Spring 2006

An Analysis of Indicator Organism Suitability for Lower James and York Rivers

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AN ANALYSIS OF INDICATOR ORGANISM SUITABILITY FOR LOWER JAMES AND YORK RIVERS

by

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B.S. May 2003, Hampton University

A Thesis Submitted to the Faculty of Old Dominion University in Partial Fulfillment of the Requirement for the Degree of

MASTER OF SCIENCE

ENVIRONMENTAL ENGINEERING

OLD DOMINION UNIVERSITY
May 2006

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UMI Number: 1433171

ABSTRACT

AN ANALYSIS OF INDICATOR ORGANISM SUITABILITY FOR LOWER JAMES AND YORK RIVERS

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The primary objectives of this thesis are 1) determine if the proper indicator organism is being utilized to determine the bacterial water quality in the State of Virginia. 2) If other environmental factors can predict the bacterial water quality. The current indicator organism of choice for bacterial water quality of waters in the State of Virginia is enterococci, for estuarine and brackish waters. E.coli is the indicator organism of choice for fresh waters in Virginia. The United States Environmental Protection Agency (US EPA), currently has no mandated recommendations, for either organism. This study analyzed which indicator organism is best for predicting bacterial water quality for recreational waters situated in the Hampton Roads Harbor, Lower James River and York River.

This study was carried out by performing water sampling and microbiological culturing and then using statistical analysis methods to determine if weather, water temperature, wind speed, wind direction, wind gusts, wave size, boats in vicinity, swimmers, sunbathers and precipitation result in high bacterial counts. These statistical analyses performed against E.coli and Enterococci counts determined which of these parameters can predict high counts of each indicator organism.

The study concluded 1) Enterococci are the best indicator organism for beaches located in the Hampton Roads Harbor and the Lower James River. 2) E.coli may be a better indicator organism during higher precipitation recreational seasons for Yorktown Beach. 3) Enterococci may be a better indicator organism

for dryer recreational water seasons. 4) *E.coli* counts were most likely affected by wind direction and precipitation. 5) Enterococci are present in significant amounts when sunbathers are present and for the sizes of waves at Yorktown Beach.

Co-Directors of Advisory Committee: Dr. Gary Schafran
Dr. Jaewan Yoon

ACKNOWLEDGMENTS

I would like to thank the Civil and Environmental Engineering Department for funding my research, my thesis advisory committee, Priyadarshan Phaltankar of the Norfolk Health District of the Virginia Department of Health, Daniel Blasche and the staff of Environmental Health of the Peninsula Health District of the Virginia Department of Health, Sherry Williams and Michelle Harrell of the Harwood Mills, Newport News Water Works, Yorktown. I would also like to thank John Ott, Rakesh Gupta and my family and friends who provided mental support during the cultivation of this work.

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CHAPTER 1
INTRODUCTION

This project's objectives are to determine whether the current indicator organism, Enterococci is the most suitable indicator for determining the bacterial health of recreational waters within the Peninsula Health District's beaches and to determine if other environmental factors can assist in the prediction of bacterial water quality. The results of this study will assist the Virginia Department of Health in its mission to protect the public from swimming related illnesses. Five recreational waters - Anderson Park, Hilton, Huntington, King-Lincoln Park and Yorktown Beach were analyzed for Enterococci and *E.coli*, the indicator organisms of choice for the Virginia Department of Health.

The Beaches Environmental Assessment and Coastal Health Act of 2000, an amendment to the Clean Water Act, was enacted to assure that all recreational waters are suitable for human recreation. The Act also requires that states and tribal entities choose indicator organisms that present an accurate representation of fecal contamination present in recreational waters for any sampling event (USEPA, 2000). This act was initiated due to public concerns of polluted waters and swimming related illnesses (USEPA, 2002b).

The sampling events in this study were performed from June 7 to August 16, 2005. Sampling was performed every Tuesday; if re-sampling was needed due to high counts of indicator organisms present in the sample, it was performed on or within two days. Grab sampling and microbiological techniques (Enterolert and mTec Agar) were employed to analyze the water samples. Statistics analyses were performed to determine which parameters were most likely influencing high counts of enterococci or *E.coli*.

1.1 BACKGROUND

In 1997, the US EPA created the Beaches Environmental Assessment and Coastal Health Program to require nationwide monitoring of coastal waters. The program was created to prevent the exposure of the public to bacterial pathogens in marine recreational waters (USEPA, 2002b). This program focused on five key areas to protect beach-goers and the environment.

These areas are the following:

a) Strengthening beach standards and testing

b) Providing better laboratory methods

c) Predicting pollution

d) Investing in health methods research

e) Informing the public

To make monitoring waters mandatory for all fifty states, the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act) amended the Clean Water Act. The BEACH Act was enacted to assure that public health is not compromised by pathogenic bacteria presence when performing recreational activities in coastal and Great Lakes recreational waters (USEPA, 2000). The BEACH Act had a requirement that, all states with coastal waters or that border the Great Lakes monitor recreational water quality, to protect the public. The U.S. Environmental Protection Agency (US EPA), under the BEACH Act, requires that each state adopt the appropriate indicator organisms that would be used to assess the quality of recreational waters to determine suitability of recreational uses.

In order to be an effective indicator organism, the organism(s) of choice should be present when pathogenic bacteria are present and specific in the prediction of the presence and absence of all possible pathogens. Presence in conjunction with pathogenic bacteria would provide the ability of an indicator organism to correctly classify a beach as unsuitable for swimming. Also, the indicator organism(s) should be easy to use and provide an accurate assessment of water quality in a short amount of time (Morrison, 2003).

Currently, only two indicator organisms are recommended by the EPA for use as indicator organisms in the United States: E.coli for freshwater and Enterococci for marine waters (USEPA 2003). The waters located in the Hampton Roads Harbor, on the Lower James and York Rivers are brackish, which means that either indicator organism could be used. Brackish water falls between fresh and marine waters. In the state of Virginia the indicator organisms of choice are *E.coli* for freshwater and Enterococci for estuarine and marine waters. Since both these indicator organisms are recommended by the State of Virginia, this study will compare the two in the Hampton Roads Harbor, the Lower James River and in the Lower York River, where the water is neither marine water nor freshwater. The limits for E.coli are - a geometric mean 235 colony forming units (cfu) per 100 mL of water sampled. Enterococci limits are - 104 colony-forming units (cfu) (*cfu will be used throughout this thesis*) per 100 mL of water sampled. This means if the sampling limits are exceeded, a swimming advisory is issued to the public.

Estuarine waters have salinities ranging from 0.5 parts per thousand (ppt) to 30 parts per thousand (ppt). Marine waters have salinities of 33 ppt or greater. Fresh waters have salinities that fall below 0.5 parts per thousand (ppt) and are generally lakes or rivers.

Based on the National Resource Commission study titled -Navigating Our Nations Waters 2005 - the most common source of fecal contamination in 2004 in Virginia was non-point source pollution from combined sewer overflows (CSOs)(Dorfman, 2005).

1.2 GEOGRAPHICAL AREA OF INTEREST

All recreational waters, for this study are located in the lower portions of the tributaries of the James and York Rivers. Global positioning points were generated using the North American Datum 1927 and the World Global System 1984 using a Geographical Positioning System (GPS) Unit. The following are the longitude and latitude points for the sampled locations:

1) Anderson Park (211) 36° 58.578 N 076° 24.060 W
2) Hilton Beach (208) 37° 01.667 N 076° 27.879 W
3) Huntington Beach (multiple points) Site 205: 37° 00.912 N 076° 27.329 W, Site 206: 37° 00.928 N 076° 27.332, Site 207: 37° 00.947 N 076° 27.336 W;
4) King-Lincoln Park 36° 58.084 N 076° 24.565 W
5) Yorktown Beach (multiple points) Site 203 37° 14.222 N 076° 30.391 W, Site 204 37° 14.183 N, 076° 30.347 W (Figure 1)

1.2.1 Climate

The area within the sampling area, located within the Tidewater area of Virginia, is humid and subtropical. Weather is affected by the Gulf Stream that flows in the Atlantic Ocean from south to north. Precipitation is created by the cold and warm fronts that pass through the area from the west. The Gulf Stream and these natural fronts create humid conditions in the summer (Hayden, 2006).

1.2.2 Characteristics of water bodies and beaches sampled

Anderson Park and King-Lincoln Park are located at the Hampton Roads Harbor, where the more saline waters of the Chesapeake Bay meet the James River. Here the Chesapeake Bay, also mixes with Atlantic Ocean waters, which are in the saltwater range (33 ppt).

In the Hampton Roads Harbor the salinity ranges between18 ppt to 28 ppt during the months of May to September. Huntington Beach and Hilton Beaches are located on the James River; Hilton Beach is approximately 2 miles upstream of the Huntington Beach. The salinity of Hilton Beach ranges from 14 ppt to 20 ppt. Huntington Beach salinities range from 16 ppt to 22 ppt.

The York River is located further north in the Chesapeake Bay Estuary and is approximately 26-35 miles away from the mouth of the Chesapeake Bay and the Atlantic Ocean. Yorktown Beach salinities range from 16 ppt to 20 ppt.

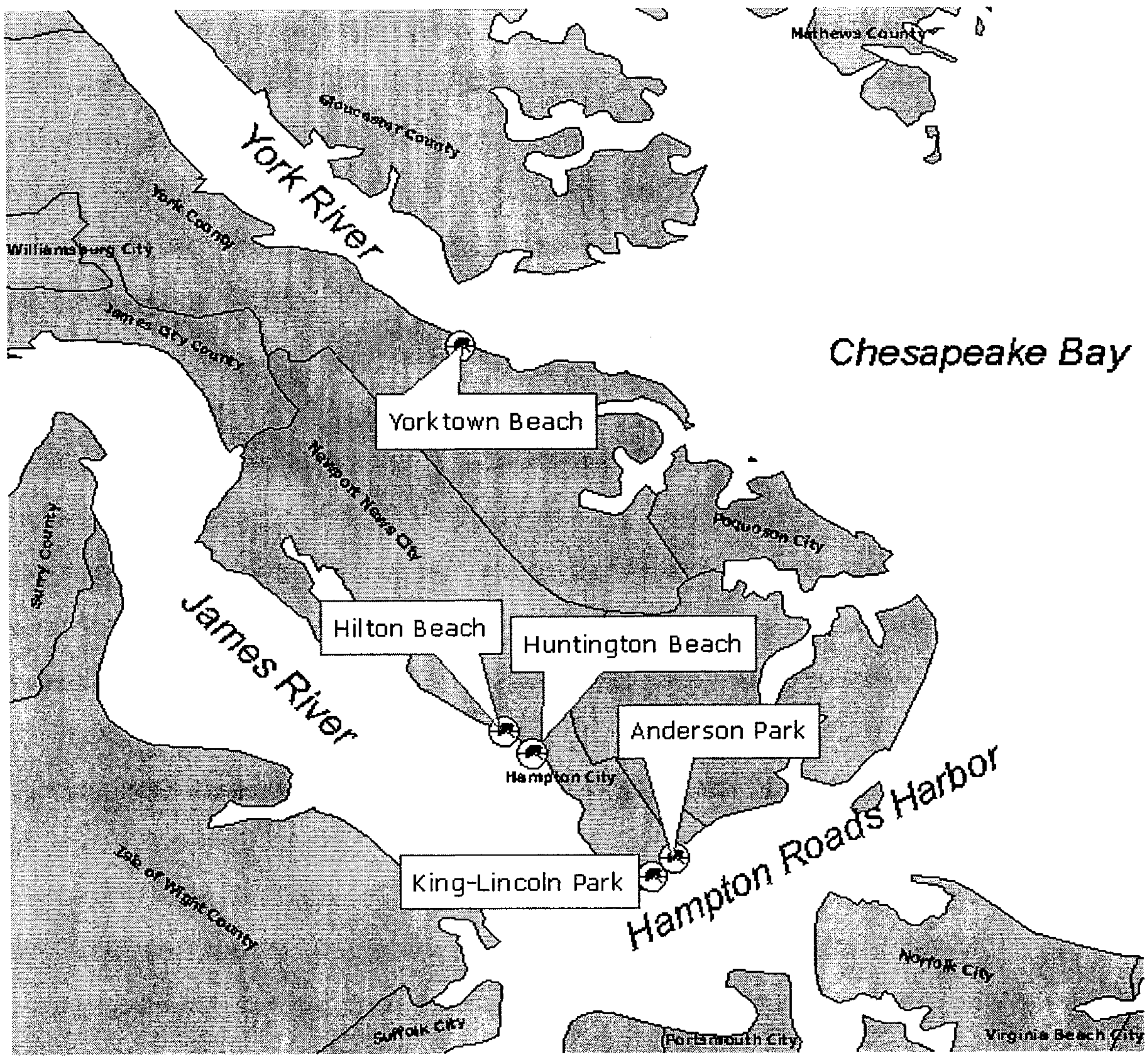

Figure 1. Water Quality Sampling Sites for the Peninsula Health District, Virginia Department of Health

The recreational swimming areas are delineated by rope and buoys at Huntington and Yorktown Beaches. These two beaches have public parking and lifeguards are also provided at Huntington Beach. The other beaches are not utilized as much and do not have defined swimming areas.

1.3 James River

The James River starts in the Allegany Mountains, at Iron Gate, Allegany County, Virginia and ends at the lower Chesapeake Bay, where the bay meets the Atlantic Ocean. The major tributaries of the James River are: Craig Creek, Maury River, Tye River, Rockfish River, Slate River, Rivanna River, Willis Creek, Appomattox River, Chickahominy River, Pagan River, and the Nansemond River.

The James River is comprised of three zones the outer marine-dominant zone, a central zone, and the inner river-dominated zone. In the outer zone, the bed load (sediment) transport is head ward. The central zone is mostly low-energy and that is where the net bed load converges. The inner, river-dominated portion is a meandering zone that has a net transport moving seaward (Dalrymple, 1992).

1.4 York River

The York River starts at West Point, Virginia and ends toward at the southeast at the Chesapeake Bay, a few miles away from Yorktown, VA. The main tributaries that serve the York River are the Mattaponi and the Pamunkey Rivers, meeting at West Point, Virginia. The rivers salinity is brackish/estuarine, ranging between 14 ppt to 22 ppt from the spring to summer respectively. The river is approximately 50-km long and is considered to be a sub-estuary of the Chesapeake Bay. The York River is divided into the lower, middle and upper York (Dellapenna, 2003).

The lower York is located below Gloucester Point. The river is approximately 3-6 km in width in the lower portion, with a broad shoal on the

north side and a narrow shoal on the south side. The salinity ranges from 20-25 ppt. The channel's depth is as much as 33 m, but on average is around 22 meters. The Middle York starts at Gloucester Point upward and generally has salinities ranging from 10 ppt to 20 ppt (Dellapenna, 2003).

The Upper York starts where the Pamunkey and Mataponi Rivers split the waters of the York River. In this area of the York River the salinities normally range from 2 to 15 ppt (Dellapenna, 2003).

1.5 LAND USE

1.5.1 Anderson Park Beach

The land surrounding Anderson Park Beach is used for transportation, residential and light commercial purposes. Short grass, oak and pine trees line the area between the apartment housing complex directly behind the beach and the beach. There are 2 storm water outfalls located on the beach. Directly across from the beach is the Norfolk Naval Base, which is the largest U.S. Naval Base on the East Coast of the United States (Figure 2). Boat traffic is prevalent in the waters off of the beach area. Crabbing boats, commercial ship traffic and sport crafts frequent the waters near Anderson Park Beach. The beach is located approximately 10 miles away from where the Chesapeake Bay and the Atlantic Ocean mix together, and is 20 miles away from Yorktown Beach.

1.5.2 Hilton Beach

Hilton Beach is located on the lower James River approximately 2-3 miles away from the James River Bridge. The land surrounding Hilton Beach is densely residential. Hilton Elementary School is located directly behind the beach. A fishing pier is located in the left corner of the beach and a storm water outfall is in

the opposite corner (Figure 3). The beach and school property is separated by a black fence.

1.5.3 Huntington Beach

Land use surrounding this beach characterized as transportation, residential, commercial and industrial (Figure 3). The area immediately surrounding Huntington Beach is Huntington Park which consists of tennis courts and volleyball on the beach. Parking located directly behind the beach separating the tennis courts from the beach. In the left corner of the beach is a restaurant and the James River Bridge which crosses the lower James River and is a part of U.S. Route 17. Huntington Beach is located approximately 15 miles away from the Chesapeake Bay.

1.5.4 King Lincoln Park

King-Lincoln Park is located in the Hampton Roads Harbor near the Monitor-Merrimac Bridge-Tunnel. A waste water treatment plant is located within 3 miles of the beach. Waterway traffic is high in the harbor on a daily basis. King-Lincoln Park is located near moderate industrial, commercial and residential land uses(Figure 2). Moderate industrial land uses consists of a boat repair facility located next to the beach. Commercial uses consists of a variety of small businesses that line Jefferson Boulevard near the beach. An apartment complex adjacent to the beach is used for residential purposes.

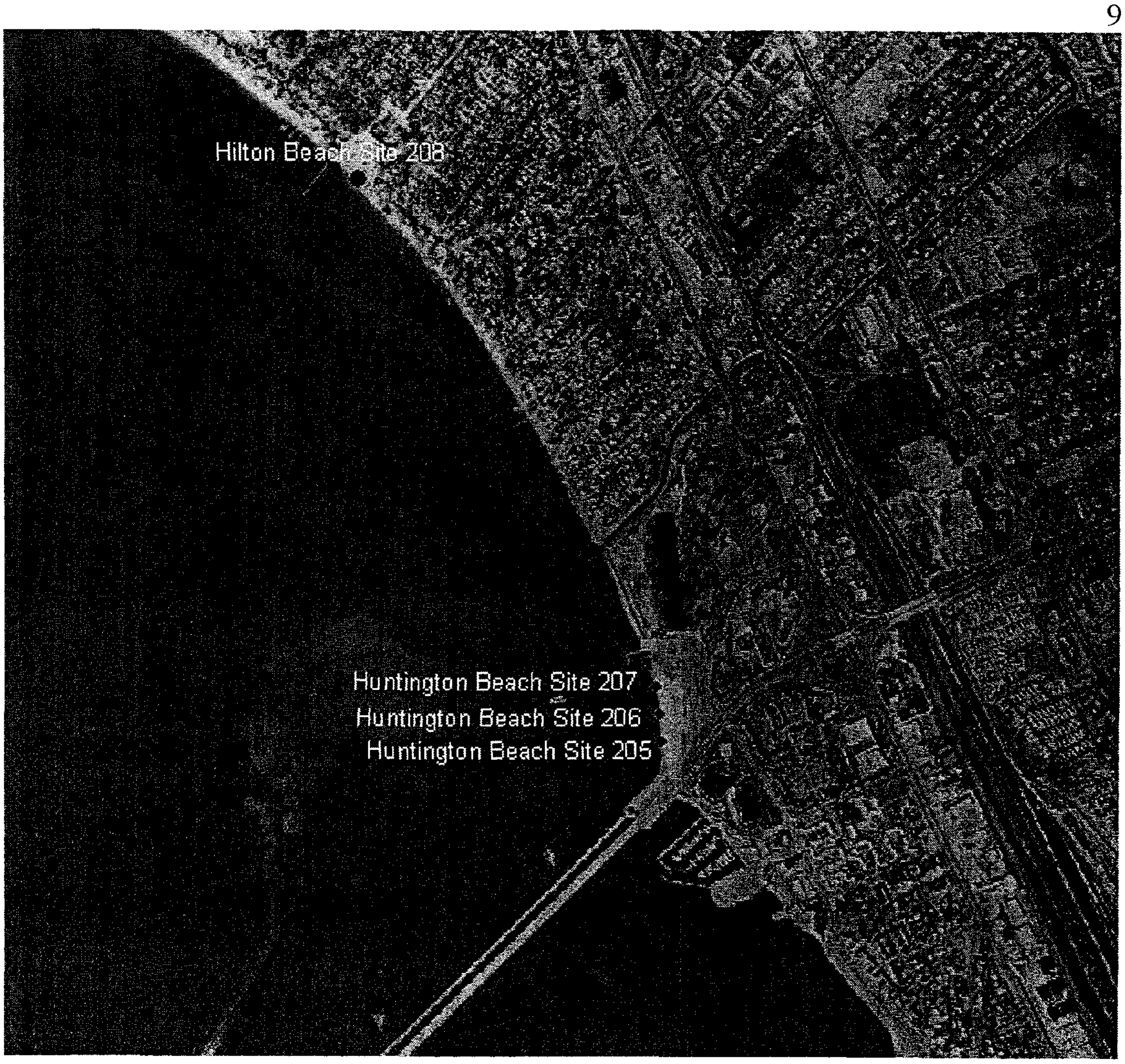

Figure 2.
Hilton and Huntington Beach Sample Sites, Newport News, VA (USGS, 1986)

Figure 3.
Anderson and King-Lincoln Park Sampling Sites, Newport News, VA (USGS, Unknown)

1.5.5 Yorktown Beach

Yorktown Beach is located on the Lower York River, near where the York River converges with the Chesapeake Bay. Directly behind the beach is a street for vehicular traffic and several restaurants. A hotel is located behind the beach as well. Commercial, transportation, residential and other land uses as a result of these structures occur in the vicinity of Yorktown Beach (Figure 4). Small crafts, commercial fishing boats, and small to medium sized ships frequent the area off-shore.

Figure 4. Yorktown Beach (USGS, 2005)

1.6 RESEARCH QUESTIONS

The following research questions were posed in by this study,

1. Is *E.coli* in addition to enterococci present in the Hampton Roads Harbor at the mouth of the James River, in the lower James or the York Rivers?
2. Does weather, water temperature, wind speed, wind direction, wind gusts, wave size, boats in vicinity, swimmers, sunbathers and precipitation have any significant effect on high counts of *E.coli* and enterococci that may be present at any of the beaches located within the Peninsula Health District?
3. Which indicator organism best suits each body of water sampled within the Peninsula Health District of the Virginia Department of Health?

The null hypothesis ($Ho=0$) is that the parameters analyzed will not affect Enterococci or E.coli bacterial counts. The alternative hypothesis ($Ha \neq 0$) is that the parameter analyzed has some significant effect on higher Enterococci or E.coli counts.

CHAPTER 2
LITERATURE REVIEW

2.1 Indicator Organisms for Recreational Waters

Indicator organisms for recreational waters have been chosen due to their detected presence with fecal contamination in waters. Indicator organisms are normally not pathogenic, but are present when pathogenic bacteria are present. The current indicator organisms used to assess the bacterial water quality are E.coli and Enterococci. Previously, fecal coliforms were used to assess whether pathogenic bacteria were present in recreational waters (USEPA, 1986). It was determined by studies in the Ambient Water Quality Criteria for Bacteria-1986 that fecal coliforms did not present any correlation with swimming associated illness (fecal coliforms were previously correlated with swimming associated illness). *E.coli* was chosen for freshwaters because the correlation coefficient for *E.coli* was slightly greater than enterococci (USEPA, 1986).

2.2 Current Analysis Methods for Indicator Organisms

Analysis methods for *E.coli* and enterococci are similar in procedure but are specific to the indicator organism being analyzed. Methods used to analyze water samples for *E.coli* are mTec agar, Colilert™, most probable number (MPN) and multiple tube fermentation. The mTec method is a two-step procedure where the bacteria are incubated for 2 hours to be resuscitated, and then placed in a hot water bath on top of a test-tube rack at 44.5± 0.2 for 24 hours.

Modified mTec agar, MPN and Colilert methods are quicker methods that involve the detection of the enzyme β-glucuronidase, which is produced by *E.coli* and would indicate a positive test. The enzyme is detected by testing due to the use of chromogens or fluorogens, which are substrates that fluoresce and

waters, but its use in recreational waters has not been tested thoroughly (Fed.Register, 1994; Francy, 1999).

In numerous studies of raw and natural fresh waters, there were no statistically significant differences in the detections of *E.coli* between the Colilert method and various membrane-filtration methods (Cowburn, 1994; Fricker, 1996). This finding could assert that there is potential for Colilert to be an acceptable method for analyzing recreational water for E.coli. However, in another study, *E.coli* counts were underestimated with Colilert, making mTec agar the most feasible choice (Francy, 1999). When Colilert (MPN) results were compared with mTec and modified mTec counts, it was determined that its values were lower most of the time, underestimating the amount fecal contamination present in the water sampled (Francy, 1999). Enterolert was tested by Budnick, et.al(1996) for its ability to analyze recreational waters. When Enterolert was compared to the standard membrane-filtration method for Enterococci in 138 fresh and marine waters, it exhibited marginally more acceptable water-quality results than the membrane filtration method.

2.3 Sediments and indicator organisms

Sediments act as potential reservoirs for microorganisms in aquatic environments by shielding the microbes from UV rays and other environmental factors that may decrease their lives (Erkenbrecher, 1981; Grimes, 1975; Hendricks, 1971). Microorganisms can attach themselves to suspended particles, when they are present in the water column. When the suspended particles settle out of the water column the organisms are still attached, protected from predators and environmental stresses. If the enteric bacteria have already died off then there is the potential for overestimation the bacterial water quality of the water column if these sediments become re-suspended (Sherer, 1992).

Many studies have found that wet weather events have a high correlation with the concentration of indicator organisms present in a water body (Jin, 2004). However, in one study, it was determined that enteric viruses were sporadically related to rain events (Ferguson, 1996). This would make indicator organisms in

some cases, over indicative of fecal contamination present in the recreational water. Bacteria that have settled out of solution into the sediments have been found to experience a more beneficial biological environment decreasing die-off times (Doyle, 1992; Sherer, 1992). Since the mortality rate is decreased by environmental factors, the possibility is presented that recontamination of the water column through microbial resuspension may occur prior to death of the microorganisms (Doyle, 1992; Sherer, 1992). If these organisms become resuspended in recreational waters frequented by recreators, there is a possibility that the water could become contaminated with pathogenic bacteria and cause illness in swimmers.

Turbidity, which is the degree of cloudiness in water is caused by suspended solids, has been correlated with high indicator organism counts when wet weather events occur (Jeng, 2005). While in the water column the microbes can attach themselves to suspended particles so that they can be shielded from the sun and for protection from predators, causing a potential health risk. These suspended particles eventually fall out of solution and become a part of the sediments and can remain for a few days before dying off (Jeng, 2005). An epidemiological study found that there may be a correlation between the numbers of *E.coli* associated with particles, but not with E.coli found in the water column. The possible reason for this may be due to illness rates being a function of the likelihood of swallowing particles containing high densities of pathogens (Dufour, 1982).

For *E.coli* particle concentration, shear rate and sewage content of the water correlated to removal rates out of the water column into the sediments (Alkan 1999). However, for Enterococci only clay concentrations and shear rate had a significant impact on removal rates (Alkan, 1999). Enterococcal species, when compared to *E.coli* have been found to have higher adsorption rates by particulate matter and are removed from the water column at higher rates. This would make enterococci a better indicator organism when dealing with sediment sampling of recreational waters (Alkan, 1999).

2.4 Non-Point Source Pollution

Non-point source pollution presence is due to high amounts of rainfall and snowmelt over and through the ground that carry pollutants to lakes, rivers, estuaries, etc and cannot be traced to a specific source (USEPA, 2006) . The opposite of non-point source pollution is point source pollution, which is pollution that can be traced to a specific source. Non-point source pollution can pose problems because of its tendency to be hard to prevent and to trace. An example of non-point source pollution would be a bird releasing guano onto the seashore and it washing into the tide and contaminating the water.

Storm water is a major contributor to the fecal contamination of recreational waters, because it initiates runoff from high landforms into lower landforms, which can be adjacent to water bodies (Jin, 2004). Storm water is generally considered to be Combined Sewer Overflows (CSOs) and is normally associated with non-point source pollution.

Bacteria that originate from storm water can be directly discharged into receiving waters and can stay in the water column and be transported for a while prior to die-off (Troussellier, 1998). After the microbes have been transported they fall out of the water column into the sediments, where the shielding process takes place, allowing the microbes to be present in high concentrations than in the water column (Doyle, 1992; Pommepuy, 1992). Enteric bacteria survival in marine environments may have some dependence on the conditions at release and also what condition the actual bacterium was in prior to release. Most enteric bacteria are released into storm water after their stationary phase of growth and probably would not have multiplied even if adverse environmental factors were not present (Troussellier, 1998).

Wild birds such as geese, gulls and ducks are other sources of non-point source pollution that can affect pathogenic bacterial counts of surface waters. Birds have been found to excrete large amounts of fecal bacteria through guano, which is a common name for bird feces, that can contain enteric pathogens (Geldrich, 1969; Ricca, 1998). This guano can also contribute to high counts of

pathogenic bacteria in addition to precipitation that fuels runoff. Determining the source of pollution can pose a problem because guano dropping is random, making estimation difficult (Kirschner, 2004). It has been determined based on this randomization of droppings that the amounts of birds in an area (such as a Beach) are significantly correlated with fecal coliforms, E.coli and Enterococci (Kirschner, 2004).

2.5 E.coli and Enterococci

Enterococci and *E.coli* were found to be better indicator organisms for predicting health risks in recreational waters in comparison to fecal coliforms, which are a conglomerate of many types of bacteria that are members of the coliform group. E.coli is a member of the coliform group, but was found to be a better indicator due to its presence in the human intestines (USEPA, 1986). *E.coli* is a natural resident of the human digestive system and generally does not cause health risks, thus making it an excellent indicator organism. Enterococci, as well as *E.coli* tend to perform better under certain environmental conditions. Enterococci are generally more resilient under saline conditions; E.coli is most resilient under freshwater conditions. Neither organism is a natural inhabitant of recreational waters and must be introduced by a source, whether of non-point or point source origins (USEPA, 1986). The EPA designates E.coli as the indicator for freshwaters and Enterococci for marine waters, but there is no main indicator organism indicated by the U.S. EPA for brackish and estuarine waters. This leave the choice of indicator bacteria used to the discretion of the government entity that performs water quality monitoring.

Some recent studies have found that Enterococci are a better indicator than *E.coli* and the fecal coliform groups due to its ability to withstand a variety of environmental stressors in brackish waters (Jin, 2004). However, some studies have found that *E.coli* survival rates are better than or close to Enterococci rates in estuarine water (Alkan, 1995; Medema, 1997). In a 1995 study of both indicator organisms survival in marine water it was determined that when both indicators are stressed with radiation, vertical mixing and turbidity enterococci

species survived only slightly longer than *E.coli* species (Alkan, 1995). The variation in findings with die-off rates of both indicator organisms is due to the strains of each organism being used in previous studies (Alkan, 1995).

A 2004 study found that log transformed fecal coliform and *E.coli* data displayed weak but significant negative correlation with salinity ($P<0.05$) (Kirschner, 2004). Enterococci displayed highly significant correlation with chlorophyll a, total phosphorus, bacterial production, carbonate and precipitation. Dissolved oxygen content was found to not have much of an affect on enterococcal counts (Kirschner, 2004).

2.6 Sunlight and other Environmental Stressors

UV radiation, predation, chemical and biological factors can decrease bacterial populations in natural waters. Two of the main culprits responsible for bacterial mortality in natural waters are sunlight and predaceous microbes (Rhodes, 1990). Solar radiation can cause a reduction in colonies in marine waters at higher rates when compared to the other environmental factors (Davies, 1989; Evison, 1982; Fujioka, 1981; Gameson, 1975; Gameson, 1967; Pommepuy, 1992). In marine waters the lives of *E.coli* can be decreased from days to hours when exposed to sunlight. *E.coli* are affected by predation by protozoa and amoebas, nutrient competition and deactivation by sunlight (Aubert, 1975; Jannasch, 1968; Mitchell, 1969; Sieburth, 1962).

Light that is near UV and visible light has been found to delay growth with recovery and caused mutation and/or death in E.coli colonies (Rhodes, 1990). This is due to visible light having the ability to damage the DNA of the bacteria (Troussellier, 1998). The mortality of *E.coli* has been found to be highest during the first four hours of exposure, with the more resistant bacteria surviving in waters collected from the York River at Gloucester Point, Virginia, United States (Rhodes, 1990). After sunlight was removed the *E.coli*, densities were found to increase, which could show that fecal contamination periods could increase if it is cloudy and also that the sun is bactericidal to *E.coli*. Light exposure, Ultra-violet A and B Rays have a marked effect on the colony-forming capacity of bacterial populations (Trousselier, 1998).

Temperature also has an effect on bacterial life expectancy, with temperature increases of 10 degrees or more doubling the die-off rate based on log scale in river water (Medema, 1997). In marine waters, temperature was found to not have as much of an adverse affect on die-off rates under light conditions (Alkan, 1995).

CHAPTER 3
METHODOLOGY

This chapter explains how this study was carried out. It describes in detail how samples were collected, what methods were used to identify the presence of indicator organisms, how the samples were analyzed, and where the parameter values came from.

3.1 COLLECTION, TRANSPORT AND STORAGE METHODS

Two grab samples were obtained from each site, one sample for the analysis of *E.coli* and the other for analysis of Enterococci. Samples were obtained in a knee-length to waist-length water at each sampling site, between June 7th and August 16th, 2005. Special care was taken to prevent sediments from entering the sampling bottle, by obtaining samples about 3-5 inches below the surface of the water. The frequency of sampling was every Tuesday. If high counts were present in a water sample, re-sampling was performed on Thursday to determine whether the bacterial levels returned to safe levels. Newport News Water Works, Harwood Mills, located in York County, Virginia, performed Enterococci analysis, while the researcher performed the *E.coli* analysis in the Environmental laboratory in Kaufman Hall, Old Dominion University.

Temperature, salinity, dissolved oxygen (mg/L), percentage of dissolved oxygen, and pH value measurements were collected using YSI multi-meter model 556. A Meridian GPS unit was used to obtain exact coordinates of the sampling sites and to also gage the wind direction with the compass function. Generally these parameters were measured before obtaining the water samples. Time of sample collection, the date the sample was taken, wind direction, weather conditions, site conditions, YSI-556 multi-meter parameters, the number of swimmers, sunbathers, and birds were documented on a field data collection sheet for each beach. The water samples, collected in IDEXX 100 mL bottles and Nalgene 200 mL bottles were placed into a cooler packed with frozen ice packs to preserve the samples for analysis.

The samples were taken in the following order on normal sampling days: Hilton Beach (Site 208), Huntington Beach (Site 205), Huntington Beach (Site 206), Huntington Beach (Site 207), King-Lincoln Park (Site 210), Anderson Park Beach (Site 211), Yorktown Beach (Site 203) and Yorktown Beach (Site 204). Generally samples were collected from 8 am to 12 pm, so that the samples could be analyzed within 6 to 8 hours. Note that all samples obtained for enterococci were reported to the public as required by the EPA and were analyzed within 6 hours. *E.coli* counts were analyzed within 8 hours, due to time constraints and were not reported to the public.

3.2 ANALYSIS METHOD FOR *E.COLI*

The *E.coli* samples were collected in the 200 mL Nalgene bottles and analyzed by the researcher in the Environmental Engineering Laboratory of the Civil and Environmental Engineering Department at Old Dominion University. Membrane filtration was performed on *E.coli* water samples to obtain bacterial counts. One to two weeks before each sampling event, m-Tec agar plates were prepared and labeled appropriately with the site number and date of sample collection. The plates were placed in the refrigerator/incubator prior to use. Once the samples arrived at the lab, the Petri-dishes with m-Tec agar were placed on a lab bench then allowed to acclimate to room temperature for ten to twenty minutes. The autoclaved membrane filtration apparatus was assembled onto a 1000 mL beaker with vacuum hookup. The beaker was then hooked up to the vacuum. A 50 mL beaker of ethyl alcohol was prepared and the forceps placed into the beaker. Flame from a Bunsen burner sterilized the alcohol-drenched forceps.

A sterile membrane filter (MF) was placed onto the membrane filtration apparatus with the sterile forceps. The sample bottle was then shaken for approximately twenty-five times to equally distribute the microbes and the water then measured using a sterilized graduated cylinder. The water in the graduated cylinder was then poured into the membrane filtration apparatus (MFA) and the vacuum was turned on. The vacuum assisted gravity to pull the water through the

MFA. Working phosphate buffer solution was used in a Nalgene squeeze bottle to rinse the sides of the funnel and the MFA. The vacuum was cut off funnel and the water was siphoned through the MFA. The MF was then removed with the sterile forceps and placed securely onto the m-Tec agar. The dish was closed, inverted and incubated for two hours in an incubator at 35 ±0.5°C, then placed into a plastic Ziploc bag sealed and placed into a water bath at 44.5 ±0.5°C for twenty-two to twenty-four hours. After the incubation period, the membrane filters were placed onto filter pads saturated with Urea for fifteen to twenty-five minutes with sterile forceps. Colonies that remain yellow, yellow-brown or yellow-green were identified as fecal E.coli. This process was repeated for water samples collected from each of the site. Each site has a 25 mL and 50 mL dilution plates until August 4th 2005, after it was determined that 50 and 100 mL was not yielding countable plates to yield the desired -20-80 colonies as recommended by the U.S. EPA. Dilutions were changed to 10 and 25 mL from August 11th to the 16th to accommodate higher plate counts for sediment sampling (USEPA, 2002a).

3.3 VERIFICATION OF *E.COLI*

Using the colonies present on the plates after the Urease test on the filter pads, the growth (8-10 isolated colonies) were transferred using a sterile inoculation loop to Nutrient Agar plates and to the Tryptic Soy Broth (TSB) and incubated for twenty four hours at 35 ± 0.5°C. After being removed from the incubator, a colony of growth from the nutrient agar was extracted with a platinum loop and deposited on the surface of a piece of filter paper that was saturated with Oxidase Reagent. If the spot turned purple within fifteen seconds, the test was determined positive.

The growth from the Tryptic Soy Broth was then transferred to the Simmons Citrate Agar, Tryptone Broth and an EC broth fermentation tube. The Simmons Citrate Agar and Tryptone Broth were incubated for forty-eight hours at 356 0.5°C; the EC broth was placed in a water bath with a temperature of 44.56

The growth from the Tryptic Soy Broth was then transferred to the Simmons Citrate Agar, Tryptone Broth and an EC broth fermentation tube. The Simmons Citrate Agar and Tryptone Broth were incubated for forty-eight hours at 356 0.5°C; the EC broth was placed in a water bath with a temperature of 44.56 0.2°C for 24 hours. Special care was taken to ensure that the water was above the EC broth in the water bath. When the Tryptone Broth was removed from the incubator, 0.5 mL of Kovacs Indole Reagent was added to the Tryptone Broth tube and shaken gently. A positive test for Indole was indicated by deep red color that develops in the alcohol layer on top of the broth.

Overall E.coli is Indole-positive, EC gas-positive, oxidase-negative and does not utilize citrate (medium stays green)(USEPA, 2002a).

3.4 ANALYSIS METHODS FOR ENTEROCOCCI

Enterococci water samples were collected in IDEXX 100 mL bottles and analyzed at Newport News Water Works, Harwood Mills, York County, VA. Enterolert (manufactured by IDEXX), MPN method using chromogenic substrate was performed to generate bacterial counts for Enterococci. The amount of fecal Enterococci can be determined by membrane filtration, multiple tube fermentation, and chromogenic substrate methods. Enterolert results are given in MPN based on the presence or absence of fluorescence in 51 individual wells each containing a sample-nutrient indicator mixture. Negative wells give off no color. Enterolert has been found to give similar results to membrane filtration.

The Enterolert reagent was removed from the refrigerator in a quantity sufficient for one day's service. Then 90 mL of sterilized DI water was placed into 2-Corning dilution bottles. The Quanti-Tray sealer was turned on, and the water sample that was previously collected in the sterile 100 mL IDEXX bottle was shaken 25 times. Then 10 (ten) mL of the sample is pipetted into a Corning bottle containing the 90 mL of sterilized DI water. The bottle was then capped

and shaken. Using an aseptic technique, one blister pack of reagent was added to each 100 mL sample, and then shaken until the reagent dissolved. These procedures are repeated for the duplicate sample. The sample was then poured into the Quanti-Tray/2000 and sealed into the sealer. The sealed Quanti-Tray/2000 was then placed into a 41°C ± 0.5°C incubator for twenty-four hours.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

The mTec agar media used to analyze water samples for *E.coli* was quality assurance (QA) tested by the Norfolk Health District of the Virginia Department of Health staff in Environmental Health on July 1st ,2005. The QA consisted of confirmed strains of fecal *E.coli* spread onto pre-made mTec agar plates prepared by the researcher and left to grow at 45±0.5°C for 24 hours. If the positive controls of *E.coli* grew on the plates, the media passed the quality assurance test. The mTec agar plates yielded colonies of fecal *E.coli* in the Quality Assurance, and was found to be suitable for this study. Plates were prepared every one to two weeks in prior to sampling events and placed into the Incubator/Refrigerator upon solidification.

The YSI-556 multi-meter was calibrated one hour prior to obtaining the first sample water sample at Hilton Beach. The DO % parameter on the probe was calibrated with ¼ of an inch of water in the transport/calibration cup with the cap loosened. The pH was calibrated using the two point option, with 30 mL of both the 4 ph buffer and 7 pH buffer initially at the start of recreational water quality monitoring season. Thereafter one point calibrations were performed with the 30 mL of the 7 pH buffer. The specific conductance was calibrated with 55 mL of the 10 mS/cm conductivity standard, for brackish waters. Between each calibration,the probes components and the transport/calibration cup were rinsed with di-ionized water.

Quality Assurance and control was performed by the researcher by using test blanks prior to and after performing membrane filtration on the samples.

Also, verification procedures provided quality assurance that fecal *E.coli* was actually represented on the mTec media.

3.6 ANCILLIARY DATA

National Oceanic and Atmospheric Administration unedited meteorological information for Newport News International Airport (Station ID= PHF) and the Yorktown U.S. Coast Guard Training Center (Station ID = 8637689) in Yorktown, VA, Latitude 37 13.6' N, Longitude 76 28.7' W were obtained to collect information on the following parameters: wind direction, wind gust, wind speed, amount of rainfall per hour, amount of rainfall per day, and weather conditions prior to sampling events (NOAA, 2005). These parameters in addition to swimmers, sunbathers and bird presence were used to compare against bacterial counts of *E.coli* and Enterococci to statistically determine which parameters could potentially cause a bacterial exceedance for each indicator.

3.6 DATA PROCESSING

The data obtained from field data sheets Harwood Mills Water Treatment Plant, the mTec Plates and the National Oceanic and Atmospheric Administration (NOAA) was compiled into a Microsoft Excel spreadsheet. The results for *E.coli* and enterococci were analyzed statistically by calculating the mean, median, mode, standard deviation, skewness, and kurtosis. The data normality was also plotted in the form of stem-and leaf plots, box plots, and normal probability plots. The plots provided visualization of the normality of the data. The normality of data determines whether parametric or non-parametric statistics will be used to analyzed the data.

Month of sample, water temperature, weather conditions, wind speed, wind direction, wind gusts, wave size, boats in the vicinity, number of swimmers, the number of sunbathers, and precipitation amounts (inches), *E.coli* and Enterococci counts in the spreadsheet were then analyzed in statistically to

determine which parameters affected the counts. *E.coli* was analyzed against all the parameters, except for enterococci, which had its own analysis against the parameters.

CHAPTER 4
RESULTS

This chapter presents the results of the verification procedures performed on each beach, the statistical analyses of *E.coli* and enterococci counts for sites 203 and 204. The results of this chapter will allow the reader to see how *E.coli* and enterococci compare to each other in the sediments and in the water column in a variety of environments at Yorktown Beach (sites 203 and 204). The statistical analyses will allow the researcher to determine whether any of the parameters tested provide any significance to concentrations of either indicator organism.

The following parameters were compared to *E.coli* and Enterococci in separate statistical analyses.

- Number of boats in vicinity
- Precipitation amounts (inches)
- Number of sunbathers
- Number of swimmers
- Water temperature (Fahrenheit)
- Wave size
- Weather
- Wind direction
- Wind gusts

- Wind speed
- Site

4.1 VERIFICATION

It was determined within the first month of the study that *E.coli* was present only at sites 203 and 204 (Tables 1, 2 and 3). The results for the other four beaches in the Hampton Roads Harbor and on the James River were found not to be valid because the growth on their respective plates were verified not to be fecal *E.coli* by the following tests performed. Enterococci were the only indicator bacteria/organism that were present at Anderson, Hilton, Huntington, and King-Lincoln Park Beaches. Verification tests were performed on water samples at all sites at least once. Huntington and Yorktown beaches have multiple sample sites therefore one sample from each site may have represented either beach. For example; Site 205 had a plate with 20-80 colonies but Sites 206 and 207 did not, so we would use Site 205's plate for verification of Huntington Beach.

Table 1
Verification Test Results for E.coli 7-14-2005

Site	EC Broth Test	Simmon's Citrate Agar	Indole Test (1% Tryptone)	Oxidase Negative
211	Positive	Positive	Positive	Negative
208	Positive	Positive	Positive	Negative
205	Positive	Positive	Negative	Negative
207	Positive	Positive	Negative	Negative
210	Positive	Positive	Positive	Negative
211	Positive	Positive	Positive	Negative
203	Positive	Negative	Positive	Negative

Table 2
Verification Test Results E.coli 8-11-2005

Site	EC Broth Test	Simmon's Citrate Agar	Indole Test (1% Tryptone)	Oxidase Negative
208	Positive	Positive	Positive	Negative
205	Positive	Positive	Negative	Negative
207	Positive	Positive	Negative	Negative

Table 3
Verification Test Results for E.coli (Yorktown Beach) 8-20-2005

Site	EC Broth Test	Simmon's Citrate Agar	Indole Test (1% Tryptone)	Oxidase Negative
203	Positive	Negative	Positive	Negative
204	Positive	Negative	Positive	Negative

Samples were obtained from June 7th to August 9th for the study (Table 4). Most plates at each of the sites displayed growth of yellow, yellow-brown, and yellow-green colonies, which are indicative of *E.coli* presence, but some sites had plates with growth determined not to be fecal *E.coli.* All sites were verified on 7-14-2005 except the Site 204 because no colonies were present on the plates (Table 1). Out of all the sites verified over a three-day period the only site that responded identical to fecal *E.coli* is site 203 located at Yorktown Beach on the York River (Tables 1 and 3). Other dates with high colony count plates were verified on August 11th 2005 and August 20th 2005 to ensure that the previous verification results were accurate. The results of these last verifications supported earlier results obtained (Tables 1 and 2).

A final verification was performed on plates collected on 8-16-2005 from Yorktown Beach Sites 203 and 204. These tests again supported earlier findings that suggested that fecal *E.coli* was present at Yorktown Beach (Table 3).

In order to be positively identified as *E.coli*, the colonies sampled should have tested Oxidase Negative (no response to oxidase within 25 seconds), produced gas in EC broth tube, Indole Reagent test should have appeared red on the upper most layer of the broth, and the Simmon's Citrate Agar must have remained green, which was negative reading on Simmon's Citrate Agar. A positive reaction on Simmon's Citrate agar would have been a color change (ex. from green to blue) (USEPA, 2002a).

4.2 *E.COLI* AND ENTEROCOCCI RESULTS FOR SITES 203 AND 204

Enterococci counts remained below 40 cfu/100mL during the study period. *E.coli* exceeded the 235 cfu/100 mL on two occasions (Table 4). One exceedance of E.coli occurred with 48 hours of a heavy rain event (Table 4). The first exceedance occurring on July 26, 2005 occurred although there was no rain observed prior to sampling (Table 4). Yorktown Beach was the last sample site to be sampled with collection occurring between the hours of 10:15 a.m. to 12:30 p.m. Sites 203 and 204 were sampled within 5 minutes of each other.

Table 4
Indicator Organism Sampling Results

Date	Site	Time Coll.	Enterococci (cfu/100 mL)	*E.Coli* (cfu/100 mL)
6/7/2005	203	11:15 AM	1	67
6/7/2005	204	11:20 AM	1	26
6/14/2005	203	10:45 AM	6	5
6/14/2005	204	10:50 AM	1	30
6/23/2005	203	12:15 PM	1	0
6/23/2005	204	12:20 PM	1	50
6/28/2005	203	10:15 AM	31	12
6/28/2005	204	10:20 AM	20	40
7/5/2005	203	12:00 PM	1	25
7/5/2005	204	12:05 PM	1	19
7/12/2005	203	12:25 PM	1	36
7/12/2005	204	12:30 PM	1	29
7/19/2005	203	10:25 AM	1	5
7/19/2005	204	10:30 AM	1	8
7/26/2005	203	11:15 AM	1	558
7/26/2005	204	11:20 AM	1	4
8/4/2005	203	11:00 AM	11	38
8/4/2005	204	11:10 AM	1	55
8/9/2005	203	10:15 AM	10	28
8/9/2005	204	10:20 AM	1	0

4.3 STATISTICAL ANALYSES

The null hypothesis for analyzing statistical differences data is there is no statistical difference between *E.coli* and the parameter in question and that their means are equal ($P>0.05$). The alternative hypothesis is that there is some statistical difference between the compared parameter and the means are not equal ($P<0.05$). SAS computer program was used to generate statistical results for this study. It was determined initially that the data was non-parametric ($P<0.001$) by performing a proc univariate, which determines the mean, median, mode comparing *E.coli* and fecal enterococci. The proc univariate was also performed in natural log (Ln(x)) and exponential (EXP(x)) forms of the *E.coli* and enterococci in separate runs to further confirm that the data was non-parametric. The equation for determining the sample mean is:

$$X := \frac{x_1 + x_2 + \dots\dots\dots + x_n}{n}$$

Where X stands for sample mean, x_1 and x_2 stand for the actual observation and n stands for the number of observations.

The mode of a sample set is defined as the most frequently occurring data value. The median is defined as the measure of central tendency that divides the date into two equal parts (Montgomery, 2003). The standard deviation of a sample is determined by calculating the square root of the variance and is defined by this equation:

$$\sigma = \sqrt{\sigma^2}$$

Where σ is the standard deviation and σ^2 is the variance (Montgomery, 2003).

Skewness applies to this study because it deals with the asymmetry of the data probability distribution, helping to determine whether the data is normally distributed. Kurtosis is the measure of the degree to which the unimodal distribution is peaked. This would apply to data that does not perfectly fit the bell-curve distribution (i.e. non-parametric data) (Montgomery, 2003).

The results for the non-parametric statistics were run using the WILCOXON-RANK SUM function in SAS, which is a statistical test procedure that arranges all observations in ascending order of the magnitude and then assigns ranks to them. WILCOXON-RANK SUM is defined as:

$$W_2 := \frac{(n_1 + n_2)(n_1 + n_2 + 1)}{2} - W_1$$

Where W_1 would be the sum of the ranks in the smaller sample (1), and W_2 would be the sum of the ranks in the other sample (Montgomery, 2003).

4.4 STATISTICAL RESULTS

Yorktown Beach was the only beach analyzed in the statistical study, due to both indicator organisms being present at only this beach. The parameters of Boats in Vicinity (during sampling), Precipitation (within 48 hours), Site (example 203 and 204), Swimmers, Sunbathers, Weather, Water Temperature, Wind Speed , Wind Direction, Wind Gusts, and Wave Size (Tables 5, 6, 7, 8 (surface samples only), and 9) were used to compare against counts of *E.coli* and enterococci (Table 4).

The Yorktown Beach (sites 203 and 204) results indicated that significant differences ($Ho \neq 0$) were present for the months of June-July (June when compared to results for July) for Enterococci for the parameter "Sunbathers" (Table 10) and for June-August (June results compared to August results) for the parameter Precipitation for *E.coli* and enterococci (Table 11). July and August parameters Wind Direction and Precipitation were significant for E.coli and wave size provided some significance for enterococci presence. Some parameters, weakly supported the null hypothesis and may provide some significance (P-values close to 0.05 but Ho = 0) as are as follows: June-August, Wave Size for *E.coli* (Table 11) and Precipitation for Enterococci (Table 11). July-August, the parameter Wave Size for *E.coli* (Table 12) may be significant.

Table 5
Yorktown Beach Field Notes

Date	Site	Boats	Swimmers	Sunbathers	Wave type
6/7/2005	203	3	10	50	calm
6/7/2005	204	3	6	50	calm
6/14/2005	203	3	3	40	wavelets
6/14/2005	204	3	0	40	wavelets
6/23/2005	203	2	30	70	wavelets
6/23/2005	204	2	3	70	wavelets
6/28/2005	203	0	8	35	wavelets
6/28/2005	204	0	1	35	wavelets
7/5/2005	203	3	0	70	wavelets
7/5/2005	204	3	0	70	wavelets
7/12/2005	203	3	30	70	wavelets
7/12/2005	204	3	5	3	wavelets
7/19/2005	203	0	3	3	wavelets
7/19/2005	204	0	1	3	wavelets
7/26/2005	203	0	5	40	wavelets
7/26/2005	204	0	1	40	wavelets
8/4/2005	203	0	25	40	wavelets
8/4/2005	204	0	0	40	wavelets
8/9/2005	203	0	0	2	small
8/9/2005	204	0	0	2	small

Table 6
Yorktown Beach Precipitation Amounts and Water Temperature

Date	Site	Rain Within 48 hrs	Amt. Rain	Water Temp
6/7/2005	203	yes	unknown	75.58
6/7/2005	204	yes	unknown	74.22
6/14/2005	203	no		79.62
6/14/2005	204	no		79.83
6/23/2005	203	no		77.16
6/23/2005	204	no		76.13
6/28/2005	203	no		74.22
6/28/2005	204	no		79.82
7/5/2005	203	no		78.71
7/5/2005	204	no		79.4
7/12/2005	203	no		83.52
7/12/2005	204	no		83.27
7/19/2005	203	yes	0.1 in	82.07
7/19/2005	204	yes	0.1 in	82.32
7/26/2005	203	no		86.15
7/26/2005	204	no		86.15
8/4/2005	203	no		85.71
8/4/2005	204	no		86.20
8/9/2005	203	yes		83.18
8/9/2005	204	yes		83.09
8/11/2005	203	no		85.62
8/11/2005	204	no		85.28
8/16/2005	203	yes	0.66 in	85.41
8/16/2005	204	yes	0.66 in	84.14

Table 7
Yorktown Beach Wind Parameter Values (NOAA)

Date	Wind Speed (m/s)	Wind Dir	Wind Gusts (m/s)
6/7/2005	2.3	SW	3.1
6/7/2005	1.8	SW	3.3
6/14/2005	2.9	SE	3.1
6/14/2005	3.1	SE	3.4
6/23/2005	3	NE	3.8
6/23/2005	3.7	NE	4.3
6/28/2005	3.1	SW	3.9
6/28/2005	3.2	SW	5.1
7/5/2005	3.1	NW	3.6
7/5/2005	3.1	NW	3.6
7/12/2005	3.4	SSE	4.4
7/12/2005	5.1	SSE	6.1
7/19/2005	4.5	SW	5.9
7/19/2005	4.9	SW	6
7/26/2005	0.9	NE	1.1
7/26/2005	1.3	NNW	1.7
8/4/2005	1.4	NE	1.7
8/4/2005	1.6	NE	1.8
8/9/2005	3.8	NW	4.8
8/9/2005	3.7	NW	4.5

Table 8
Comparison of Water Column Samples to Water Samples with 1-2 inches of Sediments Present

Date	Site	Type of Sample	Enterococci	E.coli	Rainfall	Amount of Rainfall
8/11/2005	203	Surface	6	42	No	
8/11/2005	203	Sediments	21	460	No	
8/11/2005	204	Surface	1	22	No	
8/11/2005	204	Sediments	1	14	No	
8/16/2005	203	Surface	6	375	Yes	0.66 in
8/16/2005	203	Sediments	N/R	249	Yes	0.66 in
8/16/2005	204	Surface	26	3800	Yes	0.66 in
8/16/2005	204	Sediments	N/R	TNTC	Yes	0.66 in

Table 9
Wind Data (NOAA)

Date	Site	Wind Direction	Wind Gust (m/s)	Wind Speed (m/s)	Tidal Conditions
8/11/2005	203	NE	3.6	3.1	Rising
8/11/2005	204	NE	3.7	3	Rising
8/16/2005	203	NE	3.7	3	Low
8/16/2005	204	NE	3.7	3	Low

Table 10
Results for non-parametric statistics (P-values) for June and July 2005, Yorktown Beach

Parameter	***E.coli***	**Enterococci**
Site	.7963	.5897
Weather	.9084	.3587
Water Temp	.6550	.5978
Wind Speed	.2770	.6829
Wind Direction	.6857	.6263
Wind Gusts	.5230	.4733
Wave Size	.3017	.5604
Boats in vicinity	.7328	.4197
Swimmers	.6546	.3462
Sunbathers	.7506	.0218
Precipitation	.2037	.5604

Table 11
Results for non-parametric statistics (P-values) for June-August 2005, Yorktown Beach

Parameter	*E.coli*	Enterococci
Site	.1629	.1693
Weather	.8128	.1313
Water Temp	.6000	.3134
Wind Speed	.3526	.5823
Wind Direction	.0318	.3748
Wind Gusts	.4419	.5254
Wave Size	.0740	.0431
Boats in vicinity	.4169	.9520
Swimmers	.3185	.3607
Sunbathers	.2122	.3932
Precipitation	.0306	.1878

Table 12
Results for non-parametric statistics (P-values) for July and August 2005, Yorktown Beach

Parameter	*E.coli*	Enterococci
Site	.8497	.1297
Weather	.7092	.2981
Water Temp	.3255	.5526
Wind Speed	.8714	.6896
Wind Direction	.3630	.8202
Wind Gusts	.5404	.3059
Wave Size	.0880	.3398
Boats in vicinity	.4178	.1691
Swimmers	.6009	.4375
Sunbathers	.5739	.1289
Precipitation	.0441	.0566

4.5 MINI STUDY OF WATER COLUMN AND SEDIMENT BACTERIAL COUNTS

A mini-study was performed on August 11 and 16, 2005 on the water column and sediments located at both sites at Yorktown Beach (Table 8). The sediments seemed to harbor more E.coli than the water column on days that precipitation preceded water sampling (Table 8). Enterococci colonies were not as elevated as E.coli but did show higher populations in the sediments than in the water column (Table 13). Samples were obtained during a low tidal condition on August 16th with precipitation occurring within 48 hours (Tables 8 and 9). Wind gusts, speed and direction, salinity, dissolved oxygen, water temperature, pH, dissolved oxygen percentage were similar on both days, but tidal conditions, wave size and precipitation varied (Tables 9, 13, and14).

Table 13
YSI-556 Multi-Meter Results for Yorktown Beach

Date	Site	Temperature (C°)	Salinity (ppt)	PH	DO (mg/L)	DO (%)
8/11/2005	203	29.72	21.63	7.42	7.58	112.6
8/11/2005	204	29.60	21.81	7.68	7.45	110.3
8/16/2005	203	29.67	22.41	7.76	6.43	95.7
8/16/2005	204	28.97	22.23	7.72	7	102.8

Table 14
Field Notes for the mini-study

Date	Site	Boats	Swimmers	Sunbathers	Wave type
8/11/2005	203	2	20	30	wavelets
8/11/2005	204	2	0	30	wavelets
8/16/2005	203	3	18	40	medium
8/16/2005	204	3	0	40	medium

CHAPTER 5
DISCUSSION

The only parameters that had non-equal means and were statistically different from *E.coli* were the wind direction and precipitation when comparing June and August *E.coli* results (Table 11). Enterococci were found to have non-equal means ($P< 0.05$) with only the amount of sunbathers in the June-July statistical study (Table 10). For June-August, precipitation was found to be a significant parameter for enterococci. Weak correlations with null hypothesis (P values close to 0.05) for July-August were wave size for *E.coli* and precipitation for enterococci for the June-August test (Table 11). From the results it has been determined that *E.coli* varied temporally for the months of July and August for the parameters of wind direction and precipitation. Wave size significantly differed for enterococci for the July-August statistical results (Table 12). Also, enterococci presence varied temporally for the parameter "sunbathers" for the months of June and July (Table 10). All other parameters for the months analyzed supported the null hypothesis and were found not to be significantly different for *E.coli* and enterococci.

Sunbathers are potential fecal contaminators of the shoreline waters, due to their ability to harbor fecal organisms. Some younger patrons of the beach may not seek the proper human receptacles for disposing of human wastes (ex. the bathroom). Also, with a larger amount of sunbathers, there is the potential to have a higher number of swimmers. Before the researcher arrived at the beach, the sunbathers may have swam in the water, cooled off and exited the water thus being swimmers instead of just sunbathers. These movements along with other actions that they perform at the beach may be why they are associated with enterococci presence.

For June and August statistical analyses, *E.coli* concentrations were found

to be significantly different in relation to wind direction and precipitation. Storm fronts and/or naturally occurring wind patterns (climate) can affect wind direction. The NE wind direction should be further studied in relation to fecal bacterial concentrations because of the significant statistical differences observed in this study and because of its association with the exceedances of *E.coli* in all noted cases (Tables 4, 7, 8 and 9). Winds approaching the beach may be correlated with adverse reactions on water quality causing higher bacterial counts at Sites 203 and 204 (Table 8).

The most precipitation observed during the study was August 2005. Wind direction provides a means of transportation for precipitation. Wind direction will change depending on weather conditions (i.e., precipitation). *E.coli* seemed to be most sensitive to these parameters, when compared to enterococci (Table 11). However, it must be noted, that precipitation may provide some significance to enterococcal counts found at Yorktown Beach, because it weakly supports the null hypothesis (P-value close to 0.05) as shown in Table 11. Also wave size for both *E.coli* and enterococci may provide some significance in relation to indicator organism presence, for the previous stated reason (Table 11). Waves are created by winds driven by force, which may be fueled by storm fronts which provide precipitation that may be approaching or leaving an area. This is a possible reason for the possible significance of "Wind Direction", "Wave Size" and "Precipitation" for E.coli and "Wave Size" and "Precipitation" for enterococci. Wind direction, wave size and precipitation are all related to each other. Currents should be studied at each site in addition to the wind driven parameters analyzed in this study, because currents have been found to be positively correlated to high background turbidity, which could be a parameter of concern with pathogenic bacterial presence (Alkan, 1999).

The initial high sample for *E.coli* was collected after a disturbance of the water column (Table 4). The water was unusually turbid prior to and during sampling; normally the water was clear to the point that the grain sizes of the bottom sediments in the swimming area were visible to the naked eye (20/20

vision) (Turbidity is the clarity of water, if a body of water is turbid, lots of suspended particles in the water column could give the water a cloudy appearance). These high-count plates were sent to the Soil and Environmental Sciences department, of Virginia Tech for source tracking, but it was determined after the plates were sent that there was no DNA data present for *E.coli*, so the intended comparison of sources for *E.coli* and Enterococci was not possible. The plates were observed under the microscope by the lab staff and they also confirmed that fecal *E.coli* colonies were present on the plates.

E.coli is most commonly associated with human feces, although it can come from other animal sources. *E.coli* plate counts were significantly higher for Site 204 when compared to plates for Site 203 on August 16th sampling event (Table 9), which may have been due to precipitation that drives the process of runoff. In 2005, Yorktown opened a boat dock for public use, which allowed people to park their boats for a fee adjacent to Site 203. Potential for concern may be raised when boats leave and arrive at the boat dock because large wakes may be created causing large wave actions in addition to wave actions that are already driven by winds providing potential for sediments to be suspended in the water column potentially causing adverse effects on public health. The presence of pathogens in bottom sediments has been found to pose potential risks to public health because the risk of gastro-intestinal illness has been found to correlate with the total number of E.coli associated with suspended particles, not the actual number in the water (Dufour, 1982).

Enterococci recreational water quality limits were not exceeded this season, nor has it exceeded since water quality monitoring has been performed over the past two years at Yorktown Beach. Source tracking was performed for Enterococci in 2004 and 2005 at all public beaches in Virginia. Previously in 2004, it was determined that the source of enterococci originated from wildlife at Yorktown Beach (non-point source pollution). *E.coli* recreational water quality monitoring ended on August 16 (Table 8). On August 11 and 16, 2005, the sediments were sampled for presence of Enterococci (only August 11th) and

E.coli (Table 9). On August 15th 2005, 50 gallons of waste water was released into the York River from a nearby source. This may have been a contributor to the high concentration of *E.coli* on August 16 in addition to precipitation that caused runoff which occurred within 48 hours of sampling (Table 11).

To obtain an idea of how the sediments can potentially affect the water quality at Yorktown Beach, a mini-study was performed on sediment indicator organism presence. The study was not extended to the beaches in the Hampton Roads Harbor and the Lower James, due to financial constraints. After the normal sample (water column) was obtained for each site, the researcher agitated the bottom sediments by using the feet to displace the sediments into the water column as suspended solids. Then a separate water sample was taken close to sediment bed with the suspended solids in the water. It was determined initially that *E.coli* was present in higher concentrations in the sediments than in the water column for Site 203 on August 11th 2005 (Table 1). For Site 204 on the 11th of August, *E.coli* was present in low concentrations. The most probable reasons for the exceedance at Site 204 for August 16th water column sample may be precipitation that occurred within 48 hours, which resulted in runoff or combined sewer overflows (CSO's) (Table 9). In previous studies bacteria that have been adsorbed by particulate matter and ended up in the sediments were protected from light, prolonging their presence in the sediments (Alkan, 1999).

On a few sampling days there were dogs present on the beach, which is prohibited by city ordinance. One recreator, on multiple occasions, was observed by the researcher allowing his Golden Retriever to swim in the swimming area, prior to the sampler sampling both sites.

One potential flaw in this study is that one recreational season of observations was studied, in order to determine long term best management practices further studies need to be conducted to determine long term effects of the boat ramp in addition to temporal differences for wind gust, wave size, wind direction and precipitation on *E.coli* and enterococci presence. Different bottles

were used to collect samples due to them being analyzed at different labs. Also, different methods were used to determine *E.coli* and enterococci presence (membrane filtration vs. Chromogenic substrate).

In addition, under and over estimation of each indicator organism could have been possible during this study due to the randomness of the procedure of water quality sampling.

The prevention of non-point source pollution is near impossible. It would entail preventing wildlife from dispersing guano and other fecal matter that ends up in water bodies that just happen to be used by humans for recreational purposes. Sampling is a random event, one water sample obtained in a 100 mL bottle cannot give a true 100 percent representation of a body of water. One has to contemplate that the water quality limits for indicator organisms feasible for each body of water and each beach and will they prevent the public from obtaining gastrointestinal illnesses.

This study has attempted to provide more insight into indicator organism choices. Not all beach waters are created to be equal. Different parameters (i.e., different species, population wildlife, temporal and spatial variations, and etc.) can affect the quality of water in a water sample. Enterococci may be more resilient in some studies when compared to E.coli, but in others it survives marginally more than or less than *E.coli* (Alkan, 1995; Medema, 1997). This thesis challenged indicator organism choices in order to create thoughts that may fuel future research in water quality management and assessment. From the results of this study, it can be determined that *E.coli* may be a very good indicator for recreational seasons that have high amounts of precipitation, because salinity would be lower. Enterococci may be better when drought conditions are present in the area surrounding Yorktown Beach.

This study has also proven that fecal *E.coli* is present and exceeded state limits that could have caused a beach advisory to be posted, if *E.coli* was the indicator organism of choice because the single sample mean exceeded 235 cfu/100mL (Table 4 and 9).

There was a possibility that over estimation or underestimation occurred during the study. Enterococci appeared to be less sensitive to turbidity and suspended solids in the case of July 27, 2005 sampling event (Table 9). Eventually suspended solids will settle out of the water column, but in previous studies *E.coli* have been found in the water column after the suspended solids have settled out (Alkan, 1999).

If by chance a boat comes by and stirs up the bottom sediments by creating large waves and water samples were collected directly afterwards, the analysis could return results that would report that the water is impaired. However, prior to the disturbance the water quality could have been suitable for swimming. Now, the question would be, is the water impaired? If a sample was collected a few hours after the disturbance would indicator organism presence still be elevated (assuming that the water was determined to be impaired after sample analysis had taken place)?

Recreational water quality monitoring and indicator organism standards are relatively new to a large amount of public health entities nationwide. The Peninsula Health District initiated their recreational water quality monitoring program in 2003, thanks to funding from the U.S. Environmental Protection Agency (USEPA, 2002b). There are other health departments within the State of Virginia that have initiated their programs within the past 3-4 years. The choices for indicator organisms were either Enterococci or *E.coli*, and the choices were based on the 1986 Ambient Water Quality study that was performed for the Environmental Protection Agency.

CHAPTER 6
RECOMMENDATIONS

Wind direction, wave size, and precipitation should be further studied with conjunction of *E.coli* and enterococci presence. Further studies of each of these parameters can assist in the creation of Rainfall and Wind-Based Alert Curves. These alert curves allow the Peninsula Health District to predict when the bacterial water quality may be impaired, without having to obtain water samples initially. This would decrease the amount of time that would be required to post a swimming advisory, protecting public health.

The amount of sunbathers at Yorktown Beach should be studied separately against enterococci bacterial counts because they are potential swimmers and polluters of recreational waters. In addition they may perform actions that have adverse effects on water quality. The amount of people present on the beach may be correlated to an increased bacterial presence of enterococci.

At least 5 years of sampling should be performed in order to perform the statistical analyses against *E.coli*, enterococci and the parameters that may cause each of them to exceed state limits. Small boat crafts within the vicinity of the beach should be avoided within 48 hours of a rain event due to the possibility of resuspending the sediments. Traffic logs for the Coleman Bridge and the logs of boats that utilize the new boat ramp adjacent to Yorktown Beach are needed as well, due to the ability of boats to resuspend sediments.

All parameters analyzed in this study should continue to be analyzed for consistency. Park and Recreational officers at Yorktown should step up patrols during the recreational season to ensure that pets are not present on the beach.

CHAPTER 7
CONCLUSION

Enterococci are not the only indicator organism present at beaches sampled by the Peninsula Health District of the Virginia Department of Health. Yorktown Beach, located in Yorktown, Virginia has a fecal *E.coli* presence in addition to enterococci which may be able to provide effective information about the pathogenic content of the recreational water. Enteric bacteria pose health threats to recreators who are children, elderly and/or those people that have weakened immune systems. If they are not detected, epidemiological events may occur. Not using *E.coli* in addition to enterococci as an indicator organism could possibly jeopardize public health, due to underestimation of indicator organism presence.

E.coli is not present at beaches located along the Hampton Roads Harbor and the lower James River in Newport News, Virginia. Enterococci are very good indicators of fecal contamination for the following beaches: Anderson Park Beach, Hilton Beach, Huntington Beach and King-Lincoln Park. At Yorktown Beach it is recommended that *E.coli* and enterococci be used jointly to assess whether waters are suitable for swimming. *E.coli* may be the most suitable indicator organism for waters during recreational seasons that have a high frequency of rainfall events, because the Upper and Middle York River may have a more pronounced influence on the salinity and other factors. Enterococci should be used for dry recreational swimming seasons due to its marked resilience in more saline waters.

E.coli is more specific to human feces, and is potentially fatal if strain O7:H157 is contracted by children, the elderly and persons with weakened immune systems. Therefore, it is recommended that *E.coli* in addition to enterococci be the indicator organism(s) for Yorktown Beach for at least five years. With several years of with continuous sampling results for *E.coli*,

enterococci and the recommended parameters, Rainfall and Wind Based Alert Curves can be developed along with other best management practices. This will help decrease the risk of contracting gastrointestinal illnesses in swimmers.

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Appendices

Table 15
YSI-556 Multi-Meter Results for Yorktown Beach

Date	Site	Temp (°C)	Salinity(ppt)	pH	DO (mg/L)	DO %
6/7/2005	203	24.21	16.51	6.53	6.17	80.9
6/7/2005	204	23.46	16.84	6.59	6.39	82.7
6/14/2005	203	26.46	16.2	7.55	6.48	88.2
6/14/2005	204	26.57	16.41	7.65	6.68	91.2
6/23/2005	203	25.09	20.09	7.49	6.83	92.7
6/23/2005	204	24.52	20.38	7.52	6.94	93.4
6/28/2005	203	23.46	16.84	6.59	6.39	82.7
6/28/2005	204	26.57	16.2	7.55	6.48	88.2
7/5/2005	203	25.95	20.98	7.52	6.2	85.9
7/5/2005	204	26.33	20.78	7.52	6.37	88.7
7/12/2005	203	28.62	20.78	7.48	7.95	115.2
7/12/2005	204	28.48	20.59	7.56	7.95	114.8
7/19/2005	203	27.82	22.18	7.32	7.04	101.4
7/19/2005	204	27.96	22.41	7.57	6.81	98.5
7/26/2005	203	30.08	21.64	7.56	5.99	89.3
7/26/2005	204	30.08	21.64	7.56	5.99	89.3
8/4/2005	203	29.84	21.09	6.98	7.42	109.9
8/4/2005	204	30.11	21.33	7	7.72	115
8/9/2005	203	28.43	22.27	7.48	5.42	78.9
8/9/2005	204	28.38	22.39	7.53	5.08	74

Table 16:
Plate counts before multiplication and the calculation of the geometric mean

Date	*Dilution (mL)*	*Blank (cfu)*	*203 (cfu)*	*204 (cfu)*	*Finish Blank (cfu)*
6/7/2005	50	0	32	14	0
6/7/2005	100	0	70	23	0
6/14/2005	25	0	2	8	0
6/14/2005	50	0	1	14	0
6/23/2005	25	0	*398	0	0
6/23/2005	50	0	0	1	0
6/28/2005	25	0	0	10	1
6/28/2005	50	0	6	0	0
7/5/2005	25	0	8	7	0
7/5/2005	50	0	9	5	1
7/12/2005	25	0	13	12	0
7/12/2005	50	0	10	5	0
7/19/2005	25	0	2	2	0
7/19/2005	50	0	1	0	0
7/26/2005	25	0	141	0	0
7/26/2005	50	0	276	2	0
8/4/2005	25	0	17	4	0
8/4/2005	50	0	4	47	0
8/11/2005	10	0	4	7	0
8/11/2005	25	0	3	0	1
8/16/2005	10	0	43	380	0
8/16/2005	25	0	80	TNTC	0

*Plate count was most likely background

SAS SOURCE CODE FOR UNIVARIATE PROC FE AND E.COLI

```
OPTIONS LINESIZE=72

TITLE1 'E.coli and Enterococci';
TITLE2 '** UNIVARIATE PROCEDURE **';

DATA yrktwn;

INPUT Entero E_coli @@;
CARDS;

1       70
1       23
6       8
1       28
1       0
1       80
31      12
20      40
1       8
1       7
1       13
1       12
1       8
1       8
1       552
1       4
11      38
1       55
```

```
10      11
1       14
6       44
21      460
1       24
1       16
6       320

;

PROC PRINT;

PROC UNIVARIATE FREQ PLOT NORMAL

VAR E_coli;
```

WILCOXON-RANK SUM SAS SOURCE CODE FOR YORKTOWN BEACH

```
OPTIONS LINESIZE=90;

TITLE1 "2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY
MONITORING RESULTS";
TITLE2 "DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005,
TEMP IS WATER TEMP";

DATA yorktown;
INPUT Month $ Site $ Tide $ Weather $ Temp $ Windspd $ Winddir $ Windgst $
Wvsze $ Boats $ Swmrs $ Sunbthrs $ precip $ fe ecoli @@;
CARDS;

June   203   falling   sunny   75.58   2.3   SW   3.1   calm   3   10   50
0   1   67
June   204   falling   sunny   74.22   1.8   SW   3.3   calm   3   6   50 0
1   26
June   203   low   sunny   79.62   2.9   SE   3.1   wavelets   3   3   40
0   6   5
June   204   low   sunny   79.83   3.1   SE   3.4   wavelets   3   0   40
0   1   30
June   203   high   mostlysunny 77.16   3   NE   3.8   wavelets   2   30
70  0   1   0
June   204   high   mostlysunny 76.13   3.7   NE   4.3   wavelets   2   3
70  0   1   50
```

June 203 low sunny 74.22 3.1 SW 3.9 wavelets 0 8
35 0 31 12
June 204 low sunny 79.82 3.2 SW 5.1 wavelets 0 1 35
0 20 40
July 203 high rainycloudy 78.71 3.1 NW 3.6 wavelets 3 0 70
0 1 25
July 204 high rainycloudy 79.4 3.1 NW 3.6 wavelets 3 0 70
0 1 19
July 203 rising mostlysunny 83.52 3.4 SSE 4.4 wavelets 3 30
70 0 1 36
July 204 rising mostlysunny 83.27 5.1 SSE 6.1 wavelets 3 5 3
0 1 29
July 203 falling sunny 82.07 4.5 SW 5.9 wavelets 0 3 3
.1 1 5
July 204 falling sunny 82.32 4.9 SW 6 wavelets 0 1 3 .1
1 8
July 203 rising sunny 86.15 0.9 NE 1.1 wavelets 0 5 40
0 1 558
July 204 rising sunny 86.15 1.3 NNW 1.7 wavelets 0 1 40
0 1 4
August 203 high sunny 85.71 1.4 NE 1.7 wavelets 0 25
40 0 11 38
August 204 high sunny 86.20 1.6 NE 1.8 wavelets 0 0 40
0 1 55
August 203 high cloudy 83.18 3.8 NW 4.8 small 0 0 2
0 10 28
August 204 high cloudy 83.09 3.7 NW 4.5 small 0 0 2
0 1 0
August 203 rising sunny 85.62 1.5 ENE 1.8 wavelets 2 20
30 0 6 42

```
August 204 rising sunny 85.28 1.4 SSW 1.8 wavelets 2 0
30 0 1 24
August 204 rising sunny 85.28 1.4 SSW 1.8 wavelets 2 0
30 0 1 16
August 203 low cloudy 85.41 3.1 NE 3.6 medium 3 18
40 .66 6 375
August 204 low cloudy 84.14 3 NE 3.7 medium 3 0 40
.66 26 3800

;

PROC PRINT;

DATA junjul;
set yorktown;
if month= "June" or month= "July";
OUT= junjul;

DATA junaug;
set yorktown;
if month= "June" or month= "August";
OUT= junaug;

DATA julaug;
set yorktown;
if month= "July" or month= "August";
```

```
OUT=julaug;

TITLE3 "JUNE AND JULY E.COLI AND FE RESULTS";

PROC NPAR1WAY DATA=junjul WILCOXON;
  CLASS site;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
  CLASS weather;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
  CLASS temp;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
  CLASS windspd;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
  CLASS winddir;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
```

```
 CLASS windgst;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
 CLASS wvsze;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
 CLASS boats;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
 CLASS swmrs;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
 CLASS sunbthrs;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junjul WILCOXON;
 CLASS precip;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

TITLE4 "JUNE AND AUGUST E.COLI AND FE RESULTS";
```

```
PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS site;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS weather;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS temp;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS windspd;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS winddir;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
 CLASS windgst;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;
```

```
PROC NPAR1WAY DATA=junaug WILCOXON;
  CLASS wvsze;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
  CLASS boats;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
  CLASS swmrs;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
  CLASS sunbthrs;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=junaug WILCOXON;
  CLASS precip;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

TITLE5 "JULY AND AUGUST E.COLI AND FE RESULTS";

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS site;
```

```
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS weather;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS temp;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS windspd;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS winddir;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS windgst;
  VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
  CLASS wvsze;
```

```
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
 CLASS boats;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
 CLASS swmrs;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
 CLASS sunbthrs;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;

PROC NPAR1WAY DATA=julaug WILCOXON;
 CLASS precip;
 VAR fe ecoli;
EXACT WILCOXON/ALPHA=0.05;
```

SOURCE CODE FOR EXP, LN, LOG*10, POWER, INVERSE, AND INVERSE AND EXP UNIVARIATE PROCEDURE (SAS)

```
OPTIONS LINESIZE=72;

TITLE1 'E_coli and Enterococci';
TITLE2 '** UNIVARIATE PROCEDURE **';

DATA yrktwn;

INPUT Y X @@;
  ExpY=exp(Y);
  L10Y=log10(Y);
  PowerY=10**Y;
  LnY=log(Y);
CARDS;

1  67
1  26
6   5
1  30
1   0
1  50
31 12
20 40
1  25
1  19
1  36
1  29
1   5
1   8
1  558
1   4
11 38
1  55
10 28
1  0
6  42
1  24
6  375
26 3800
```

```
;

PROC PRINT;

PROC UNIVARIATE FREQ PLOT NORMAL;

VAR ExpY;
VAR LnY;
VAR PowerY;
VAR ExpY;
VAR InvY;
VAR InvExpY;
```

SAS SOURCE COD FOR UNIVARIATE PROCEDURE FOR ENTEROCOCCI AND *E.COLI*

```
OPTIONS LINESIZE=72;

TITLE1 'E_coli and Enterococci';
TITLE2 '** UNIVARIATE PROCEDURE **';

DATA yrktwn;

INPUT Entero E_coli @@;
CARDS;

1  67
1  26
6   5
1  30
1   0
1  50
31 12
20 40
1  25
1  19
1  36
1  29
1   5
1   8
1  558
1   4
11 38
1  55
10 28
1  0
6  42
1  24
6  375
26 3800


;


PROC PRINT;
```

```
PROC UNIVARIATE FREQ PLOT NORMAL;

VAR E_coli;;
```

LST FILE FOR THE NON-PARAMETRIC STATISTICS

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 1

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

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```
                                        S
             W      W  W W          u
             e     i  i i        n p
  M           a      n  n n  W     B S b r     e
  o  S T      t    T  d  d d  v     o w t e     c
O  n   i i     h    e  s  d g  s    a m h c     o
b  t   t d     e    m  p  i s  z    tr r i  f  l
s  h   e e     r    p  d  r t  e    ss s p  e  i

 1 June   203 falling sunny   75.58 2.3 SW  3.1 calm     3 10 50 0   1   67
 2 June   204 falling sunny   74.22 1.8 SW  3.3 calm     3 6  50 0   1   26
 3 June   203 low     sunny   79.62 2.9 SE  3.1 wavelets 3 3  40 0   6   5
 4 June   204 low     sunny   79.83 3.1 SE  3.4 wavelets 3 0  40 0   1   30
 5 June   203 high    mostlysu 77.16 3  NE  3.8 wavelets 2 30 70 0   1   0
 6 June   204 high    mostlysu 76.13 3.7 NE  4.3 wavelets 2 3  70 0   1   50
 7 June   203 low     sunny   74.22 3.1 SW  3.9 wavelets 0 8  35 0   31  12
 8 June   204 low     sunny   79.82 3.2 SW  5.1 wavelets 0 1  35 0   20  40
 9 July   203 high    rainyclo 78.71 3.1 NW  3.6 wavelets 3 0  70 0   1   25
10 July   204 high    rainyclo 79.4  3.1 NW  3.6 wavelets 3 0  70 0   1   19
11 July   203 rising  mostlysu 83.52 3.4 SSE 4.4 wavelets 3 30 70 0   1   36
12 July   204 rising  mostlysu 83.27 5.1 SSE 6.1 wavelets 3 5  3  0   1   29
13 July   203 falling sunny   82.07 4.5 SW  5.9 wavelets 0 3  3  .1  1   5
14 July   204 falling sunny   82.32 4.9 SW  6   wavelets 0 1  3  .1  1   8
15 July   203 rising  sunny   86.15 0.9 NE  1.1 wavelets 0 5  40 0   1   558
16 July   204 rising  sunny   86.15 1.3 NNW 1.7 wavelets 0 1  40 0   1   4
17 August 203 high    sunny   85.71 1.4 NE  1.7 wavelets 0 25 40 0   11  38
18 August 204 high    sunny   86.20 1.6 NE  1.8 wavelets 0 0  40 0   1   55
19 August 203 high    cloudy  83.18 3.8 NW  4.8 small    0 0  2  0   10  28
20 August 204 high    cloudy  83.09 3.7 NW  4.5 small    0 0  2  0   1   0
21 August 203 rising  sunny   85.62 1.5 ENE 1.8 wavelets 2 20 30 0   6   42
22 August 204 rising  sunny   85.28 1.4 SSW 1.8 wavelets 2 0  30 0   1   24
23 August 204 rising  sunny   85.28 1.4 SSW 1.8 wavelets 2 0  30 0   1   16
24 August 203 low     cloudy  85.41 3.1 NE  3.6 medium   3 18 40 .66 6   375
25 August 204 low     cloudy  84.14 3   NE  3.7 medium   3 0  40 .66 26  3800
```

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 2
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Site

Site	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
203	8	72.0	68.0	6.491019	9.0
204	8	64.0	68.0	6.491019	8.0

Average scores were used for ties.

Wilcoxon Two-Sample Test

Statistic 72.0000

Normal Approximation
Z 0.5392
One-Sided Pr > Z 0.2949
Two-Sided Pr > |Z| 0.5897

t Approximation
One-Sided Pr > Z 0.2988
Two-Sided Pr > |Z| 0.5977

Z includes a continuity correction of 0.5.

Monte Carlo Estimates for the Exact Test

One-Sided Pr >= S
Estimate 0.3698
95% Lower Conf Limit 0.3603
95% Upper Conf Limit 0.3793

Two-Sided Pr >= |S - Mean|	
Estimate	0.7343
95% Lower Conf Limit	0.7256
95% Upper Conf Limit	0.7430
Number of Samples	10000
Initial Seed	43728

Kruskal-Wallis Test

Chi-Square	0.3797
DF	1
Pr > Chi-Square	0.5377

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 3
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Site

Site	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
203	8	65.0	68.0	9.514901	8.1250
204	8	71.0	68.0	9.514901	8.8750

Average scores were used for ties.

Wilcoxon Two-Sample Test

Statistic 65.0000

Normal Approximation
Z -0.2627
One-Sided Pr < Z 0.3964
Two-Sided Pr > |Z| 0.7927

t Approximation
One-Sided Pr < Z 0.3982
Two-Sided Pr > |Z| 0.7963

Z includes a continuity correction of 0.5.

Monte Carlo Estimates for the Exact Test

One-Sided Pr <= S
Estimate 0.3914
95% Lower Conf Limit 0.3818
95% Upper Conf Limit 0.4010

Two-Sided Pr >= |S - Mean|	
Estimate	0.7829
95% Lower Conf Limit	0.7748
95% Upper Conf Limit	0.7910

Number of Samples	10000
Initial Seed	43728

Kruskal-Wallis Test

Chi-Square	0.0994
DF	1
Pr > Chi-Square	0.7525

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 4
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Weather

Weather	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
sunny	10	94.0	85.0	6.284903	9.40
mostlysu	4	28.0	34.0	5.621388	7.00
rainyclo	2	14.0	17.0	4.293406	7.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	2.0506
DF	2
Pr > Chi-Square	0.3587

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.5281
95% Lower Conf Limit	0.5183
95% Upper Conf Limit	0.5379
Number of Samples	10000
Initial Seed	43728

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 5
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Weather

Weather	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
sunny	10	84.0	85.0	9.212763	8.400
mostlysu	4	37.0	34.0	8.240146	9.250
rainyclo	2	15.0	17.0	6.293515	7.500

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	0.1922
DF	2
Pr > Chi-Square	0.9084

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.9184
95% Lower Conf Limit	0.9130
95% Upper Conf Limit	0.9238
Number of Samples	10000
Initial Seed	43728

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 6

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

JUNE AND JULY E.COLI AND FE RESULTS

12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Temp

Temp	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
75.58	1	7.0	8.50	3.142451	7.00
74.22	2	23.0	17.00	4.293406	11.50
79.62	1	14.0	8.50	3.142451	14.00
79.83	1	7.0	8.50	3.142451	7.00
77.16	1	7.0	8.50	3.142451	7.00
76.13	1	7.0	8.50	3.142451	7.00
79.82	1	15.0	8.50	3.142451	15.00
78.71	1	7.0	8.50	3.142451	7.00
79.4	1	7.0	8.50	3.142451	7.00
83.52	1	7.0	8.50	3.142451	7.00
83.27	1	7.0	8.50	3.142451	7.00
82.07	1	7.0	8.50	3.142451	7.00
82.32	1	7.0	8.50	3.142451	7.00
86.15	2	14.0	17.00	4.293406	7.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	11.1551
DF	13
Pr > Chi-Square	0.5978

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.9083

95% Lower Conf Limit	0.9026
95% Upper Conf Limit	0.9140

Number of Samples	10000
Initial Seed	43728

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 7
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Temp

Temp	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
75.58	1	15.00	8.50	4.606381	15.00
74.22	2	15.00	17.00	6.293515	7.50
79.62	1	3.50	8.50	4.606381	3.50
79.83	1	11.00	8.50	4.606381	11.00
77.16	1	1.00	8.50	4.606381	1.00
76.13	1	14.00	8.50	4.606381	14.00
79.82	1	13.00	8.50	4.606381	13.00
78.71	1	8.00	8.50	4.606381	8.00
79.4	1	7.00	8.50	4.606381	7.00
83.52	1	12.00	8.50	4.606381	12.00
83.27	1	10.00	8.50	4.606381	10.00
82.07	1	3.50	8.50	4.606381	3.50
82.32	1	5.00	8.50	4.606381	5.00
86.15	2	18.00	17.00	6.293515	9.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	10.4713
DF	13
Pr > Chi-Square	0.6550

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.9261

95% Lower Conf Limit	0.9210
95% Upper Conf Limit	0.9312

Number of Samples	10000
Initial Seed	43728

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 8

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

JUNE AND JULY E.COLI AND FE RESULTS

12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Windspd

Windspd	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
2.3	1	7.0	8.50	3.142451	7.000
1.8	1	7.0	8.50	3.142451	7.000
2.9	1	14.0	8.50	3.142451	14.000
3.1	4	37.0	34.00	5.621388	9.250
3	1	7.0	8.50	3.142451	7.000
3.7	1	7.0	8.50	3.142451	7.000
3.2	1	15.0	8.50	3.142451	15.000
3.4	1	7.0	8.50	3.142451	7.000
5.1	1	7.0	8.50	3.142451	7.000
4.5	1	7.0	8.50	3.142451	7.000
4.9	1	7.0	8.50	3.142451	7.000
0.9	1	7.0	8.50	3.142451	7.000
1.3	1	7.0	8.50	3.142451	7.000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	9.2326
DF	12
Pr > Chi-Square	0.6829

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.9115
95% Lower Conf Limit	0.9059

95% Upper Conf Limit	0.9171

Number of Samples	10000
Initial Seed	43729

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 9

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

JUNE AND JULY E.COLI AND FE RESULTS

12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Windspd

Windspd	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
2.3	1	15.00	8.50	4.606381	15.00
1.8	1	9.00	8.50	4.606381	9.00
2.9	1	3.50	8.50	4.606381	3.50
3.1	4	32.00	34.00	8.240146	8.00
3	1	1.00	8.50	4.606381	1.00
3.7	1	14.00	8.50	4.606381	14.00
3.2	1	13.00	8.50	4.606381	13.00
3.4	1	12.00	8.50	4.606381	12.00
5.1	1	10.00	8.50	4.606381	10.00
4.5	1	3.50	8.50	4.606381	3.50
4.9	1	5.00	8.50	4.606381	5.00
0.9	1	16.00	8.50	4.606381	16.00
1.3	1	2.00	8.50	4.606381	2.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	14.3814
DF	12
Pr > Chi-Square	0.2770

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.0421
95% Lower Conf Limit	0.0382

95% Upper Conf Limit	0.0460

Number of Samples	10000
Initial Seed	43729

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 10
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Winddir

Winddir	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
SW	6	59.0	51.00	6.284903	9.833333
SE	2	21.0	17.00	4.293406	10.500000
NE	3	21.0	25.50	5.067050	7.000000
NW	2	14.0	17.00	4.293406	7.000000
SSE	2	14.0	17.00	4.293406	7.000000
NNW	1	7.0	8.50	3.142451	7.000000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	3.4810
DF	5
Pr > Chi-Square	0.6263

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.6773
95% Lower Conf Limit	0.6681
95% Upper Conf Limit	0.6865
Number of Samples	10000
Initial Seed	43729

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 11
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Winddir

Winddir	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
SW	6	51.50	51.00	9.212763	8.583333
SE	2	14.50	17.00	6.293515	7.250000
NE	3	31.00	25.50	7.427567	10.333333
NW	2	15.00	17.00	6.293515	7.500000
SSE	2	22.00	17.00	6.293515	11.000000
NNW	1	2.00	8.50	4.606381	2.000000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	3.0928
DF	5
Pr > Chi-Square	0.6857

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.7627
95% Lower Conf Limit	0.7544
95% Upper Conf Limit	0.7710
Number of Samples	10000
Initial Seed	43729

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 12
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Windgst

Windgst	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
3.1	2	21.0	17.00	4.293406	10.50
3.3	1	7.0	8.50	3.142451	7.00
3.4	1	7.0	8.50	3.142451	7.00
3.8	1	7.0	8.50	3.142451	7.00
4.3	1	7.0	8.50	3.142451	7.00
3.9	1	16.0	8.50	3.142451	16.00
5.1	1	15.0	8.50	3.142451	15.00
3.6	2	14.0	17.00	4.293406	7.00
4.4	1	7.0	8.50	3.142451	7.00
6.1	1	7.0	8.50	3.142451	7.00
5.9	1	7.0	8.50	3.142451	7.00
6	1	7.0	8.50	3.142451	7.00
1.1	1	7.0	8.50	3.142451	7.00
1.7	1	7.0	8.50	3.142451	7.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	12.6741
DF	13
Pr > Chi-Square	0.4733

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.5964

95% Lower Conf Limit	0.5868
95% Upper Conf Limit	0.6060

Number of Samples	10000
Initial Seed	43730

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 13

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

JUNE AND JULY E.COLI AND FE RESULTS

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The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Windgst

Windgst	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
3.1	2	18.50	17.00	6.293515	9.250
3.3	1	9.00	8.50	4.606381	9.000
3.4	1	11.00	8.50	4.606381	11.000
3.8	1	1.00	8.50	4.606381	1.000
4.3	1	14.00	8.50	4.606381	14.000
3.9	1	6.00	8.50	4.606381	6.000
5.1	1	13.00	8.50	4.606381	13.000
3.6	2	15.00	17.00	6.293515	7.500
4.4	1	12.00	8.50	4.606381	12.000
6.1	1	10.00	8.50	4.606381	10.000
5.9	1	3.50	8.50	4.606381	3.500
6	1	5.00	8.50	4.606381	5.000
1.1	1	16.00	8.50	4.606381	16.000
1.7	1	2.00	8.50	4.606381	2.000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	12.0563
DF	13
Pr > Chi-Square	0.5230

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.7519

95% Lower Conf Limit	0.7434
95% Upper Conf Limit	0.7604

Number of Samples	10000
Initial Seed	43730

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 14

DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP

JUNE AND JULY E.COLI AND FE RESULTS

12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Wvsze

Wvsze	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
calm	2	14.0	17.0	4.293406	7.000000
wavelets	14	122.0	119.0	4.293406	8.714286

Average scores were used for ties.

Wilcoxon Two-Sample Test

Statistic 14.0000

Normal Approximation
Z -0.5823
One-Sided Pr < Z 0.2802
Two-Sided Pr > |Z| 0.5604

t Approximation
One-Sided Pr < Z 0.2845
Two-Sided Pr > |Z| 0.5690

Z includes a continuity correction of 0.5.

Monte Carlo Estimates for the Exact Test

One-Sided Pr <= S
Estimate 0.6514
95% Lower Conf Limit 0.6421
95% Upper Conf Limit 0.6607

Two-Sided Pr >= |S - Mean|	
Estimate	1.0000
95% Lower Conf Limit	0.9997
95% Upper Conf Limit	1.0000
Number of Samples	10000
Initial Seed	43730

Kruskal-Wallis Test

Chi-Square	0.4882
DF	1
Pr > Chi-Square	0.4847

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 15
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Wvsze

Wvsze	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
calm	2	24.0	17.0	6.293515	12.0
wavelets	14	112.0	119.0	6.293515	8.0

Average scores were used for ties.

Wilcoxon Two-Sample Test

Statistic 24.0000

Normal Approximation
Z 1.0328
One-Sided Pr > Z 0.1508
Two-Sided Pr > |Z| 0.3017

t Approximation
One-Sided Pr > Z 0.1590
Two-Sided Pr > |Z| 0.3181

Z includes a continuity correction of 0.5.

Monte Carlo Estimates for the Exact Test

One-Sided Pr >= S
Estimate 0.1650
95% Lower Conf Limit 0.1577
95% Upper Conf Limit 0.1723

Two-Sided Pr >= |S - Mean|	
Estimate	0.3295
95% Lower Conf Limit	0.3203
95% Upper Conf Limit	0.3387
Number of Samples	10000
Initial Seed	43730

Kruskal-Wallis Test

Chi-Square	1.2371
DF	1
Pr > Chi-Square	0.2660

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 16
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Boats

Boats	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
3	8	63.0	68.0	6.491019	7.875000
2	2	14.0	17.0	4.293406	7.000000
0	6	59.0	51.0	6.284903	9.833333

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	1.7366
DF	2
Pr > Chi-Square	0.4197

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.4359
95% Lower Conf Limit	0.4262
95% Upper Conf Limit	0.4456
Number of Samples	10000
Initial Seed	43730

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 17
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
12:08 Tuesday, February 28, 2006

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Boats

Boats	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
3	8	75.50	68.0	9.514901	9.437500
2	2	15.00	17.0	6.293515	7.500000
0	6	45.50	51.0	9.212763	7.583333

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	0.6218
DF	2
Pr > Chi-Square	0.7328

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.7535
95% Lower Conf Limit	0.7451
95% Upper Conf Limit	0.7619
Number of Samples	10000
Initial Seed	43730

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 18
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
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The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Swmrs

Swmrs	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
10	1	7.0	8.50	3.142451	7.000000
6	1	7.0	8.50	3.142451	7.000000
3	3	28.0	25.50	5.067050	9.333333
0	3	21.0	25.50	5.067050	7.000000
30	2	14.0	17.00	4.293406	7.000000
8	1	16.0	8.50	3.142451	16.000000
1	3	29.0	25.50	5.067050	9.666667
5	2	14.0	17.00	4.293406	7.000000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	7.8481
DF	7
Pr > Chi-Square	0.3462

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.3547
95% Lower Conf Limit	0.3453
95% Upper Conf Limit	0.3641
Number of Samples	10000
Initial Seed	43731

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 19
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
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The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Swmrs

Swmrs	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
10	1	15.0	8.50	4.606381	15.000000
6	1	9.0	8.50	4.606381	9.000000
3	3	21.0	25.50	7.427567	7.000000
0	3	26.0	25.50	7.427567	8.666667
30	2	13.0	17.00	6.293515	6.500000
8	1	6.0	8.50	4.606381	6.000000
1	3	20.0	25.50	7.427567	6.666667
5	2	26.0	17.00	6.293515	13.000000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	5.0442
DF	7
Pr > Chi-Square	0.6546

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.7808
95% Lower Conf Limit	0.7727
95% Upper Conf Limit	0.7889
Number of Samples	10000
Initial Seed	43731

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 20
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
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The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable fe
Classified by Variable Sunbthrs

Sunbthrs	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
50	2	14.0	17.00	4.293406	7.000
40	4	35.0	34.00	5.621388	8.750
70	5	35.0	42.50	6.017336	7.000
35	2	31.0	17.00	4.293406	15.500
3	3	21.0	25.50	5.067050	7.000

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	11.4636
DF	4
Pr > Chi-Square	0.0218

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.0146
95% Lower Conf Limit	0.0122
95% Upper Conf Limit	0.0170
Number of Samples	10000
Initial Seed	43731

2005 YORKTOWN BEACH RECREATIONAL WATER QUALITY MONITORING RESULTS 21
DATA WAS COLLECTED FROM JUNE 7TH-AUGUST 16 OF 2005, TEMP IS WATER TEMP
JUNE AND JULY E.COLI AND FE RESULTS
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The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable ecoli
Classified by Variable Sunbthrs

Sunbthrs	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
50	2	24.00	17.00	6.293515	12.000000
40	4	32.50	34.00	8.240146	8.125000
70	5	42.00	42.50	8.820549	8.400000
35	2	19.00	17.00	6.293515	9.500000
3	3	18.50	25.50	7.427567	6.166667

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	1.9196
DF	4
Pr > Chi-Square	0.7506

Monte Carlo Estimate for the Exact Test

Pr >= Chi-Square	
Estimate	0.7977
95% Lower Conf Limit	0.7898
95% Upper Conf Limit	0.8056
Number of Samples	10000
Initial Seed	43731

THE LST FILE FOR THE EXP, LN, LOG*10, POWER, INVERSE, AND INVERSE EXP UNIVARIATE PROCEDURE

E_coli and Enterococci 1

** UNIVARIATE PROCEDURE **

18:34 Tuesday, February 28, 2006

Obs	Y	X	LnY	L10Y	PowerY	ExpY	InvY	InvExpY
1	1	67	0.00000	0.00000	10	2.72	1.00000	0.36788
2	1	26	0.00000	0.00000	10	2.72	1.00000	0.36788
3	6	5	1.79176	0.77815	1000000	403.43	0.16667	0.00248
4	1	30	0.00000	0.00000	10	2.72	1.00000	0.36788
5	1	0	0.00000	0.00000	10	2.72	1.00000	0.36788
6	1	50	0.00000	0.00000	10	2.72	1.00000	0.36788
7	31	12	3.43399	1.49136	1E31	29048849665247	0.03226	0.00000
8	20	40	2.99573	1.30103	1E20	485165195.41	0.05000	0.00000
9	1	25	0.00000	0.00000	10	2.72	1.00000	0.36788
10	1	19	0.00000	0.00000	10	2.72	1.00000	0.36788
11	1	36	0.00000	0.00000	10	2.72	1.00000	0.36788
12	1	29	0.00000	0.00000	10	2.72	1.00000	0.36788
13	1	5	0.00000	0.00000	10	2.72	1.00000	0.36788
14	1	8	0.00000	0.00000	10	2.72	1.00000	0.36788
15	1	558	0.00000	0.00000	10	2.72	1.00000	0.36788
16	1	4	0.00000	0.00000	10	2.72	1.00000	0.36788
17	11	38	2.39790	1.04139	100000000000	59874.14	0.09091	0.00002
18	1	55	0.00000	0.00000	10	2.72	1.00000	0.36788
19	10	28	2.30259	1.00000	10000000000	22026.47	0.10000	0.00005
20	1	0	0.00000	0.00000	10	2.72	1.00000	0.36788
21	6	42	1.79176	0.77815	1000000	403.43	0.16667	0.00248
22	1	24	0.00000	0.00000	10	2.72	1.00000	0.36788
23	6	375	1.79176	0.77815	1000000	403.43	0.16667	0.00248
24	26	3800	3.25810	1.41497	1E26	195729609428.84	0.03846	0.00000

E_coli and Enterococci 2
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: LnY

Moments

N	24	Sum Weights	24
Mean	0.82348228	Sum Observations	19.7635748
Std Deviation	1.24743084	Variance	1.5560837
Skewness	1.06042882	Kurtosis	-0.5256289
Uncorrected SS	52.0648789	Corrected SS	35.7899252
Coeff Variation	151.482414	Std Error Mean	0.25463075

Basic Statistical Measures

Location		Variability	
Mean	0.823482	Std Deviation	1.24743
Median	0.000000	Variance	1.55608
Mode	0.000000	Range	3.43399
		Interquartile Range	1.79176

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	3.234025	Pr > |t|	0.0037
Sign	M	4	Pr >= |M|	0.0078
Signed Rank	S	18	Pr >= |S|	0.0078

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.67713	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.412086	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.716608	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	3.715946	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	3.43399
99%	3.43399
95%	3.25810
90%	2.99573
75% Q3	1.79176
50% Median	0.00000
25% Q1	0.00000
10%	0.00000
5%	0.00000
1%	0.00000

E_coli and Enterococci 3
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: LnY

Quantiles (Definition 5)

Quantile	Estimate
0% Min	0.00000

Extreme Observations

----Lowest----		-----Highest-----	
Value	Obs	Value	Obs
0	22	2.30259	19
0	20	2.39790	17
0	18	2.99573	8
0	16	3.25810	24
0	15	3.43399	7

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
0.00000000	16	66.7	66.7	2.99573227	1	4.2	91.7
1.79175947	3	12.5	79.2	3.25809654	1	4.2	95.8
2.30258509	1	4.2	83.3	3.43398720	1	4.2	100.0
2.39789527	1	4.2	87.5				

```
          E_coli and Enterococci                 4
        ** UNIVARIATE PROCEDURE **
                   18:34 Tuesday, February 28, 2006

        The UNIVARIATE Procedure
           Variable:  LnY

Stem Leaf                  #          Boxplot
  3 034                    3             |
  2                                      |
  2 34                     2             |
  1 888                    3          +-----+
  1                                   |     |
  0                                   |  +  |
  0 0000000000000000      16          *-----*
    ----+----+----+----+


           Normal Probability Plot
3.25+                          *  +*++
    |                        * ++++
    |                       **+++
1.75+                       ***++
    |                   ++++
    |                 ++++
0.25+    *   *   * ** ******* ****
     +----+----+----+----+----+----+----+----+----+----+
        -2     -1      0      +1     +2
```

E_coli and Enterococci 5
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: L10Y

Moments

N	24	Sum Weights	24
Mean	0.35763381	Sum Observations	8.58321147
Std Deviation	0.54175233	Variance	0.29349559
Skewness	1.06042882	Kurtosis	-0.5256289
Uncorrected SS	9.82004516	Corrected SS	6.75039852
Coeff Variation	151.482414	Std Error Mean	0.11058473

Basic Statistical Measures

Location		Variability	
Mean	0.357634	Std Deviation	0.54175
Median	0.000000	Variance	0.29350
Mode	0.000000	Range	1.49136
		Interquartile Range	0.77815

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	3.234025	Pr > |t|	0.0037
Sign	M	4	Pr >= |M|	0.0078
Signed Rank	S	18	Pr >= |S|	0.0078

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.67713	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.412086	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.716608	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	3.715946	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	1.491362
99%	1.491362
95%	1.414973
90%	1.301030
75% Q3	0.778151
50% Median	0.000000
25% Q1	0.000000
10%	0.000000
5%	0.000000
1%	0.000000

E_coli and Enterococci 6
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: L10Y

Quantiles (Definition 5)

Quantile	Estimate
0% Min	0.000000

Extreme Observations

----Lowest----		-----Highest-----	
Value	Obs	Value	Obs
0	22	1.00000	19
0	20	1.04139	17
0	18	1.30103	8
0	16	1.41497	24
0	15	1.49136	7

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
0.00000000	16	66.7	66.7	1.30103000	1	4.2	91.7
0.77815125	3	12.5	79.2	1.41497335	1	4.2	95.8
1.00000000	1	4.2	83.3	1.49136169	1	4.2	100.0
1.04139269	1	4.2	87.5				

E_coli and Enterococci 7
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: L10Y

```
Stem Leaf                #      Boxplot
  14 19                  2         |
  12 0                   1         |
  10 04                  2         |
   8                               |
   6 888                 3      +-----+
   4                            |     |
   2                            |  +  |
   0 0000000000000000   16      *-----*
    ----+----+----+----+
 Multiply Stem.Leaf by 10**-1
```

```
              Normal Probability Plot
1.5+                              *   *+++
   |                           *  ++++
   |                         ** ++++
   |                         +++
   |                      ***+
   |                    ++++
   |                  +++
0.1+    *   *   * ** ******* ****
    +----+----+----+----+----+----+----+----+----+----+
        -2       -1        0       +1       +2
```

E_coli and Enterococci 8
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: PowerY

Moments

N	24	Sum Weights	24
Mean	4.16671E29	Sum Observations	1.00001E31
Std Deviation	2.04124E30	Variance	4.16666E60
Skewness	4.89897948	Kurtosis	24
Uncorrected SS	1E62	Corrected SS	9.58333E61
Coeff Variation	489.892837	Std Error Mean	4.16666E29

Basic Statistical Measures

Location		Variability	
Mean	4.167E29	Std Deviation	2.04124E30
Median	10.0000	Variance	4.16666E60
Mode	10.0000	Range	1E31
		Interquartile Range	999990

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	1.00001	Pr > |t|	0.3277
Sign	M	12	Pr >= |M|	<.0001
Signed Rank	S	150	Pr >= |S|	<.0001

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.208979	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.539187	Pr > D	<0.0100
Cramer-von Mises	W-Sq	1.843739	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	8.745298	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	1E31
99%	1E31
95%	1E26
90%	1E20
75% Q3	1000000
50% Median	10
25% Q1	10
10%	10
5%	10
1%	10

E_coli and Enterococci 9
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: PowerY

Quantiles (Definition 5)

Quantile	Estimate
0% Min	10

Extreme Observations

----Lowest----		------Highest-----	
Value	Obs	Value	Obs
10	22	1E10	19
10	20	1E11	17
10	18	1E20	8
10	16	1E26	24
10	15	1E31	7

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
10.0000	16	66.7	66.7	1E20	1	4.2	91.7
1000000	3	12.5	79.2	1E26	1	4.2	95.8
1E10	1	4.2	83.3	1E31	1	4.2	100.0
1E11	1	4.2	87.5				

E_coli and Enterococci 10
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: PowerY

```
Stem Leaf                    #        Boxplot
 10 0                        1           *
  9
  8
  7
  6
  5
  4
  3
  2
  1
  0 00000000000000000000000  23       +--*--+
    ----+----+----+----+---
 Multiply Stem.Leaf by 10**+30
```

```
                 Normal Probability Plot
1.05E31+                              *
       |
       |
       |
       |
 5.5E30+                                 +++
       |                             +++++
       |                         +++++
       |                     +++++
       |                 +++++
   5E29+     *   *  * ** *******+***** * ** *  *
        +----+----+----+----+----+----+----+----+----+----+
            -2       -1        0       +1       +2
```

E_coli and Enterococci 11
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: ExpY

Moments

N	24	Sum Weights	24
Mean	1.21854E12	Sum Observations	2.92451E13
Std Deviation	5.92796E12	Variance	3.51408E25
Skewness	4.8986176	Kurtosis	23.9975262
Uncorrected SS	8.43874E26	Corrected SS	8.08238E26
Coeff Variation	486.479178	Std Error Mean	1.21004E12

Basic Statistical Measures

Location		Variability	
Mean	1.219E12	Std Deviation	5.92796E12
Median	2.7183	Variance	3.51408E25
Mode	2.7183	Range	2.90488E13
		Interquartile Range	400.71051

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	1.007028	Pr > |t|	0.3244
Sign	M	12	Pr >= |M|	<.0001
Signed Rank	S	150	Pr >= |S|	<.0001

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.211068	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.526827	Pr > D	<0.0100
Cramer-von Mises	W-Sq	1.83202	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	8.697343	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	2.90488E+13
99%	2.90488E+13
95%	1.95730E+11
90%	4.85165E+08
75% Q3	4.03429E+02
50% Median	2.71828E+00
25% Q1	2.71828E+00
10%	2.71828E+00
5%	2.71828E+00
1%	2.71828E+00

E_coli and Enterococci 12
** UNIVARIATE PROCEDURE **
18:34 Tuesday, February 28, 2006

The UNIVARIATE Procedure
Variable: ExpY

Quantiles (Definition 5)

Quantile	Estimate
0% Min	2.71828E+00

Extreme Observations

------Lowest-----		-------Highest-------	
Value	Obs	Value	Obs
2.71828	22	2.20265E+04	19
2.71828	20	5.98741E+04	17
2.71828	18	4.85165E+08	8
2.71828	16	1.95730E+11	24
2.71828	15	2.90488E+13	7

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
2.71828183E+00	16	66.7	66.7	4.85165195E+08	1	4.2	91.7
4.03428793E+02	3	12.5	79.2	1.95729609E+11	1	4.2	95.8
2.20264658E+04	1	4.2	83.3	2.90488497E+13	1	4.2	100.0
5.98741417E+04	1	4.2	87.5				

E_coli and Enterococci 13
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: ExpY

```
Stem Leaf                  #        Boxplot
  2 9                      1           *
  2
  1
  1
  0
  0 00000000000000000000000   23      +--*--+
    ----+----+----+----+---
Multiply Stem.Leaf by 10**+13
```

```
              Normal Probability Plot
2.75E13+                              *
       |
       |                            ++
       |                     +++++++++
       |                ++++++++
2.5E12+    *   *  * ** *******+*****+* ** *  *
       +----+----+----+----+----+----+----+----+----+----+
          -2       -1       0      +1      +2
```

E_coli and Enterococci 14
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: InvY

Moments

N	24	Sum Weights	24
Mean	0.70048453	Sum Observations	16.8116287
Std Deviation	0.43390702	Variance	0.1882753
Skewness	-0.7740689	Kurtosis	-1.5060735
Uncorrected SS	16.1066177	Corrected SS	4.33033186
Coeff Variation	61.94384	Std Error Mean	0.0885709

Basic Statistical Measures

Location		Variability	
Mean	0.700485	Std Deviation	0.43391
Median	1.000000	Variance	0.18828
Mode	1.000000	Range	0.96774
		Interquartile Range	0.83333

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	7.908744	Pr > |t|	<.0001
Sign	M	12	Pr >= |M|	<.0001
Signed Rank	S	150	Pr >= |S|	<.0001

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.626024	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.421656	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.81859	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	4.450179	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	1.0000000
99%	1.0000000
95%	1.0000000
90%	1.0000000
75% Q3	1.0000000
50% Median	1.0000000
25% Q1	0.1666667
10%	0.0500000
5%	0.0384615
1%	0.0322581

E_coli and Enterococci 15
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: InvY

Quantiles (Definition 5)

Quantile	Estimate
0% Min	0.0322581

Extreme Observations

-------Lowest------		----Highest---	
Value	Obs	Value	Obs
0.0322581	7	1	15
0.0384615	24	1	16
0.0500000	8	1	18
0.0909091	17	1	20
0.1000000	19	1	22

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
0.0322580645	1	4.2	4.2	0.1000000000	1	4.2	20.8
0.0384615385	1	4.2	8.3	0.1666666667	3	12.5	33.3
0.0500000000	1	4.2	12.5	1.0000000000	16	66.7	100.0
0.0909090909	1	4.2	16.7				

```
            E_coli and Enterococci                    16
          ** UNIVARIATE PROCEDURE **
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            The UNIVARIATE Procedure
              Variable:  InvY

   Stem Leaf                 #           Boxplot
    10 0000000000000000      16            +-----+
     9                                     |     |
     8                                     |     |
     7                                     |  +  |
     6                                     |     |
     5                                     |     |
     4                                     |     |
     3                                     |     |
     2                                     |     |
     1 0777                  4             +-----+
     0 3459                  4                |
       ----+----+----+----+
    Multiply Stem.Leaf by 10**-1


              Normal Probability Plot
   1.05+              **** *******+** *  *   *
       |                  ++
       |                 ++
       |                +++
       |               ++
   0.55+                ++
       |             ++
       |            +++
       |           ++
       |          ++  * * *
   0.05+        *  +*+ * *
        +----+----+----+----+----+----+----+----+----+----+
            -2   -1    0    +1   +2
```

E_coli and Enterococci 17
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: InvExpY

Moments

N	24	Sum Weights	24
Mean	0.24556539	Sum Observations	5.89356942
Std Deviation	0.17669998	Variance	0.03122288
Skewness	-0.7552015	Kurtosis	-1.5680043
Uncorrected SS	2.16538297	Corrected SS	0.71812628
Coeff Variation	71.9563839	Std Error Mean	0.03606873

Basic Statistical Measures

Location		Variability	
Mean	0.245565	Std Deviation	0.17670
Median	0.367879	Variance	0.03122
Mode	0.367879	Range	0.36788
		Interquartile Range	0.36540

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	6.808262	Pr > |t|	<.0001
Sign	M	12	Pr >= |M|	<.0001
Signed Rank	S	150	Pr >= |S|	<.0001

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.599281	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.422265	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.847713	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	4.780213	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	0.36787944
99%	0.36787944
95%	0.36787944
90%	0.36787944
75% Q3	0.36787944
50% Median	0.36787944
25% Q1	0.00247875
10%	0.00000000
5%	0.00000000
1%	0.00000000

E_coli and Enterococci 18
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
Variable: InvExpY

Quantiles (Definition 5)

Quantile	Estimate
0% Min	0.00000000

Extreme Observations

--------Lowest-------		------Highest-----	
Value	Obs	Value	Obs
3.44248E-14	7	0.367879	15
5.10909E-12	24	0.367879	16
2.06115E-09	8	0.367879	18
1.67017E-05	17	0.367879	20
4.53999E-05	19	0.367879	22

Frequency Counts

		Percents				Percents	
Value	Count	Cell	Cum	Value	Count	Cell	Cum
3.44247711E-14	1	4.2	4.2	4.53999298E-05	1	4.2	20.8
5.10908903E-12	1	4.2	8.3	2.47875218E-03	3	12.5	33.3
2.06115362E-09	1	4.2	12.5	3.67879441E-01	16	66.7	100.0
1.67017008E-05	1	4.2	16.7				

```
E_coli and Enterococci                19
** UNIVARIATE PROCEDURE **
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The UNIVARIATE Procedure
  Variable:  InvExpY

Stem Leaf                 #          Boxplot
  3 7777777777777777      16          +-----+
  3                                   |     |
  2                                   |  +  |
  2                                   |     |
  1                                   |     |
  1                                   |     |
  0                                   |     |
  0 00000000               8          +-----+
    ----+----+----+----+
Multiply Stem.Leaf by 10**-1


                Normal Probability Plot
0.375+                **** *******+** *  *   *
     |                  ++
     |                 +++
     |                +++
     |               +++
     |              +++
     |             +++
0.025+      *   * +* ** * *
      +----+----+----+----+----+----+----+----+----+----+
          -2       -1        0       +1       +2
```

FIGURE. 5: NORTHERN NEWPORT NEWS, VA LAND USE

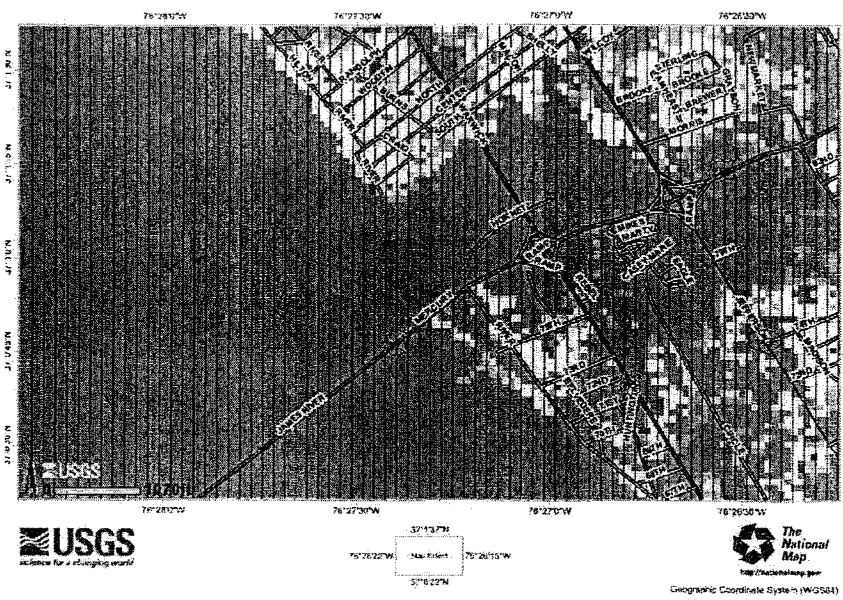

FIGURE 6: SOUTHERN NEWPORT NEWS, VA LAND USE

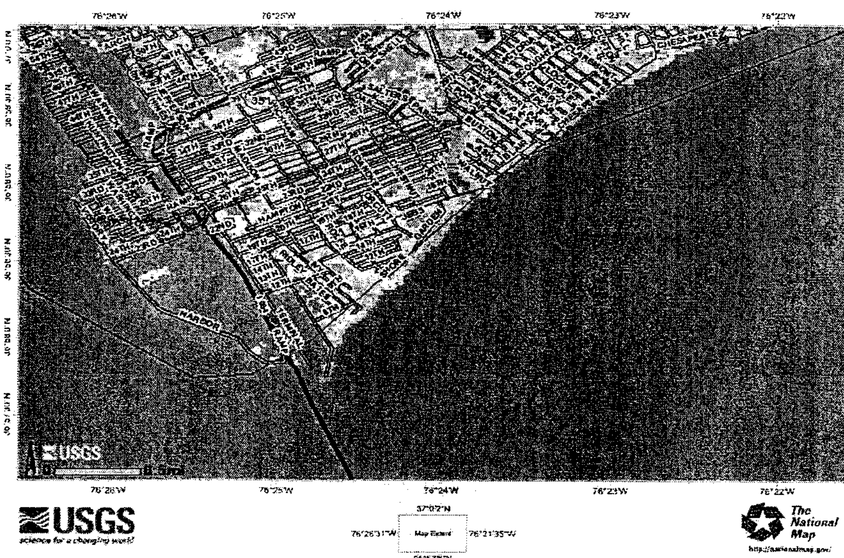

FIGURE 7: YORKTOWN, VA LAND USE

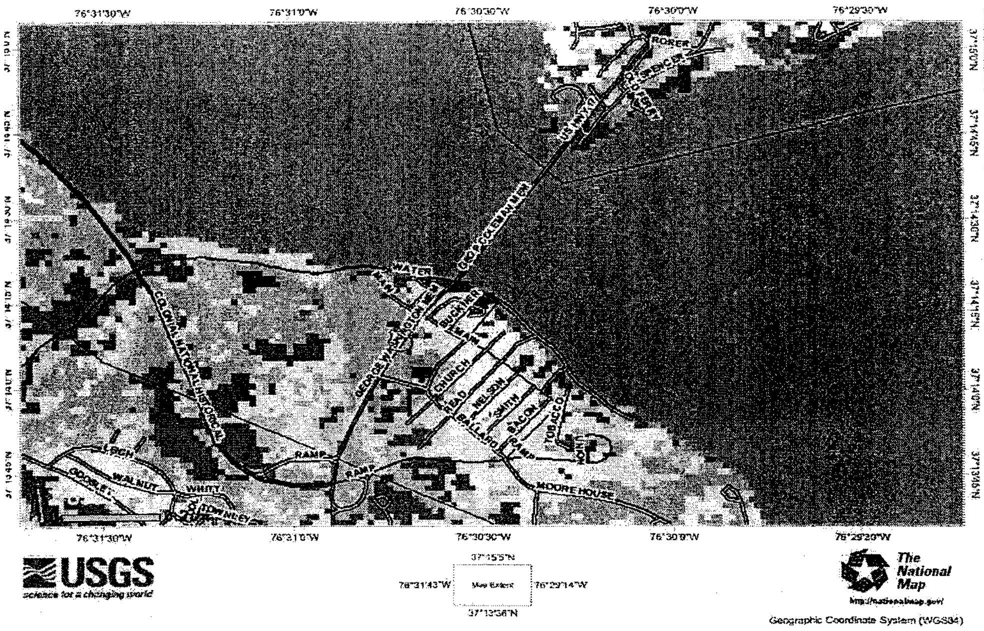

FIGURE 8: THE LEGEND FOR FIGURES 5, 6, AND 7