AGRICULTURAL CHARACTERIZATION, LAND USE ASSESSMENT AND MICROBIAL SOURCE TRACKING WITHIN THE WRECK POND BROOK WATERSHED

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ABSTRACT

Rutgers Cooperative Extension (RCE) has characterized the agricultural and recreational lands in the Wreck Pond Brook Watershed; an area that has contributed to the majority of NJ ocean beach closings in 2005. The watershed is approximately 12 sq. miles in size and is comprised of a wide variety of land uses. RCE is part of a Regional Stormwater Management Planning Committee that addresses environmental impairments and recommends Best Management Practices (BMP's) to remediate any non-point source contributions of nutrient loading and fecal coliform within the watershed.

Geographic Information System (GIS) and tax assessment information were used to identify and characterize the quantity of agricultural and recreational land in the watershed. A YSI Multiparameter Probe, a Hach Colorimeter and macroinvertebrate sampling were utilized to assess nutrient levels as nitrogen and phosphorus in ponds and streams. Nutrient levels in the soil were assessed with soil probes.

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Innovative Microbial Source Tracking (MST) methods, qPCR and Multiple Antibiotic Resistance, were utilized and improved upon in an effort to determine the source of microbial contamination whether they be human, livestock or waterfowl. The characterization yielded no obvious point sources of either nutrient or microbial contaminations from agricultural sources indicating a combined origin from multiple nonpoint sources. The results led to the conclusion that an important BMP will be public education regarding nutrient runoff and soil erosion. Educational workshops are planned for various stakeholders such as rain gardens for homeowners and landscapers and full-scale demonstrations of on-farm manure management practices for farmers.

KEYWORDS

Stormwater Management, Water Quality Monitoring, Agricultural Assessments, Agricultural Best Management Practices, Macroinvertebrates, Multiparameter Probe, Microbial Source Tracking, qPCR, Multiple Antibiotic Resistance Analysis, Geographic Information Service

INTRODUCTION

Water quality impairments in the Wreck Pond Brook Watershed contribute to area beach closings, and have led to the watershed's identification as one of the Governor's Coastal Initiatives projects for 2005. The Regional Stormwater Management Planning Committee that formed to address this challenge will characterize and analyze the watershed as a necessary part of the planning process, and in doing so, recommend best management practices (BMPs) to address and correct impairments.

As part of the Wreck Pond Regional Stormwater Management Plan, Rutgers Cooperative Extension (RCE) have characterized the agricultural lands in the watershed, and analyzed their contribution to fecal coliform and nutrient loading to Wreck Pond. Education, outreach, and recommendations for best management practices are outcomes of the characterization process.

This Final Report and the recommendations contained herein, summarizes RCE's involvement in the Wreck Pond Regional Stormwater Management Plan and incorporates MST data gathered with project partners Monmouth University and Najarian Associates. This report details methodologies and provides results of the agricultural and recreational lands survey and nutrient water quality monitoring. It also includes recommendations for actions needed to be taken to reduce the impact that NPS pollutants from agricultural and recreational land may have on the Wreck Pond Watershed.

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METHODS

Agricultural and Recreational Land Survey

Through the use of the Monmouth County GIS system, feature classes for streams, road centerlines, watershed boundaries, land use and land cover, and municipal tax records, as well as aerial photography were obtained. Examination of the tax records provided records that were labeled “3a” or “3b” with respect to farmland. These records indicate farm house and qualified farm properties. To become a qualified farm, a parcel must be actively involved in agriculture on at least five acres of the property. The Wall township municipal Tax Atlas information used was from the year 2005, although online data from more recent years was consulted for comparison.

In addition, 1997 land use and land cover feature classes were analyzed to assess farm properties. The feature classes were queried under the 1997 label field and the 1997 SCS description field, and a feature class was made out of all agricultural and recreational lands in the Wreck Pond Brook watershed. Both sets of data were selected for land parcels within 500 feet of any water body in the Wreck Pond Brook watershed. This group was identified for potential water quality impacts. The sum of this information generated data tables with owner information for each parcel on the tax map.

An agricultural land use survey was constructed to assess the characteristics of these parcels, and determine which were still in use as farmland. The survey was confidential, and employed the use of an identification number to make participants more comfortable answering questions. There were twenty questions on land use of the property, overall knowledge of best management practices, and willingness to let RCRE tour the property and discuss management of manure and fertilizer and chemical applications with the owners. A full survey with included cover letter is attached to this summary.

Water Quality Monitoring

A nutrient concentration study was performed to collect data to be used in conjunction with the Wreck Pond committee data. Samples were taken once a week for one year at eight sites along the upper and lower portions of the watershed on both the wreck Pond Brook and Hannabrand Brook (Figure 1). Nitrate and Ammonia were collected along with conventional water quality parameters using a YSI 6600 probe, and orthophosphate data was collected with an optical calorimeter kit, initially ChemMetrics, and more recently by Hach. *E. coli* and *Enterococci* were also monitored as indicator species whose frequency and abundance can also be related to erosion and soil transport of nutrients and bacteria

Macroinvertebrate Sampling

In addition to chemical parameters, macroinvertebrate samples were also taken at all sites once a month in June, July and August. Samples were taken using the EPA Rapid Bioassessment Protocols for Multiple Habitat Benthic Macroinvertebrate Sampling. The results of the sampling are discussed in the “Results” section.

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Farm Tours

Based on the data obtained from the agricultural survey (see, Agricultural Survey Methods and Results from "Phase 1 Summary Report") key agricultural land that may have an environmental impact on the Wreck Pond Watershed was inspected. The information gathered included the acreage of land actively farmed, the type, amount, and rate of fertilizers applied, herbicides and pesticides applied and the manure storage practices implemented by each farm. The information was acquired and documented through personal interviews with the farm owners/managers, soil samples analyzed at the Rutgers University Soil Testing Lab and photographs. An information packet was also handed out containing runoff and erosion BMPs from the USDA – Natural Resource Conservation Service (NRCS). As the results of the soil tests are completed, the Monmouth County Agricultural Agent Dr. William Sciarappa, will make BMP recommendations. These recommendations will further assure that those managing the farm lands are adhering to the appropriate Stormwater Management Regulations and USDA – NRCS measures, as well as preventing soil erosion and nutrient and pathogen runoff from their lands.

Soil Analysis

The purpose of the soil sampling program was to determine the soil conditions existing naturally in the Wreck Pond watershed compared to the soil conditions found in representative agricultural operations as well as developed areas. The location of the soil samples was associated with the location of the stream water quality samples.
In order to assess the general nutrient and fertility levels in the watershed, the area was first divided into four separate categories.

A. Ag lands
B. Between ag lands and control
C. Control
D. Development

Ag lands were defined as dense agricultural areas that were farmland assessed. Control areas were forest and meadow regions with little agriculture or development. Development areas were covered with residential housing, businesses and schools. Most stream segments had a range of these various categories within their boundaries (Figure 2).

Soil samples were made in proximity to the stream/water quality samples that were done previously. Natural local soils were sampled either just above the stream bank or at the farm site or home site. The selected soil areas in the stream site program were randomly sub-sampled ten times within a 25 foot line. The selected soil areas in the farm site program were randomly sub-sampled ten times within a one to two acre block. The selected soil areas in the home site or business program were randomly sub-sampled ten times within the half-acre of property.

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A Gempler soil probe of one inch diameter was inserted vertically into the soil at a depth of 6 to 8 inches. Ten replicates of these samples were mixed within a bucket and a one pint collective sample was withdrawn and taken to the soil lab for analysis. Soil analysis consisted of levels of soil acidity as measured by pH and macronutrient levels of phosphorus, potassium, magnesium and calcium as measured in pounds per acre. Micronutrients of zinc, copper, manganese, boron and iron were measured in parts/million. The cation exchange capacity and basis saturation was measured in meq/100G. Additionally, special tests were run on soil organic matter as measured by organic matter percentage and percentage of organic carbon. Inorganic nitrogen was measured in the form of nitrate-N and ammonium-N in parts/million.

GPS/GIS maps were developed for all sampled areas both for the stream bank soil samples and the upland ag and developed areas (Figure 2).

Microbial Source Tracking

Two emerging technologies were implemented to track the source of bacterial contamination. The first technology used was quantitative polymerase chain reaction. The first step in the MST assay was to filter a 100 mL water sample aseptically onto a membrane filter which was cut into quarters using a sterile blade. The DNA was then extracted from total filtered biomass using a DNeasy® tissue kit (Qiagen). All DNA was quantified by spectroscopy and diluted in sterile water to a concentration of 1 µg/ml. Then qPCR was used to measure the number of bacteroidetes present : Total (AllBac), Human (HuBac) and Bovine (BoBac). A TaqMan® based assay was produces using Applied Biosystems reagents and standard conditions on an Applied Biosystems 7300 Real-Time PCR system. Finally, copy numbers of each target were calculated by comparison to a standard curve made with plasmids containing human- or bovine-sourced target 16S RNA genes amplified with the primers Bac 32f and Bac 708r (Bernhard and Field, 2000).

The second technology used was performed by Monmouth University's Urban Coast Institute (UCI). The UCI performed an Antibiotic Resistance Analysis (ARA). Antibiotic Resistance Analysis (ARA) is a phenotypic library-based MST technique developed as a method for microbial source tracking based on the assumption that bacteria from the intestines of humans and domestic animals will have different antibiotic profiles. The antibiotic profiles should differ because hosts exposed to different antibiotics or differing amounts of the same or similar antibiotics will develop varying resistance to those antibiotics (Atherholt, 2005:USEPA, 2005).

Samples were taken from twelve sites throughout the watershed and tested against twelve various antibiotics. The bacteria under inspection was *E. coli*. The AR profiles were grouped into five categories: humans, pets, farm animals, avifauna, and non-avifauna.

In addition to these new tools, more conventional methods were used to create a baseline data set of the type and quantity of bacterial contamination. Compiling a comprehensive

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background of information is an important aspect of the multiple-tool, tiered approach to MST. Water samples were taken by Monmouth County and Najarian Associates. Bacterial species sampled for were Fecal Coliform using the SM 9222D method and Enterococci using the SM 9230C method. Samples were taken at 8 sites within the watershed weekly for more than one year.

Figure 1. Wreck Pond Brook Watershed - Water Quality Monitoring Sampling Locations.

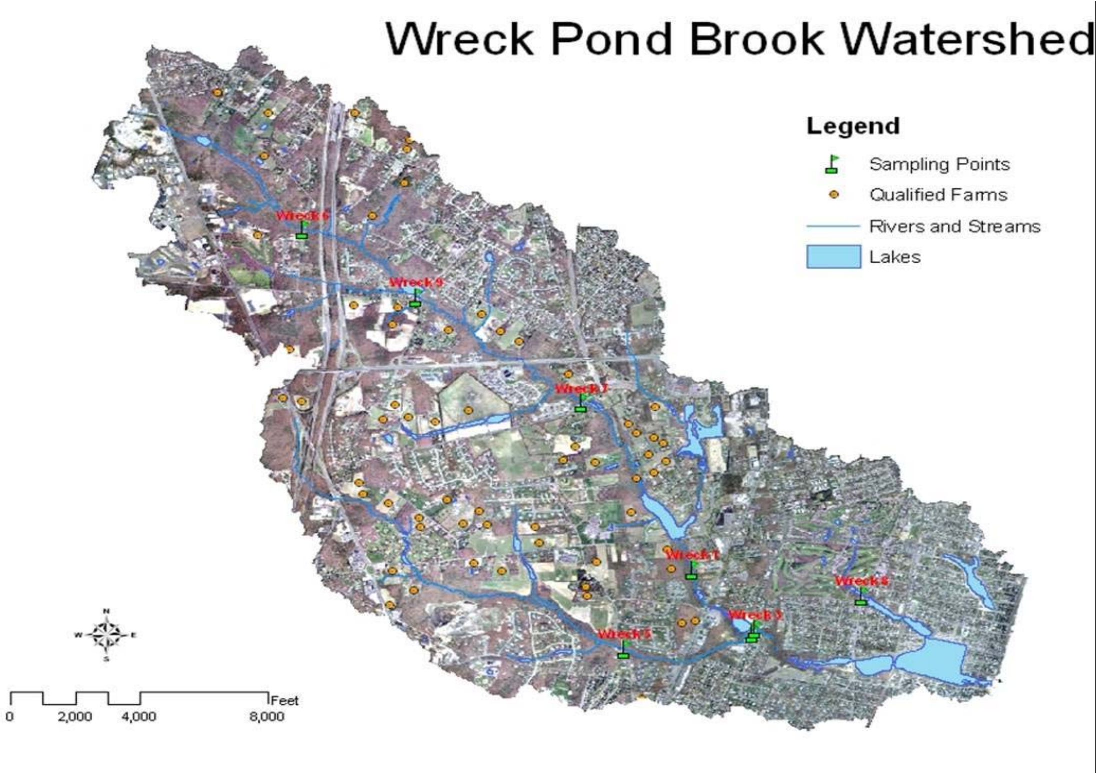

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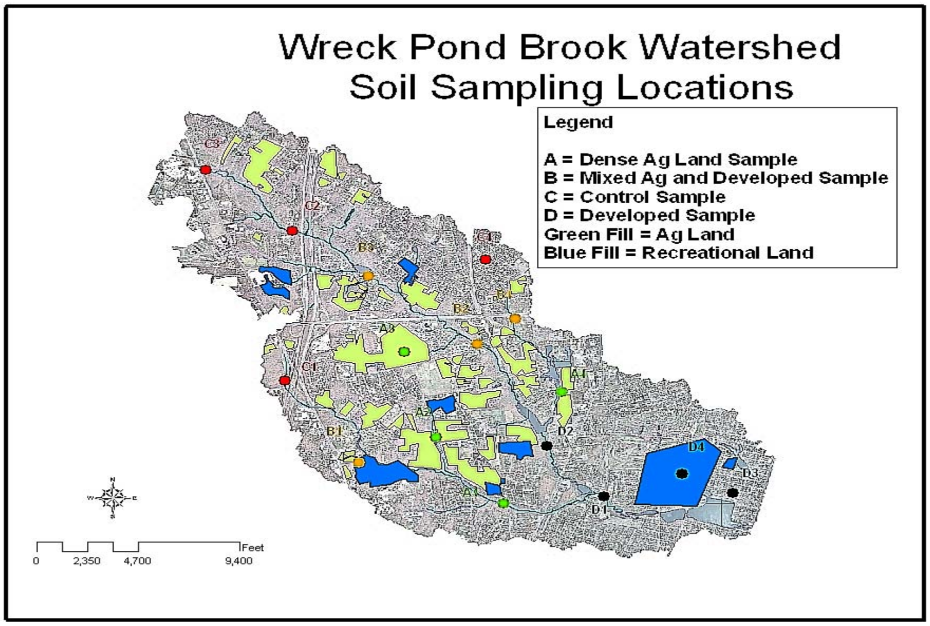
Figure 2. Wreck Pond Brook Watershed – Soil Sampling Locations.



RESULTS

Agricultural and Recreational Land Survey

A total of 49 property owners, all in Wall Township, were identified with "qualified" agricultural properties within 500 feet of a Wreck Pond Brook tributary. The survey was sent to landowners in August 2005. Out of the 49 surveys sent, three never reached their intended recipients, indicating either a database address error or a change in land use. Nineteen of the forty-six recipients returned the mail survey. Out of the 28 remaining property owners, correct phone numbers were found for 50% (14), with the remaining numbers unlisted or disconnected. A follow up phone survey was performed on these 14 owners, with 7 not responding to the phone call, 6 refusing to answer the questions, and one owner answering a brief phone version of the survey. This indicates that 41% of the recipients answered the survey on the first attempt to contact them, while another 28% were contacted a second time by phone. In total, 20 property owners have responded to date, yielding a 43% overall response rate.

All 20 respondents answered that their land was currently in use as agricultural property and had been for the past 5 years. There are challenges involved with interpreting the results of any survey. Some respondents accidentally skipped the questions on the back of the first page, lowering some of the response rates. One respondent answered yes and no for several questions, which, in analysis was recorded as "Not sure". An equal 44% percent of respondents indicated that there either was or was not a drainage or stream running through the property, while 11% said they didn't know. Seventy eight percent of

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respondents owned and farmed between 5 and 20 acres, with a few (5%) farming 0-5 acres, and the remaining 17% farming between 20 and 50 acres. No respondents farmed more than 50 acres.

Table 1. Uses of farmland by respondents, in percent. Respondents were allowed to choose as many answers as applied, so totals exceed 100%.

Use	Percent of respondents
Crop/Vegetable	67
Orchard/Vineyard	22
Livestock/Animal	22
Ornamental/Nursery	39
Other	17

Table 1 shows the percentage of respondents engaged in various categories of farming. Of respondents, 37% said there were domestic animals or livestock on their property, while 63% answered negatively. Table 2 shows the breakdown of the 219 livestock identified in the survey, although one owner failed to specify the number of horses on the property. This data will be further analyzed to estimate manure loads for the watershed. Only 21% of respondents reported using manure as a nutrient addition on their farm fields, however only 74% of respondents answered this question.

Table 2**.** Animals owned by survey respondents, with number and number of owners. Asterisk (*) indicates one horse owner failed to specify the number of horses.

Animal	Total Animal number	Number of Owners
Chickens	70	2
Cows	12	1
Cats/Dogs	3	3
Horses*	78	2
Mini Donkeys	7	2
Pigs	4	1
Rabbits	40	1
Sheep	5	1
Total	219	

Only five respondents (29%) of the nineteen mail surveys indicated that they had manure on site, while the remainder did not. The five respondents used such manure management practices as storing manure away from water, using a flat concrete pad closed on three sides, and composting manure on site. As far as respondents performing cropland application, 33% had soil tested for proper application, and 66% only applied manure as necessary, once a year. Sixty three percent of respondents of the 78% that answered the question, were willing to let RCRE staff tour their property. These seven

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owners have been identified, and will be contacted for further research. These results help locate specific sites to sample and characterize any specific bacteria to track.

Table 3 shows all the total of all agriculturally assessed land in the Wreck Pond Watershed as of 2005. They are broken down into agricultural land use, total size and the area of those total sizes actively used for agricultural purposes. Table 4 is a summary of all recreational land in the Wreck Pond Watershed as of 2005. This table breaks the recreational land into land use, size and amount of impervious surfaces within each parcel. The majority of recreational and athletic fields are municipal schools or parks.

Table 3. Total Agriculturally Assessed Land in the Wreck Pond Watershed as of 2005.

Land Use	Size (acres)	Area Actively Farmed (acres)
Pasture	164.17	128.18
Crop	836.62	382.53
Nursery	27.71	17.35
Total	1208.5	528.06

Table 4. Total Recreational/Athletic Land in the Wreck Pond Watershed as of 2005.

Land Use	Size (acres)	Impervious (acres)
Recreational	140.25	9.38
Golf Course	369.2	50
Athletic Field	23.92	0
Total	533.37	59.38

Nutrient Assessment

A full year, November 2005 – November 2006, of calibrated water quality measurements were made once a week at each of the eight monitoring sites, with nine water quality parameters tested. In addition, 641 non-calibrated measurements were taken beginning in July 2005 and lasting until November 2005. Although some of the non-calibrated water quality data may be relatively accurate, it will not be used in any final reporting or recommendations because of the possible margin of error. Raw uncalibrated and calibrated data will be sent to the committee chair and also attached to the final report for inspection by the Wreck Pond Brook Regional Stormwater management committee.

Tables 5 and 6 summarize the calibrated water quality results collected with ranges and median values. Most of these values seem reasonable for flowing waters, although some of the dissolved oxygen measurements were rather high, and were likely resultant from instrument membrane issues. Although Table 6 shows over 50% of the calibrated samples exceed the pH standard range established, many of these values were just under 6.5, as shown by the 6.35 median value. In this case, the Freshwater category two standards indicate that the natural and prevailing pH supersedes the established standard range, and this may be an example of a slightly lower normal pH for this watershed. In

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most cases, the majority of values collected were well within the FW2 established criteria.

In addition to the dissolved oxygen and pH parameters, Table 6 shows two other parameters, nitrate and turbidity also had exceedences, though to a lesser extent. Of the 318 nitrate samples taken, only three exceeded the criteria, as shown in Figure 2. It should be noted that these three exceedences all occurred at different sampling sites on the same day, December 9, 2005. It should also be noted that the three sampling sites (WP 1, 2, 8) are located in close proximity to each other, in the more developed, residential and commercial downstream portion of the watershed, just prior to the Wreck Pond itself. Also on the same day, sampling Site 3, adjacent to Site 2 narrowly passed the 10 mg/L criteria with a reading of 9.45 mg/L. The surface water temperatures on Dec. 9, averaged slightly lower, 38.52 ^{o}F, than the sampling dates just prior and after Dec. 9, November 21 and January 13, averaging 47.59 ^{o}F and 46.77 ^{o}F, respectively. The nitrate and turbidity exceedences were also compared to precipitation data taken from the Rutgers University Weather and Climate Network weather station in nearby Farmingdale. The three nitrate exceedences on December 9, 2005 had no precipitation within 24 or 48 hours prior to sampling.

Spikes in nitrates are often caused by lawn fertilizing in high residential areas such as Spring Lake, but the December date when they occurred makes that assumption unlikely. A more likely conclusion may involve the numerous private and public parks, athletic fields and golf courses, which surround the three sites as can be seen on Figure 1.

The turbidity exceedences showed less of a pattern than the nitrate, as Figure 3 shows. Of the 318 samples taken, 9 of these exceeded the 50 NTU criteria. The 9 exceedences were spread evenly throughout the warmer months of April, June and July. Furthermore, a pattern was not observed in the sample locations. Exceedences were recorded on both the upper, Wreck Pond Brook Tributary, Sites 6, 7 and 3, and the lower, Hannabrand Brook Tributary, Sites 2 and 5, as seen on Figure 1. Of the nine turbidity exceedences, six had no precipitation within 24 hours (Table 7), two were unknown and only one received 0.29 inches of rain. These results lead to the conclusion that precipitation was not a significant factor in influencing turbidity. One possible explanation may have to do with various, unrelated construction projects going on during those months, where erosion requirements were not met or were insufficient. Eroded soil particles may increase transport of N, P, and bacteria through particle adherence.

Samples for ortho-phosphate were also taken throughout the sampling period. No criteria for ortho-phosphate currently exist. However, of the samples taken, the majority were within the range of 0.20 – 0.60 mg/L, with only five samples exceeding 1.00 mg/L.

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Table 5. Calibrated water quality measurements in Wreck Pond Brook Watershed (November 05 – November 06).

Parameter	Units	Range (Min & Max Observed)	# of Observations	Median Values
Temperature	ºC	2.92 - 30.34	318	16.53
Specific Conductivity	mS/cm	0.090 - 16.200	301	0.179
Dissolved Oxygen	mg/L	3.47 - 27.87	214	10.39
pH	pH	5.18 - 7.48	318	6.35
Ammonia	NH_3 mg/L	0.00 - 0.040	310	0.00
Nitrate	NO_3 mg/L	0.02 - 15.79	318	0.62
Turbidity	NTU	0.00 - 308.3	318	5.4
Chlorophyll	µg/L	0.0 - 82.0	310	2.8
Ortho-Phosphate	PO_4^{-3} mg/L	0.05 - 1.50	223	0.27

Table 6**.** Wreck Pond water quality data exceeding FW2 water quality criteria (November 05 – November 06). Asterisk (*) indicates this table only shows calibrated data measurements.

Parameter	Criteria	# of Samples*	# of Exceedences
Nitrate	< 10 mg/L	318	3
pH	6.5-8.5	318	212
Dissolved Oxygen	> 4.0 mg/L	214	2
Turbidity (NTU)	< 50 NTU	318	9

Table 7. Precipitation 24 hrs. prior to sampling during turbidity exceedences.

Parameter	Criteria	Date and Time	Site	Reading (NTU)	Precipitation (in.)
Turbidity	< 50 NTU	4/21/06 3:33 PM	5	175.5	Unknown
Turbidity	< 50 NTU	4/21/06 3:23 PM	7	55.2	Unknown
Turbidity	< 50 NTU	4/25/06 2:49 PM	6	138.2	0
Turbidity	< 50 NTU	6/07/06 11:05 AM	6	202.8	0
Turbidity	< 50 NTU	6/16/06 10:28 AM	3	169	0
Turbidity	< 50 NTU	6/16/06 10:12 AM	7	145.2	0
Turbidity	< 50 NTU	7/19/06 11:51 AM	3	166.6	0.29
Turbidity	< 50 NTU	7/26/06 11:09 AM	2	308.3	0
Turbidity	< 50 NTU	7/26/06 11:01 AM	5	285.6	0

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Figure 3. Nitrate exceedences in the Wreck Pond Watershed. Nitrate Criteria for FW2-NT, < 10 mg/L.

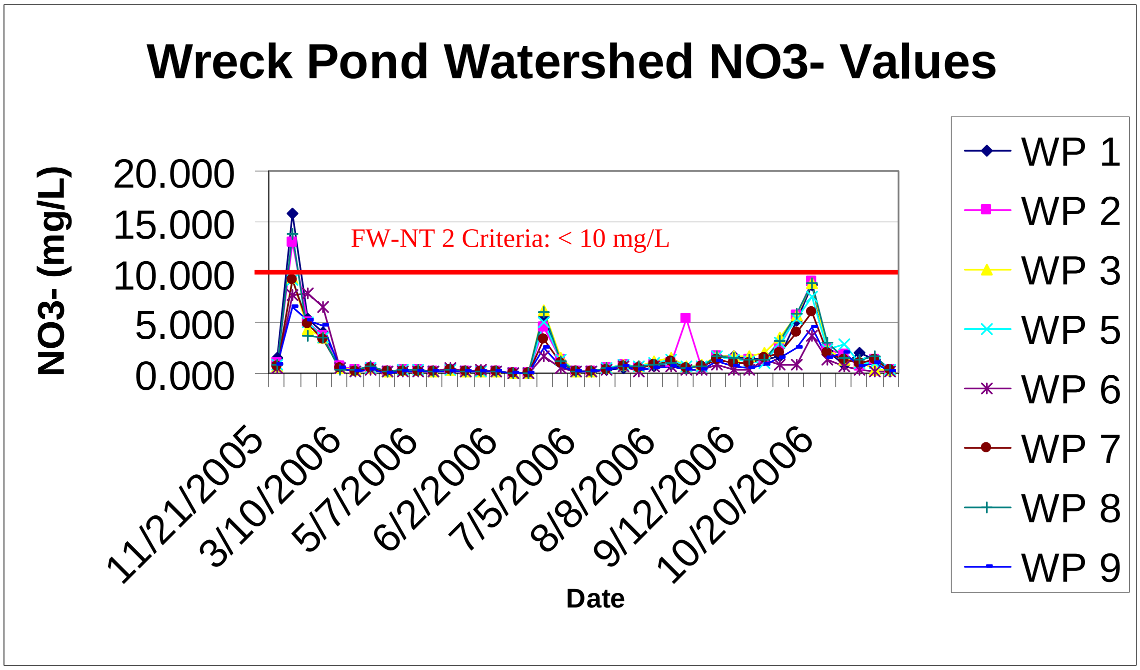
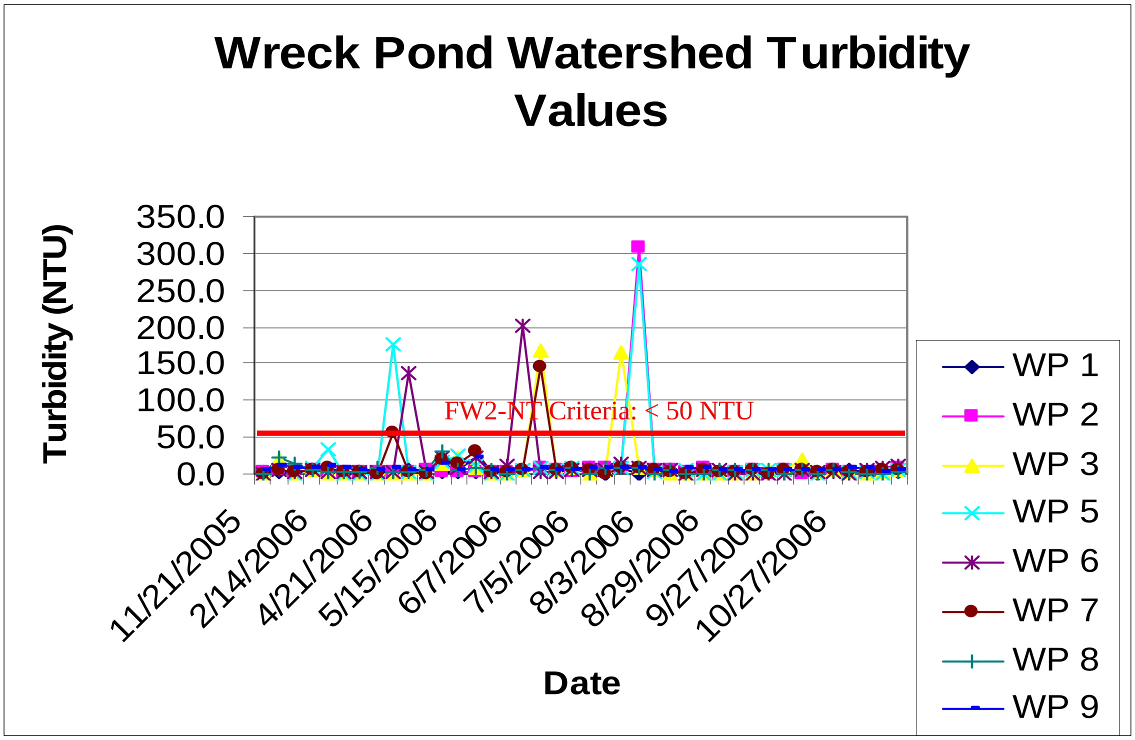


Figure 4. Turbidity exceedences in the Wreck Pond Watershed. Turbidity Criteria for FW2-NT, <50 NTU.



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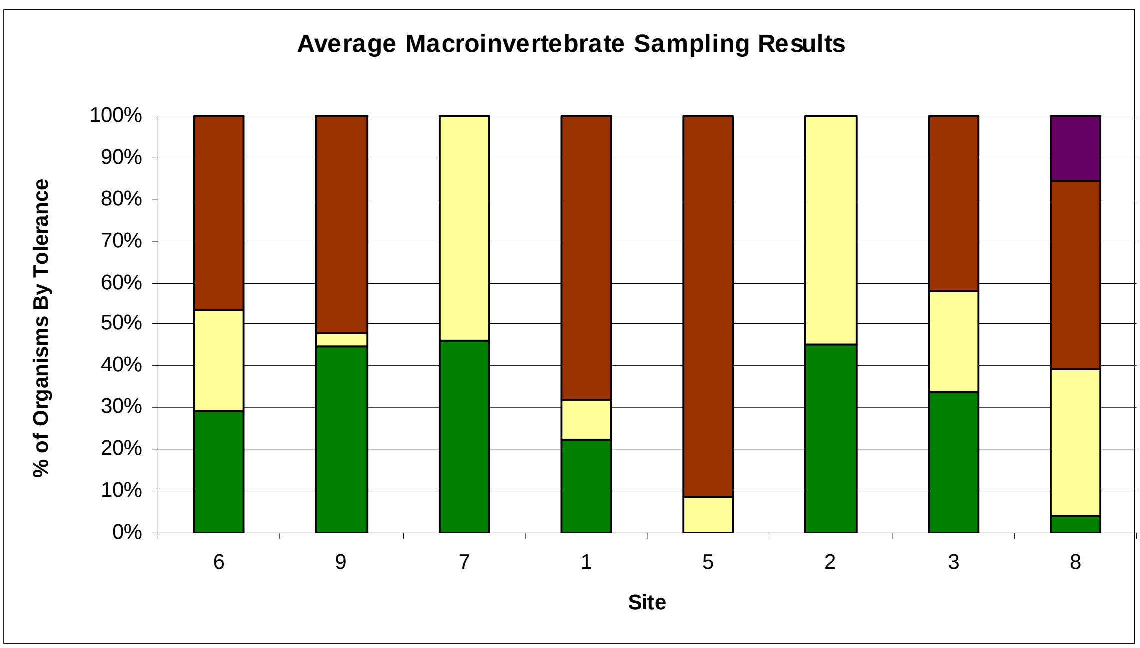
Macroinvertebrate Sampling

The results of the macroinvertebrate samples show a large variation between samples taken from the upper portion of the watershed and the lower portion of the watershed. Figure 5 shows the percentages of sensitive organisms (green), somewhat sensitive organisms (yellow) or tolerant organisms (red). In general, the sites from the upper portion of the watershed had a higher percentage of sensitive organisms indicating historically cleaner water. The sites from the lower portion of the watershed contained a lower percentage of sensitive organisms indicating a history of greater pollution and degraded water quality. Since the chemical monitoring results have shown no major nutrient loading problems, the macroinvertebrate results lead to the conclusion that the lower portion of the watershed may be experiencing higher negative effects from erosion and sedimentation. Figure 5 shows the percentage of dominant organisms found at each site. These percentages indicate the biodiversity of macroinvertebrates at each site. The results of the percent dominance calculations make it apparent when compared to the results from Figure 4 that the sites with the higher percentage of sensitive organisms also had a higher biodiversity, and the sites with a lower percentage of sensitive organisms had a lower biodiversity. Site 5 in particular should also be noted. There were no sensitive organisms found at Site 5 which was back tracked to a major pollution point source.

Figure 5. Macroinvertebrate sampling average results from the months of June through August. Green represents sensitive organisms, yellow represents somewhat sensitive organisms and red represents tolerant organisms.



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Farm Tours

A total of seven farms were visited and assessed. The seven farms visited were diverse in size and animals raised or crops grown. The inspections, while few in number, are believed to have given an accurate representation of what are typical practices among the agricultural operations in the Wreck Pond Watershed. It was found through grower testimony that the quantities of fertilizers applied did not exceed what the crops can readily absorb, meaning, nutrients (Nitrogen, Phosphorous and Potassium) applied to the fields are not likely to run-off during storm events into the surrounding rivers and streams. The results from the nutrient monitoring (Tables 5 and 6) support this assumption.

However, of the four farms which raised animals, three of those farms may be impacting the watershed in a negative way in regards to manure management. It was observed that although the quantity of manure produced was relatively low, and the land was not directly adjacent to the stream, some microorganisms may reach the small tributaries of the Wreck Pond Watershed during large storm events. Table 8 describes the possible sources of contamination.

Table 8. Manure Management of Farms in Wreck Pond Watershed and Potential for Contamination into Water Bodies.

Farm	Animals Raised	Appropriate Manure Management Practices?
1	18 head of steer	Yes
2	7 miniature donkeys	No
3	~ 20 chickens, 4 pigs	No
4	~ 10 sheep, ~ 20 chickens and turkeys	No

Soil Analysis

The results of the stream bank soil tests (Tables 9 – 12) revealed that in all four categories, Ag, Mixed, Developed and Control, had macronutrient levels of phosphorus, potassium, magnesium and calcium that were either below optimum or optimum, rarely above. As for micronutrients, zinc, copper, manganese boron and iron were all either low or adequate, with the exception being iron. Iron levels were consistently high. However, these high iron readings are expected in the Wreck Pond Brook Watershed which has naturally occurring, highly glauconitic soils. The agricultural and developed stream banks showed a slightly higher level of organic matter and carbon, as well as nitrate-N and ammonium-N, than the control and mixed stream bank samples.

The results of the agricultural land soil tests revealed that more often than the stream bank samples, one or more macronutrients were above optimum levels, approximately 36 out of 48 samples (Table 13). The micronutrients were normal, with the exception of

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iron, for the same reasons as described above. Organic matter, organic carbon, nitrate-N and ammonium-N had a wide range of results, depending on the field tested.

The results of the recreational and homeowner land soil tests were similar to those of the agricultural land results. The macronutrients occasionally reached above optimal levels 20 out of 32 samples, especially in phosphorus (Table 14). Iron was the only high micronutrient, again for naturally occurring reasons. The organic matter, organic carbon, nitrate-N and ammonium-N showed no obvious distinction between the stream bank results or the agricultural land results.

Table 9. Agricultural Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)
A1a	4.90	40	83	160	1226	Iron - High	14.70	8.53	4
A1b	5.05	39	127	175	825	Iron - High	4.25	2.46	10
A2a	5.20	266	170	202	982	Iron - High	3.06	1.78	8
A2b	5.10	87	138	233	820	Iron - High	3.60	2.09	5
A3	5.05	117	106	192	953	Iron - High	5.14	2.98	2
A4	4.15	45	134	105	477	Iron - High	3.98	2.31	8

Table 10. Mixed Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)
B1	6.25	39	116	139	1849	Iron - High	3.58	2.08	7
B2	4.55	39	126	101	768	Iron - High	7.52	4.36	5
B3	5.45	58	116	162	873	Iron - High	2.74	1.59	3
B4	4.50	74	64	96	688	Iron - High	10.22	5.93	9

Table 11. Developed Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)
D1	5.65	9	69	188	1324	Iron - High	3.25	1.89	7
D2	5.10	95	211	137	936	Iron - High	2.49	1.44	11
D3	5.40	30	122	237	1092	Iron - High	4.90	2.84	13
D4	6.00	44	244	277	1999	Iron - High, Zinc - High	4.25	2.46	10

Table 12. Control Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)
C1	4.65	4	131	89	329	Iron - High	4.29	2.49	2
C2	5.15	1	44	80	343		1.86	1.08	2
C3	6.60	1	51	101	731	Iron - High	1.82	1.05	2
C4	5.50	17	162	153	797	Iron - High	3.25	1.88	2

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Table 13. Agricultural Land Soil Results

Description	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)
Hay	4.10	3	73	58	274	Iron - High	2.29	1.33
Hay	4.85	143	125	84	396	Iron - High	1.03	0.6
Hay	5.15	55	128	82	648		1.33	0.77
Hay	5.00	43	147	91	642	Iron - High	1.6	0.93
Hay	5.20	45	303	185	880	Iron - High	2.32	1.35
Hay	5.35	113	333	148	716	Iron - High	1.6	0.93
Hay	5.10	78	222	92	465	Iron - High	1.6	0.93
Hay	5.55	102	259	125	912	Iron - High	2.59	1.5
Hay	5.15	35	182	85	619	Iron - High	2.59	1.5
Hay	5.05	227	216	88	733	Iron - High	1.67	0.97
Hay	5.60	1037	183	91	2188	Iron - High	2.69	1.56
Mixed Vegetables	6.65	493	642	303	1874	Iron - High	3.03	1.76
Steer	7.80	113	179	224	1363	Iron - High	2.65	1.54
Steer	6.10	176	220	212	1413	Iron - High	3.03	1.76
Steer	5.90	211	290	240	1744	Iron - High	3.22	1.87
Mini Donkeys	6.15	64	69	197	1229	Iron - High		
Mini Donkeys	6.10	138	167	226	1362	Iron - High	2.58	1.5
Mini Donkeys	5.25	90	74	153	956	Iron - High	2.05	1.19
Hay	5.15	25	180	136	610	Iron - High	3.41	1.98
Mixed Vegetables	6.55	284	246	282	2321	Iron - High	4.28	2.48
Christmas Trees	5.15	275	46	57	479	Iron - High	1.56	0.91
Christmas Trees	4.75	376	47	37	203	Iron - High	1.17	0.68
Christmas Trees	4.75	344	80	42	211	Iron - High	1.01	0.59
Christmas Trees	4.85	353	82	52	305	Iron - High	1.09	0.63
Christmas Trees	5.00	377	83	51	371	Iron - High	1.33	0.77
Christmas Trees	4.95	221	47	64	560	Iron - High	1.37	0.79
Christmas Trees	4.85	370	50	45	421	Iron - High	0.94	0.54
Mixed Vegetables	6.50	587	421	129	1561	Iron - High	1.09	0.63
Mixed Vegetables	6.80	631	446	158	2127	Iron - High	1.8	1.04
Mixed Vegetables	6.70	611	488	137	1510	Iron - High	1.09	0.63
Mixed Vegetables	7.25	433	343	135	2652	Iron - High	1.52	0.88
Sweet Corn	6.80	439	340	112	1553	Iron - High	1.01	0.59
Sweet Corn	7.05	401	314	158	2282	Iron - High	1.6	0.93
Sweet Corn	6.75	373	343	154	1555	Iron - High	1.05	0.61
Sweet Corn	6.75	362	401	190	1780	Iron - High	1.56	0.91
Sweet Corn	7.20	334	453	169	2232	Iron - High	1.68	0.97
Sweet Corn	7.10	243	306	133	1488	Iron - High	1.01	0.59
Timber	4.30	143	101	62	341	Iron - High		
Timber	4.25	238	56	39	216	Iron - High		
Timber	4.15	191	103	51	355	Iron - High		
Timber	4.40	110	45	56	319	Iron - High		
Christmas Trees	5.35	221	137	108	463	Iron - High		
Christmas Trees	5.40	157	177	180	861	Iron - High		
Christmas Trees	5.60	106	64	192	817	Iron - High		
Horse Pasture	5.55	99	72	189	1041	Iron - High	2.64	1.53
Horse Pasture	5.75	141	284	224	1282	Iron - High	2.3	1.33
Mums	4.80	654	473	153	1202	Iron - High	2.41	1.4
Horse Pasture	6.30	137	282	259	1690	Iron - High	2.87	1.67
Horse Pasture	6.10	106	319	189	1183	Iron - High	1.45	0.84

Table 14. Recreational / Homeowner Land Soil Results

Description	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)
Soccer Field - Wall Board of Ed	5.35	64	184	182	1245	Iron - High	3.06
Baseball Field - Wall Board of Ed	5.05	97	198	170	1035	Iron - High	3.33
Soccer Field - Wall Mun Complex	6.00	122	345	336	1560	Iron - High	3.41
Soccer Field - Wall Mun Complex	6.45	66	244	462	1928	Iron - High	3.94
Golf Course - Spring Lake	6.00	168	441	209	1517	Iron - High	4.5
Golf Course - Spring Lake	6.40	123	284	195	1459	Iron - High	2.55
Golf Course - Spring Lake	5.50	125	311	164	1254	Iron - High	3.54
Golf Course - Spring Lake	5.70	117	267	179	1155	Iron - High	3.28
Golf Course - Bel Aire	6.25	317	184	234	2494	Iron - High	3.58
Golf Course - Bel Aire	6.20	212	174	244	1444	Iron - High	2.48
Baseball Field - Wall Board of Ed	6.45	43	141	219	1221	Iron - High	1.71
Soccer Field - Wall Board of Ed	5.95	42	89	155	834	Iron - High	1.6
Driving Range - Quail Ridge	5.95	42	127	395	2045	Iron - High	4.54
Driving Range - Quail Ridge	5.45	155	92	154	860	Iron - High	3.42
Playground - Wall Board of Ed	4.85	116	155	88	409	Iron - High	2.62
Soccer Field - Wall Board of Ed	4.95	68	117	90	384	Iron - High	2.12
Homeowner	5.45	39	94	240	1030	Iron - High	
Homeowner	5.40	50	130	245	1207	Iron - High	
Homeowner	5.80	143	69	206	1570	Iron - High, Copper - High	
Homeowner	6.95	347	417	470	4105	Iron - High	
Homeowner	5.35	135	283	259	1323	Iron - High	
Homeowner	5.55	316	287	290	1491	Iron - High	
Homeowner	6.60	32	49	126	1176	Iron - High	
Homeowner	5.35	32	133	146	1760	Iron - High	
Homeowner	4.60	137	300	161	1134	Iron - High	
Homeowner	7.15	33	201	384	2312	Iron - High	
Homeowner	6.75	30	148	252	1337	Iron - High	
Homeowner	6.50	20	130	301	1725	Iron - High	
Homeowner	7.15	170	93	573	2642	Iron - High	
Homeowner	6.75	151	130	366	2889	Iron - High	
Homeowner	8.10	233	202	506	13585	Iron - High	
Homeowner	6.70	382	244	377	3779	Iron - High	
Homeowner	6.70	229	281	247	2318	Iron - High	

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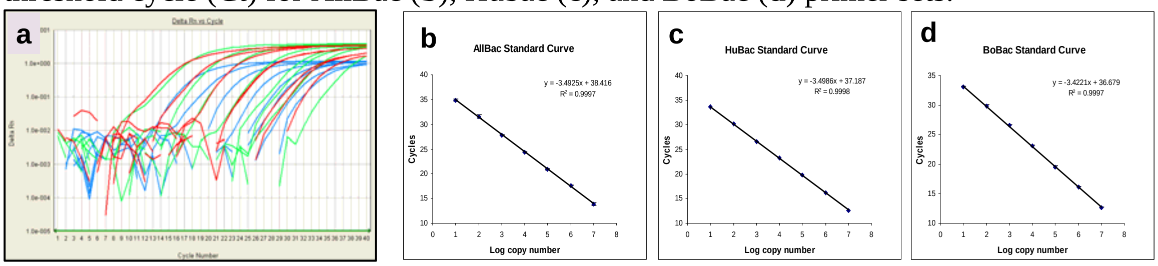
Microbial Source Tracking

Clonal libraries of 16S RNA genes generated from PCR of human and bovine feces yielded plasmids specific for HuBac and BoBac primer sets. These plasmids were quantified and used as standards for the qPCR assay. Dilutions of plasmid DNA provided standard curves which were linear from 10 to 100,000 copies per µL (Figure 6). During quantitative analysis, Bacteroidetes were detectable in samples from all stations at various times.

Figure 6. Standard Curves for quantification of Bacteroidetes: Amplification plot of all three standard curves (**a**), and the individual standard curves plotting log copy number vs. threshold cycle (Ct) for AllBac (**b**), Hubac (**c**), and BoBac (**d**) primer sets.



The ARA results confirmed that fecal pollution in the watershed does not come from a single source. Mixed sources of fecal pollution including human, avifauna, wildlife, and farm animals are consistently detected in surface waters and sediment in the watershed. General patterns of source inputs suggest that important physical environmental factors such as mixing and variation in flow through the watershed affects the predominant source detected at any given time.

The results of the conventional bacterial monitoring for Fecal Coliform and Enterococci are summarized in Table 15. The results show that the highest counts were found at station W9. Bacteria data were not collected after every storm event. The decision to close the beaches is based on rainfall. Monmouth County Health Department currently requires the beaches near the outfall in Spring Lake and Sea Girt to close whenever more than 0.1 inches of rain fall during the previous 24 hours. NJDEP extended the length of the Wreck Pond outfall to move the discharge away from the bathing zone and thus reduce the occasions when the outfall would cause bacteria levels to rise above the bathing beach standard. The actual impact of the extension of the outfall on recreational water quality in the bathing beach area has not been determined. MCHD did water quality studies last summer and NJDEP is initiating sampling within the surf zone this summer to determine if the rainfall provisional ban can now be modified.

The Monmouth County Health Department conducts monitoring of bacteria levels at beaches during the CCMP program, including Monday morning sampling. The data does not consistently show a direct correlation between rainfall during the previous 24 hours and bacteria levels at bathing beaches. For example, York Ave. beach in Spring Lake shows exceedances of the bacteria standard when the previous rainfall was zero as well as no exceedances when rainfall is 0.83 inches. In fact, for the sampling that occurred

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following the second-highest rainfall (0.83 inches) only the Terrace showed any detected bacteria and, at 20 cfu, was below the standard. This was on September 5, 2006.

Interestingly, the highest values at all of the beaches occurred when there was no antecedent rainfall for the previous week at the Wall Township station. On the July 17, 2006 event, elevated enterococci bacteria levels were noted at the York and Brown Avenue beaches, just north of Wreck Pond as well as the Terrace and Beacon Boulevard locations south of the Pond. The highest reading was at Beacon Blvd. at 12,400 cfu. Further south in Sea Girt the Philadelphia Ave. beach testing showed no detection and the Newark Ave was 20 cfu. Beaches to the North of York Ave also were not impacted.

Table 15: Water Quality Data for Wreck Pond Brook Watershed - Bacteria

Site	N	GeoMean	Median	Max	Min	25th	75th
Fecal Coliform							
W6	70	40	25	3900	4	10	156
W9	70	174	209	TNTC	4	69	528
W7	70	96	140	5300	4	40	298
W1	70	41	34	9200	4	10	105
W3	70	49	58	3700	4	17	123
W5	70	56	45	20000	4	16	160
W2	70	75	100	12100	4	15	283
W8	70	61	90	5200	4	13	230
Enterococci							
W6	70	45	40	5100	4	10	178
W9	70	149	150	TNTC	4	49	416
W7	70	97	100	6600	5	34	260
W1	70	36	30	TNTC	4	10	100
W3	70	46	40	TNTC	4	16	100
W5	70	59	48	12000	4	15	220
W2	70	75	70	5800	4	20	290
W8	70	54	60	7300	4	13	159

CONCLUSIONS

The results from this project indicate that neither the agricultural nor recreational lands are having a significant impact on the overall health of the Wreck Pond Brook Watershed. As Table 6 shows, throughout the monitoring year, there were very few water quality exceedences, with the exception of pH which was consistently slightly above the standard. However, this slightly high value can be contributed to the naturally occurring high pH for the area, similarly to phosphorus, which is also expected to be slightly above the recommended standard due to the regions highly glauconitic soils. The only sampling location that is in obvious need of remediation is Site 5 (Figure 5). Field observations make it apparent that it is being impacted by heavy soil erosion. This soil erosion is believed to be originating from a point source directly upstream. This issue is

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not related to agricultural or recreational lands and will be addressed in the Wreck Pond Brook Regional Watershed Management Plan.

The ARA results revealed that multiple inputs were affecting each site throughout the watershed in an unknown quantity. The qPCR results revealed that Bacteroidetes from all sources could be readily detected in 100ml surface water samples by using a highly sensitive qPCR assay. Human and Bovine contributions to fecal contamination could be distinguished from each other and pollution sources could be determined by the frequency of detection of specific markers at particular stations over the course of the summer. Despite the lack of obvious correlations between total Bacteroidetes and fecal coliforms, or any of the other water quality measurements, we were able to gain useful data was gained about the sources and extent of fecal contamination in the watershed.

The recommended action by the RCE to maintain surface water quality and further reduce what little impact agricultural or recreational lands are having on the watershed involves public education. The RCE have always recommended that prior to any planting or fertilizing that soil tests be done to first gauge the amount of nutrients already available in the land. If farmers, landscapers and homeowners follow the recommendations provided in their soil results, little nutrient run-off will take place. This policy benefits growers and landscapers in that given the high price of fertilizers, needless applications will greatly reduce costs. In addition to fertilizing practices, manure management also needs to be addressed. While it has been observed through farm tours that the majority of large, commercial Confined Animal Feeding Operations (CAFOs) appear to be complying with existing regulations in terms of manure management, smaller lands that may only have a few farm animals (Table 2), do not fall into this category. These small “hobby farms” are difficult to identify and regulate. Owner education appears to be the most effective option.

The RCE plans to increase their efforts in educating growers, landscapers and homeowners on the negative impacts over fertilizing has not only on their land, but the health of the entire watershed. Public informational workshops are planned for any and all stakeholders to reiterate the importance of reducing stormwater runoff and erosion, as well as easily implementable low-cost Best Management Practices. On-farm demonstrations of manure management facilities and practices are planned to take place in the near future. Follow-up MST research programs were initiated recently to expand the use of qPCR in such sensitive coastal watersheds.

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