwood Beach West during the first flush and as high as 181.13 inside the pipe at Site 2 of Beachwood Beach West. Of all the data, the highest optical brightener reading of 1322 occurred at Site 2 of Pine Beach's West Beach during baseline sampling on one occasion, which accounted for the high average of optical brightener readings at this particular site.

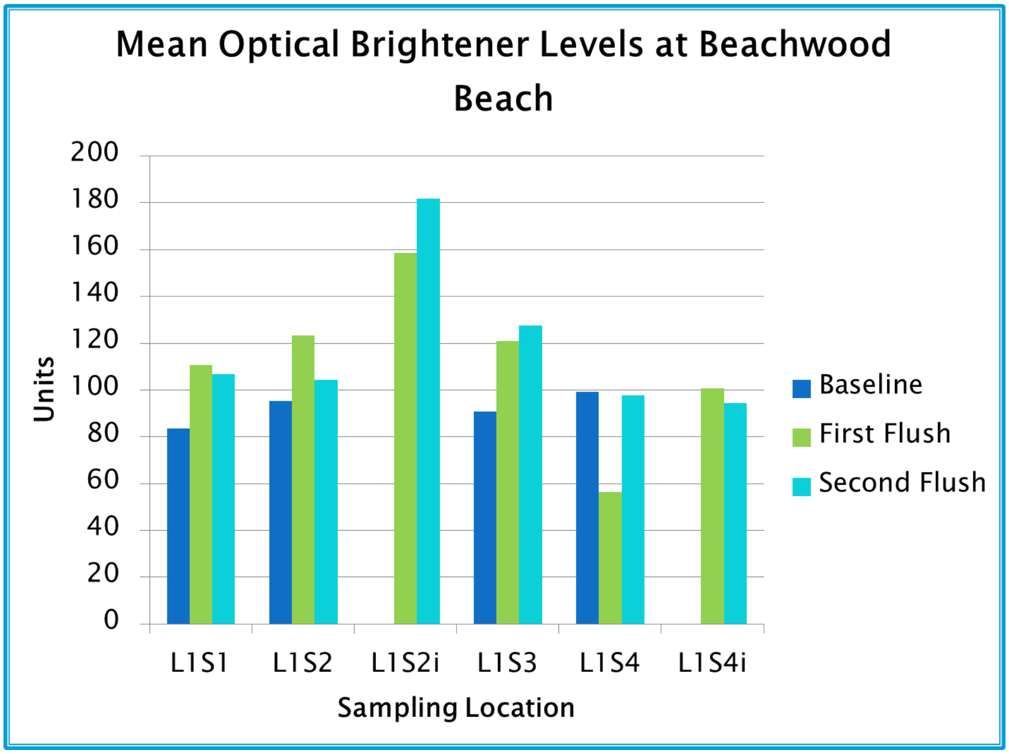


Figure 14. Average Optical Brightener levels at Beachwood Beach West.

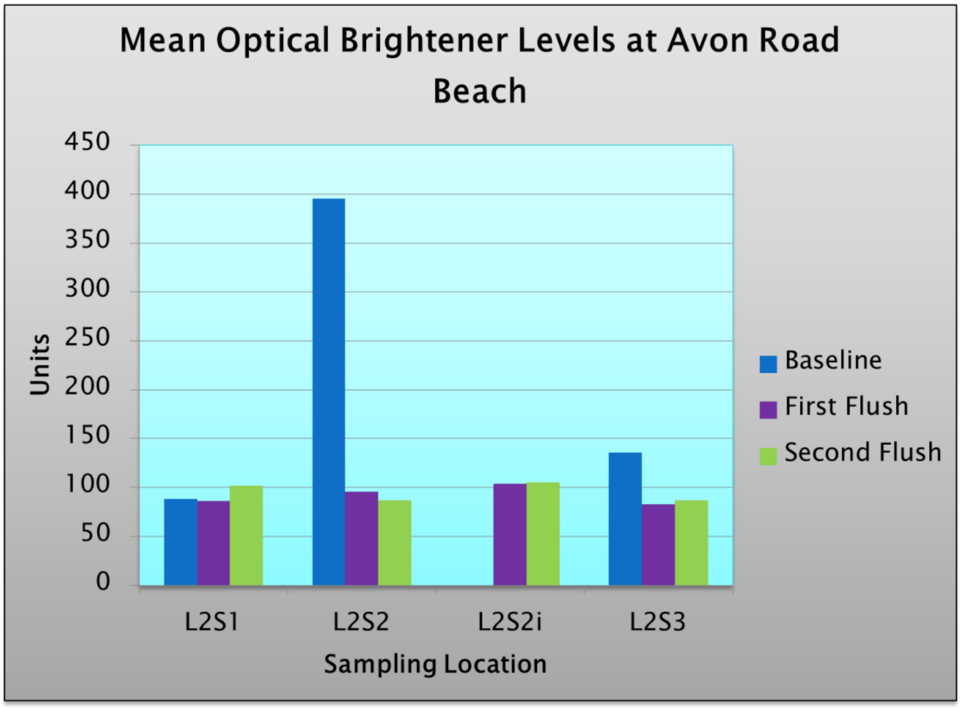


Figure 15. Average Optical Brightener Levels at West Beach of Pine Beach.

A statistical analysis using linear regression was run to compare the levels of *Enterococcus* and optical brighteners for each sample (See Fig. 16). This test turned out an $R^2$ value of 0.00009, indicating no correlation between *Enterococcus* and optical brightener readings. The same test was performed to chart *Enterococcus* data against rainfall levels in inches, which generated an $R^2$ value of 0.4146, indicating that there is a relation between both parameters (See Fig. 17).

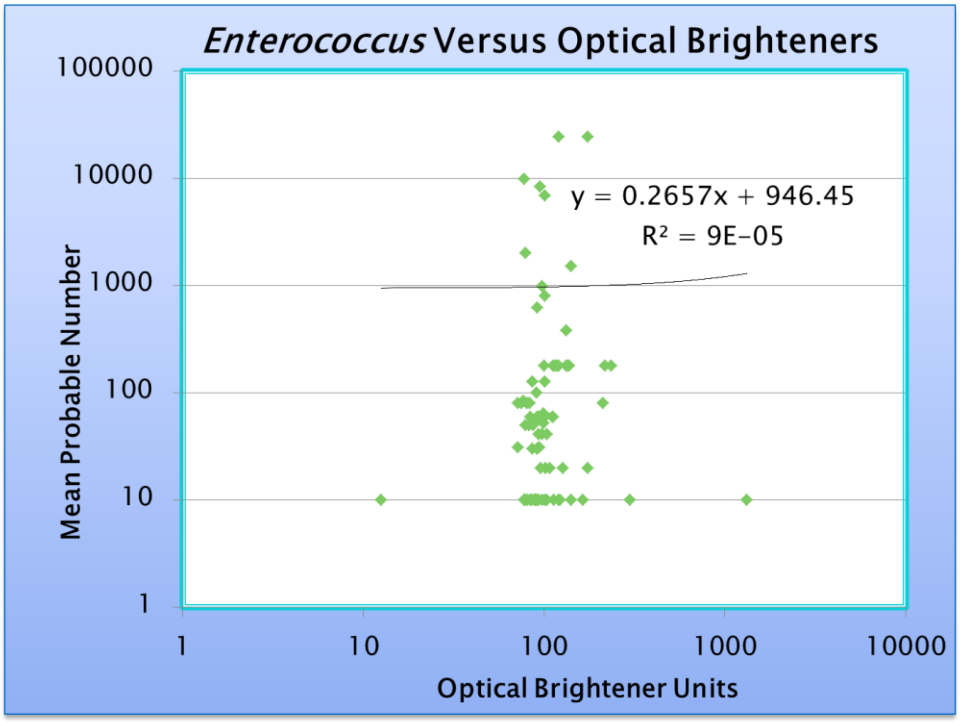


Figure 16. Linear Regression of *Enterococcus* vs. Optical Brightener Levels.

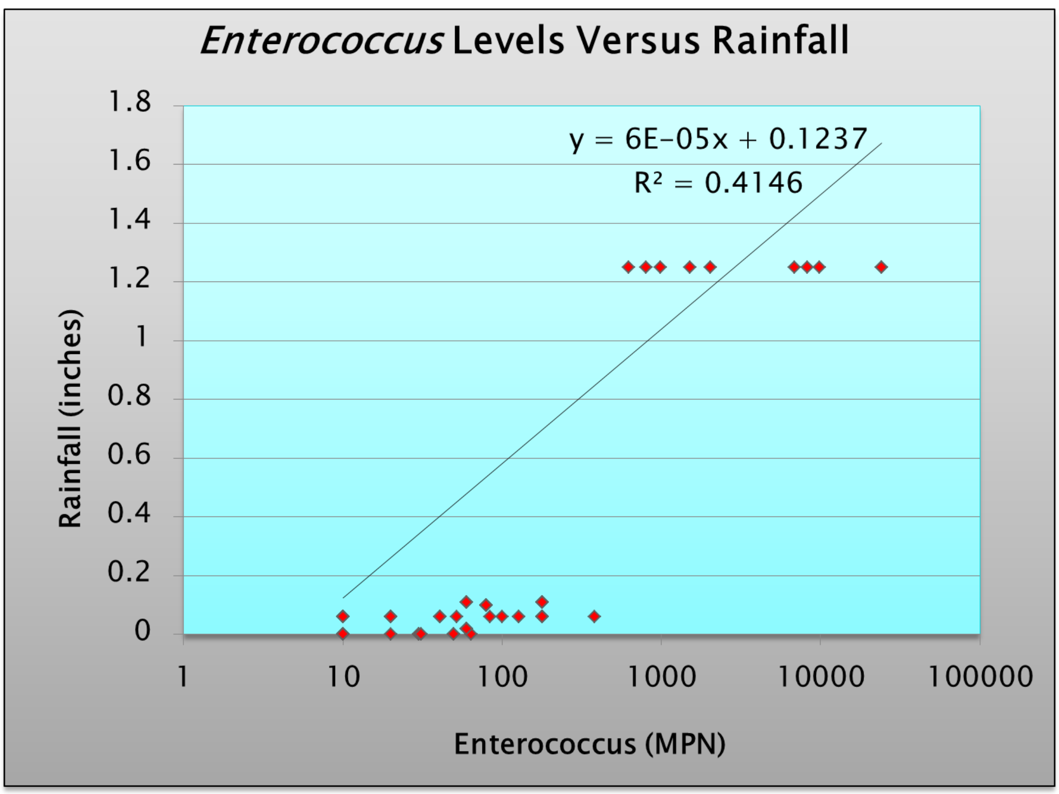


Figure 17. Liner Regression of *Enterococcus* vs. Rainfall (inches).

For comparison, a sample taken from the secondary treatment effluent at the Ocean County Utilities Authority (OCUA) read at 380 for optical brighteners and contained less than 10 MPN *Enterococcus* and 100 colonies *E. coli* per 100mL.

The *Enterococcus* data collected from each site at both locations during the baseline sampling sessions was averaged and checked against the Ocean County Health Department data as shown in Table 1 below. According to Table 1, the data was generally close in comparison with that of the health department.

| Date | Beachwood (CFU/100 mL) | | Avon (CFU/100 mL) | |
|---|---|---|---|---|
| | Health Dept. | Ours (Average) | Health Dept. | Ours (Average) |
| 6/27/11 | 10 | 11.892 | 34.641 | 18.371 |
| 7/18/11 | 10 | 10 | 10 | 10 |
| 7/25/11 | 40 | 13.269 | 10 | 14.581 |
| 8/1/11 | 20 | 11.892 | 30 | 18.566 |

Table 1. Average Baseline *Enterococcus* data vs. Ocean County Health Department data.

## Discussion

A compilation of different methods were utilized in this study to examine the full aspect of Beachwood and Pine Beach's water quality during dry and stormy weather. Although this area of the Barnegat Bay is considered brackish, the data supported reasoning that the low salinities can provide sufficient conditions for *E. coli*, commonly found in freshwater, and *Enterococcus* to persist. For this reason, samples were tested with both of the Coliscan Easygel and IDEXX Enterolert techniques.

According to Figures 8 and 9, *E. coli* was found in exceedingly high numbers at both Beachwood Beach West and West Beach of Pine Beach during all weather conditions. The average baseline readings taken during dry weather at each location tested well over the standard for fresh waters. This indicates that *E. coli* is present in these waters on a daily basis without stormwater discharge; therefore, raising concerns of health risks. At both locations, the average *Enterococcus* counts in baseline samples did not exceed the marine standard, yet they were still present. In order to get a better perspective of the environment, all observations were taken into careful consideration when performing sampling. For example, during one particular baseline sampling session, a bag of pet waste was found on the beach at the Pine Beach location. Objects like this can be washed into the water, further perpetuating the water quality issue. This evidence is an important piece to the puzzle in determining sources of bacteria.

During rainfall events, levels of *E. coli* and *Enterococcus* noticeably rose after the first and second flushes at both locations. Since the first flush typically exhibits higher bacteria levels, the elevated *E. coli* and *Enterococcus* counts witnessed from the second flush denote that there is substantial polluted stormwater runoff discharging into the water (Kirwan, 2005). Storm samples taken within the storm pipes at Beachwood Beach West and West Beach of Pine Beach highlight this issue in great depth (See Figs.

10 and 13). Within the Site 2 storm pipe at West Beach at Avon Road, counts of *E. coli* increased from the first to second flush as much as three times and *Enterococcus* rose as high as 56 times during the same time interval. This significant jump in bacteria levels indicates that there may be delay in stormwater flow due to blockages further up in the storm drain system (*Cooperative Coastal Monitoring Program: Summary Report for 2010*).

To track down the source of the bacteria, levels of optical brighteners were monitored to determine whether the influence could be of human origin. After analysis of all the sample data, there was no obvious pattern with optical brightener levels in dry or wet weather conditions (See Figs. 14 and 15). Furthermore, statistical analysis tests did not report any correlation between *Enterococcus* counts and optical brightener levels (See Fig. 16). However, the average optical brightener readings at individual sites may hold more meaning.

Optical brightener readings taken inside both of the storm pipes at Beachwood Beach West and West Beach of Pine Beach during rainfall noticeably increased between the first and second flushes (See Figs. 14 and 15). This data, in conjunction with the high bacteria counts found within the storm pipes during storm events (See Figs. 10 and 13), suggests human influence. Since optical brighteners are found in laundry detergents, their elevated presence in storm pipes implies that the laundry effluent is found in the sewage or septic systems (Floresguerra, 2003), therefore, hinting at the possibility of sewage leaking into the water of Beachwood Beach West and West Beach of Pine Beach. During a rainfall event on July 8, one of the team members observed a black cloud of matter discharging from the storm pipe at Beachwood Beach West accompanied by an unpleasant odor. Samples taken from this storm pipe during the second flush contained astronomical counts of *E. coli* and *Enterococcus*, and high optical brightener levels. With support from visual and olfactory observations, it is strongly suggested that these data may have been a result of raw sewage leaking into the water.

Optical brightener levels were present in all of the baseline samples, however, the levels were not as elevated as those during rainfall events. Yet, on one occasion, a baseline sample taken at Site 2 of West Beach in Pine Beach read at 1322 for optical brighteners. It is important to point out that this site is located near a dock housing a number of boat slips. Boaters often use boat soaps with heavy concentrations of optical brighteners, for example, Gel Coat Labs Premium Gel Boat Wash (Deering Yacht Club), which may cause high optical brightener readings during dry weather.

Even with calibration of the Aquaflor Fluorometer prior to every sampling session, interference with readings may have occurred. At the beginning of the experiment, readings of 70 and over seemed abnormal and caused doubt in equipment efficiency. However, it has been reported that optical brightener readings may not always come from human sources, but rather naturally occurring compounds (Floresguerra, 2003), such as tannins.

The sample collected from the secondary treatment outflow at the OCUA contained fairly high levels of optical brighteners, but low levels of bacteria. The OCUA chlorinates this water to help kill any residual bacteria, which supports the low bacteria results, yet it does not have the capabilities to remove optical brighteners from the effluent water, thus readings of optical brighteners were extremely high. This data was intended to determine where the optical brightener readings of the samples collected in this study stood against thoroughly treated water. It appears that no conclusion that can be made between the optical brightener readings of the OCUA sample and the study's samples. However, this does indicate that optical brighteners should be investigated alongside other methods to effectively track bacteria sources, such as Antibiotic Resistance Analysis (ARA) (Meays et al., 2004). This method employs biochemical testing to distinguish bacteria with resistance to antibiotics often associated with humans and animals in order to determine sources of bacteria.

Although ARA is expensive and can contain false positives, it would prove useful in regulating beach closings. With ARA, it would be easier to determine if bacteria was coming from human sewage or simply, waterfowl waste. Dickerson et al. (2007) proved ARA can be useful when combined with optical brightener testing and thus tracked down human-origin pollution at a couple of bathing beaches in Newport News, Virginia. This study then led municipal officials to repair the faulty sewage infrastructure systems at both sites. If bacteria is properly identified, ARA can be used to isolate pathogens that are human-specific (Palladino et al., 2005), resulting in immediate beach closings which would greatly reduce negative impacts on human health. Currently, beaches close for samples in violation of the daily maximum bacteria standard and precautionary measures, such as rainfall, waste wash-ups or sewage leaks (*Testing the Waters 2011: NJ*). In this study, a statistical analysis showed that the amounts of *Enterococcus* slightly increased with more rainfall (See Fig. 16). Though the trend was just seemingly positive, it still offers grounds for beach closings after considerable amounts of rainfall.

As quality assurance was woven into the entire study, the baseline data compared well against that of the Ocean County Health Department (See Table 1). The data may not have always matched exactly, but it did fall within considerable proximity.

## Conclusion

The methods utilized and data collected in this study shed new light on the questions behind the water quality issue in the Barnegat Bay.

Although this area of the bay has tidal influence, the considerable presence of *E. coli*, a freshwater indicator bacterium, in the baseline samples raised many concerns. Here, sources of bacteria may be anything from pet waste to trash on the beaches washing into the water, and even nearby boats pumping out human wastes.

Taking samples during rainfall events proved valuable when monitoring levels of *E. coli* and *Enterococcus* over time. As bacteria levels increased between the first and second flushes of rainfall events, results indicate that stormwater discharging from the outfall pipes is carrying significant amounts of pollutants; this was revealed best by the storm pipe bacteria data. The noticeable time lag between the bacteria counts of the first and second flush at both locations supports the reasoning that there may be blockages within the storm drain systems or cross-connections in the infrastructure causing the problem.

Although there was no discernable trend with optical brighteners in dry and wet weather, higher levels of optical brighteners along with high bacteria counts reported within the storm pipes during storm events may be linked to laundry effluent possibly containing human sewage. Increased levels of optical brighteners occurring in dry weather are most likely caused by boat soaps used by local boaters.

Many natural chemicals found in the environment have been known to interfere with optical brightener readings, for instance tannins. However, when tested in conjunction with other methods, optical brighteners can be useful in tracking bacteria sources. The technique of Antibiotic Resistance Analysis is still in the beginning stages of its development, yet it may hold the key to determining differences between bacteria of human and animal origins, thereby preventing exposure to serious health risks caused by pathogens.

## Recommendations

After careful consideration of the results, a list of recommendations was devised to ensure the safety of frequent beach goers and local citizens.

Since bacteria levels generally rose during rainfall, it was suggested that Beachwood Beach West and West Beach of Pine Beach close for a 72-hour period after a storm event totaling 0.10 inches or greater. The Ocean County Health Department tests bathing beach waters on Mondays, thus in the event that a storm occurred over the weekend, taking this precaution would remove the dangers of exposure to heightened bacteria levels that occur after large amounts of rainfall.

According to the results obtained from this study, storms exceeding 0.05 inches can produce harmful increases in bacteria levels. Therefore, to avoid these circumstances, it is highly suggested that the storm drains undergo monthly inspections and cleanings. The Ocean County Health Department has storm drain cameras available which the local municipalities can use to inspect their storm drains for possible blockages or infrastructure concerns.

These beaches should also be cleaned on a regular basis and local waterway authorities should increase enforcement of Ocean County's Pumpout Boat Program (Ocean County Department of Planning) to eliminate any disposal of human pollution contributing bacteria sources in the bay.

## Acknowledgements

This study would not have been possible without a list of supporters, mentors, and team members. I would first like to thank the Barnegat Bay Student Grant Committee for providing me with this wonderful opportunity to offer my enthusiasm for Barnegat Bay and share my experiences with the local community.

Thank you to the NJDEP for providing the team with many pieces of equipment as well as information resources. The NJDEP presented us with a list of locations to study in this experiment and ultimately guided us to focus on Beachwood Beach West and West Beach located near Avon Road of Pine Beach. Also, thanks to the NJDEP Leeds Point staff at the Bureau of Marine Water Monitoring for allowing us to bring them our samples to test for quality assurance. We are grateful for Deb Waller offering her wisdom in editing our quality assurance plan.

Thank you to the Marine Academy of Technology and Environmental Science for hosting the project presentations, as well as providing the materials to ensure that the YSI-85® and pH meter were always calibrated.

The mentors assigned to the team for this project went above and beyond our expectations. I thank Mrs. Danielle Donkersloot of the NJ DEP for lending her knowledge of the NJ DEP's Water Monitoring Program. Danielle gave us great advice during the experiment and when compiling our methodology and presentation of the results. I thank Ms. Cara Muscio of the Rutgers Cooperative Extension of Ocean County for extending her inventory of water quality equipment and materials to us so that we could perform this study. Cara provided us with helpful insight on interpreting our results and conveying them to the community.

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# Appendix

## Barnegat Bay Student Grant Program Quality Assurance Plan

Materials:

- YSI 85 (Temperature, Conductivity, Salinity, DO)
- Turner Design handheld Fluorometer (Turbidity/OB's)
- Oyster pH meter
- DO Kits
- Deionized water (1 Carboy)
- Kim wipes
- Sodium thiosulfate-treated WhirlPaks
- 10 Nalgene Lab bottles
- IDEXX Sealer
- Incubators (2)
- Rain Gauges (2)
- GPS
- Cuvettes
- Optical Brightener Standard
- Turbidity Standard
- Gloves
- IDEXX Quanti-Trays (Large and small wells)
- Enterolert Media
- Coliscan Easygel petri dishes
- Easygel Media

Site Locations

- Beachwood Beach (4 sampling points)
- Avon Road in Pine Beach (3 sampling points)

Sampling will occur:

- Within 30 minutes after storm has begun
- Within the second 30 minute period after the storm has begun
- Base-line sampling will occur on a Bi-Weekly basis on Mondays to compare bacterial data with the Health Department
- OB's will be tested before the first flush of each storm

Sampling sites include:

- Sampling within storm pipes during storm events
- Sampling at each storm pipe
- Sampling at control locations

Testing for:

- Temperature (YSI 85)
- Conductivity (YSI 85)
- Salinity (YSI 85)

- Dissolved Oxygen (YSI 85)
- Percent Saturation (YSI 85)
- Optical Brighteners (Turner Design handheld meter)
- Turbidity (Turner Design handheld meter)
- *Enterococcus* bacteria (IDEXX)
- *E. coli* (Coliscan Easygel)
- pH (Oyster meter)

Observations:

- Rain levels
- Weather patterns
- Time of sampling
- Changes in environment (Beach erosion, pollution)
- Wildlife (birds, fish)
- Possible septic breaks

Quality Assurance

- All equipment will be calibrated before every sampling event
- Duplicate samples will be taken once every testing block to meet the 1:20 ratio
- pH will be tested within 15 minutes of sampling
- Bacteriological tests will be prepared within 6 hours of obtaining samples
- Split samples will be sent to the NJDEP Leeds Point lab at every sampling session for comparison (Beachwood Only)
- Baseline samples will be compared to Ocean County Health Department water quality testing
- Enterolert samples will be diluted with 1:10 sterile Deionized water
- Every sampling block, a media blank will be run to assess our quality control methodology
- Separate incubators will be used to incubate IDEXX Enterolert samples and Coliscan Easygel samples as they require different incubation temperatures
- Wear gloves when plating samples and collecting water samples
- Deionized water to prevent contamination of samples (triple rinse all equipment)
- The YSI 85 will be maintained and checked to the DEP standards and regulations on a weekly basis (Winkler titration for D.O., conductivity standard, etc.)
    - Dissolved oxygen readings must be accurate to within 0.3 ppm
- Kim wipes to clean equipment & provide optimal light transmission
- Use new Whirlpaks to collect each sample

Sample Collection:

- Samples will be collected directly in the sterile container following procedures set forth in NJDEPE, Field Sampling Procedures Manual (Chapter 7, Section F, Bacteriology), Trenton, NJ, 1992; and in Chapter IX (Public Recreational Bathing) of the State Sanitary Code, N.J.A.C. 8:26-1 et seq. (revised May 2000).
- Samples will be collected in sterile containers in an area with a stabilized water depth between the sampler’s lower thighs and chest with the optimum depth being at the sampler’s waist. The sample container shall be placed approximately eight to twelve

inches below the water surface with the lid and stopper still attached. With the collector's arms extended to the front, the container shall be held near its base and downward at a 45-degree angle. The cap shall be removed and the container filled in one slow sweeping motion (downward or horizontally, not upward.) The mouth of the container shall be kept ahead of the collector's hand and the container recapped while it is still submerged. The cap shall remain submerged during sample collection and care shall be taken not to touch the inner surfaces of the cap. During cold water sampling use of a sampling pole is permitted.

- Samples shall be refrigerated or kept in an ice chest and held at a maximum of 4 degrees Celsius while being transported to the laboratory. Samples will be taken to a certified laboratory within six hours of collection for processing. Time and date of sample collection, tidal conditions, air and water temperature, rainfall, winds and other general conditions will be gathered in the field at the time of sampling and from weather forecasts for the site, and will be recorded on field sheets or in field logbooks by the sampler.