Great Lakes Beach Association Annual Meeting

3rd Annual Meeting
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Abstracts and Posters

Beach Monitoring Updates from the Great Lake States

S. Briggs
Michigan Department of Environmental Quality, P.O. Box 30273, Lansing, Michigan (517) 335-1214 briggssl@michigan.gov

Beach Monitoring Program Coordinators from each of the Great Lake States will have an opportunity to describe their state program. State coordinators will highlight accomplishments, expectations for next year, time saving tools, and cost effective ideas. This is an excellent opportunity to gain information from a regional perspective.

Beach Water Quality Models: Lessons Learned about Water Quality Predictive Models for Bradford and South Shore Beaches in Milwaukee

M. E. Bruesch and P. Biedrzycki
City of Milwaukee Health Department Division of Disease Control and Prevention
(414) 286-5744, (414) 286-5164 (fax), mbrues@milwaukee.gov

Since the mid-1990's the City of Milwaukee Health Department (MHD) has developed and used predictive models to assess beach water quality and protect the public from waterborne pathogens. The early"traditional"models relied on measurement of *E. coli* (as an indicator organism) as rainfall events as a surrogate for run-off. Because inexpensive, rapid and real-time tests for *E. coli* are unavailable, and because alternative predictive models may be more reliable and accurate in assessing water quality at the point and time of swimmer contact, the MHD has continued to pursue and pilot various "environmental" models." In 2003, MHD tracked the sensitivity and specificity of three categories of beach models at Bradford and South Shore beaches in the City of Milwaukee; "Traditional" (based on previous day's *E. coli* and wave height/mixing and/or rainfall, "Multivariate" (based on a model that uses several parameters measured in 2000 and 2001), and "Adjusted Multivariate" (Multivariate adjusted with a correction factor). During this past season, comparative analysis of the three categories revealed that all varied in sensitivity and specificity, and overall number of correct predictions. Of the models tested, the most sensitive and specific was the Adjusted Multivariate model used for Bradford Beach. Individual variables and their relationship with *E. coli* levels in lab-analyzed samples are also being examined in order to better understand their influence on *E. coli* levels in beach water. Sensitivity and specificity of each model are being tracked throughout the season to

determine if any model was more accurate in predicting daily *E. coli* levels during a specific period of time. *Prediction of E. coli levels can support but does not assure accurate prediction of risk to swimmers at the time of contact.* Usefulness of *E. coli* as a surrogate depends on its source (human vs. animal) and local conditions (replication or persistence of *E. coli (*under certain temperature and water conditions). For example, at Bradford Beach over the past five years, the presence of heavy algae was frequently associated with elevated *E. coli* levels. However, it is unknown if the presence of the algae was associated with pathogens, or if it provided nutrients and physical conditions that supported replication of *E. coli*, resulting in an elevation of *E. coli* without an increased probability of pathogens. Researchers are currently investigating the cause(s) of heavy algae at Bradford Beach. Information resulting from this investigation may be useful in evaluating whether the use of algae level as a variable in the predictive model for Bradford Beach. For beaches where *E. coli* appears to be a better surrogate for pathogens (beaches directly impacted by sources known to contain human pathogens), environmental models can serve as an inexpensive real-time means of predicting the presence of human pathogens in the absence of rapid tests for pathogens themselves. MHD and other researchers are currently evaluating use of *E. coli* as a surrogate for pathogens in beach water through efforts such as land-use analysis, subtyping and pathogen testing.

Persistence and Growth of *Escherichia coli* and Enterococci in *Cladophora* in Nearshore Water and Beach Sand of Lake Michigan

M. N. Byappanahalli, D. A. Shively, M. B. Nevers, M. J. Sadowsky, and R. L. Whitman
Lake Michigan Ecological Research Station, United States Geological Survey,
Porter, Indiana 46304

The green alga, *Cladophora*, is found in streams and lakes worldwide. Each summer, this nuisance alga (*C. glomerata*) amasses along Lake Michigan beaches, creating nearshore anoxia and unsightly, malodorous mats that can attract problem animals and detract from visitor enjoyment. The relationship between fecal indicator bacteria and *Cladophora* remains essentially unstudied. The purpose of this study was to (1) describe the local and regional density of *Escherichia coli* and enterococci in *Cladophora* along beaches in the four states (Wisconsin, Illinois, Indiana, and Michigan) bordering Lake Michigan, and (2) determine the growth potential of *E. coli* and enterococci in *Cladophora*. Both *E. coli* and enterococci were ubiquitous (up to 97% occurrence), with overall log mean densities (± standard errors) of 5.3 (± 4.8) and 4.8 (± 4.5) per g (dry weight). Algal washing (leachate) readily supported *in vitro* multiplication of *E. coli* and enterococci, suggesting that leachates contain necessary growth-promoting substances, such as carbon and energy sources. *E. coli* survived for over six months in dried *Cladophora* stored at 4°C; residual *E. coli* grew after mat rehydration, reaching a carrying capacity of 8-log CFU g^{-1} in 48 h. Further, preliminary genetic analysis (by Rep-PCR DNA fingerprinting) showed that the *E. coli* strains associated with *Cladophora* were highly related; in most instances they were genetically different from each other, suggesting that the relationship between *E. coli* and *Cladophora* may be casual. These findings indicate that *Cladophora* provides a suitable

environment for indicator bacteria to persist for extended periods and to grow under natural conditions. In conclusion, *Cladophora* amassing along the beaches of Lake Michigan may be an important environmental source of indicator bacteria and call into question the reliability of *E. coli* and enterococci as indicators of water quality for freshwater recreational beaches.

National Epidemiological and Environmental Assessment of Recreational Water Study

A.P. Dufour[1], R. L. Calderon[2], M. J. Beach[3], T. J. Wade[2], E. A. Sams[2]
1. National Exposure Research Laboratory, Cincinnati, OH; 2. National Health and Environmental Effects Laboratory, Chapel Hill, NC; 3. Centers for Disease Control and Prevention, Atlanta, GA.

Evidence from different studies around the world indicate that there is a relationship between gastroenteritis in swimmers and the quality of the bathing water as measured with bacterial indicators of fecal contamination. Current EPA guidelines recommend the use of cultural methods for *E. coli* and enterococci to measure beach water quality. These methods produce results in 24 hours creating the conundrum, "we can tell you tomorrow, what you swam in today." This shortcoming in current practice for measuring beach water quality has led EPA to consider new technology and indicators that will provide rapid (2 hours or less) measurement of beach waters.

The NEEAR Water Study is a 5-year research project that will document human health effects associated with recreational water use. Data collected from this study will be useful in identifying new water quality indicators and rapid methods for measuring water quality. The NEEAR Water Study will conduct a series of prospective cohort studies that will include 9-11 marine and freshwater beaches in the nation. Approximately 4000-6000 persons from each beach will be surveyed to determine swimming exposure and risk factors for illness. Follow-up interviews at one and then two weeks later will reveal illnesses possibly related to the beach visit. The water quality will be measured during the swimmer exposure using the currently recommended cultural method for enterococci as well as quantitative PCR and optical fiber/fluoroimmunoassay technology. The latter two tests can produce results in 2 hours or less using enterococci and *Bacteroides* sp. as the analyte. The analysis will focus on water quality parameters and their association with increased prevalence of swimming-related health effects. Water quality guidelines will be developed from the data showing the best relationship between swimmer health effects and water quality measurements.

Predicting the Movement and Bacteria Concentrations of River Plumes in Lake Michigan Using Hydrodynamic Modeling

W. Frick[1], T. Khangaonkar[2], R. Whitman[3], A. Dufour, Z. Yang[2], G. Korinek[3], C. West[4]
[1]Regulatory Support Branch, ERD-Athens, U.S. EPA; [2]Battelle Memorial Institute, Seattle Research Center; [3]Lake Michigan Ecological Research Station, United States Geological Survey ; [4]Ecosystems Research Division, U.S. EPA
Contact Information: Walter Frick, Regulatory Support Branch, ERD-Athens, U.S. EPA, 960 College Station Rd., Athens, GA 30605, (706) 355-8319, frick.walter@epa.gov

Lake Michigan beaches are frequently closed due to poor water quality conditions. Closure decisions are based on the results of monitoring methods that typically take 24 hours to complete. The long delay in obtaining results leads to notification of risk due to swimming after the exposure to unsafe water has occurred. A solution to this problem would be to use meteorological, hydrological and microbiological data to develop a model that will provide a forecast of beach microbiological water quality in advance of swimming activity. Completely accurate forecasting models are impossible to achieve but, if they could be, they would provide information for beach closures prior to an exposure, permit rapid re-opening of beaches, and serve as source material for independent empirical models for designing monitoring programs, as well as for responding to treatment breakdowns. The Battelle Lake Michigan Beach Bacteria Model is an attempt to move towards that ideal. The model, developed in connection with the USEPA Beaches Program, is a numerical hydrodynamic model that simulates the movement of the microbial contaminated Burns Ditch plume into southern Lake Michigan and represents a first attempt to model the transport of contaminants that reach the beaches. This poster describes the theory, methods, data development and verification, and results of the model. It also includes a limited comparison to Visual Plumes model runs of Burns Ditch issuing into Lake Michigan.

Concentrations of *Escherichia coli* in water and bed sediments in Maumee Bay, Toledo and Oregon, Ohio

A. M. Gifford, D. S. Francy, P. Struffolino, and D. F. Dwyer
U.S. Geological Survey, 6480 Doubletree Avenue, Columbus, Ohio 43229, 614/430-7769 (telephone), 614/430-7777 (fax), dsfrancy@usgs.gov

Maumee Bay is often impaired for recreational use as the result of high *E. coli* concentrations. It has been hypothesized that the re-suspension of accumulated *E. coli* from bed sediments may contribute to high *E. coli* concentrations in the water column. Other reasons for elevated *E. coli* concentrations in Maumee Bay may be incoming fecal contamination from the Maumee and Ottawa Rivers and from drainage ditches, elevated temperatures from heated effluents that are conducive to the growth of *E. coli*, and the lack of disinfection of treatment-plant effluents during the winter months.

A 3-year investigation (2003-2005) by the U.S. Geological Survey and University of Toledo is underway to (1) investigate the spatial and temporal distribution of *E. coli* in sediments of Maumee Bay, (2) examine the relation between environmental and water-quality variables and densities of *E. coli* in bed sediment and lake water in the nearshore area (including the state park beach), and (3) determine whether significant concentrations of *E. coli* are re-suspended in Maumee Bay by storms.

Twenty-four sampling sites have been established throughout the study area and include nearshore and offshore sites within Maumee Bay and sites in the lower Maumee and Ottawa Rivers. Bed-sediment and lake-water samples were collected on five days during the recreational season of 2003 at the 24 sites. Samples were analyzed for concentrations of *E. coli* by use of the Colilert Quantitray method for sediment and by use of the modified mTEC method for water; pH, dissolved oxygen, specific conductance and water temperature were measured at the time of sampling, and bed sediment particle-size distributions were determined once for each site. Environmental variables that were compiled or measured included ultraviolet intensity, wind direction and speed, wave height, rainfall amounts, number of birds on the beach, and lake-water levels.

During our 2003 investigations, bed-sediment *E. coli* concentrations ranged from <1 to >660 most-probable number per gram dry-weight sediment. The highest concentrations of *E. coli* in bed sediments were found at sites near or in the shipping channel and the Maumee River. Water *E. coli* concentrations ranged from <1 to 680 colonies per 100 milliliters. The highest water concentrations were found at the mouth of drainage ditches and (or) near boat docks. Water and bed sediment *E. coli* concentrations were not related.

Sampling will continue during the fall and winter of 2003-2004, although less frequently than during the recreational season. Taking the results from 2003 and early 2004, we will concentrate our field efforts on a few "hot spots" of high *E. coli* concentrations during the recreational season of 2004. A total of 24 to 36 samples will be collected during each of two sampling rounds from a few sites along transects extending from possible sources of fecal contamination.

Ontario Perspective of Great Lakes Beach Issues

A. Jain
Senior Safe Water Consultant, Ministry of Health and Long-Term Care, Ontario Canada

In the Province of Ontario, Canada, the beaches along the Great Lakes are monitored during the bathing season by local public health units as mandated by the provincial government. Limits for posting a beach are developed collaboratively between the federal and provincial governments. Data collected as a result of the Health Units' monitoring program can be a useful indicator of ecosystem health. This presentation will highlight the status and programmatic future of the provincial and federal recreational water quality program by providing a brief history with data related to statistics on swimming criteria

and historical background level and the status of provincial/federal legislation in relation to the Great Lakes in Ontario.

Occurrence of Indicator Bacteria and Enteric Viruses in Michigan Tributaries

T. M. Jenkins[1], T. M. Scott[1], M. R. Woodall[2], and J. B. Rose[1, 2]
Michigan State University, [1]Dept. of Crops and Soil Sciences and [2]Dept. of Fisheries and Wildlife, East Lansing MI 48824

In order to meet the requirements of the federal Clean Water Act, the state of Michigan has dedicated a large amount of effort toward water toxics, surface water chemistry, and contaminated sediments programs. A water microbiological program would complement these existing programs as current standards and guidelines associated with fecal coliform and enterococci bacteria have closed many beaches and put waters on impairment lists. This project is a pilot study focusing on samples from nine tributaries that have been shown to carry high nutrients, bacteria or toxics.

Of the nine tributaries sampled seven contained levels of *Escherichia coli* and *Enterococci spp*. that exceed the allowable limits set for recreational waters. Of these seven, four (Kalamazoo River, Rouge River, Grand River, and Shiawasee River) were confirmed for the presence of enteric viruses. All nine rivers were tested for the presence of the toxin microcystin, produced by some blue-green algae, but levels for each river were well below those suggested for finished waters by the World Health Organization. The presence of enteric viruses and elevated indicator levels indicates that these waters pose a threat to the health of individuals using them for recreation and therefore illustrates the need for a more sound water microbiological program for the waterways of Michigan.

Evaluating the Efficacy of a Storm Sewer Outfall Re-engineered for the Reduction of Bacterial Contamination to Surface Water

J. L. Kinzelman[1, 2], R. J. Van Swol[3], and R. C. Bagley[1]
[1]City of Racine Health Department, Racine, WI, [2] Univ. of Surrey, Guildford, UNITED KINGDOM, [3]Univ. of Wisconsin, Milwaukee, WI.
Contact information: Julie Kinzelman, 730 Washington Avenue, Racine, WI 53403, PH: (262) 636-9501, FAX: (262) 636-9576, jkinzelman@cityofracine.org

Racine, Wisconsin, located on the southwestern shore of Lake Michigan, experiences frequent recreational water quality advisories. A previous sanitary survey in conjunction with laboratory testing indicated that a storm sewer outfall was a significant point source contributor of bacterial contamination to the adjacent surface water. This storm sewer outfall was re-engineered in 2000. Engineering controls included: 1) the relocation of the outfall on an embankment, 2) the installation of a Vortechs System® (Vortechnics, Inc., Scarborough, ME), and 3) the placement of a series of nine natural sand bottom infiltration/evaporation beds. During rainfall events the first flush of storm water (1-2 cm)

is diverted through the Vortechs System®, designed for the removal of solid wastes, contaminated sediments, and oils, and then channeled to the infiltration/evaporation beds that provide surface runoff retention. This system has a finite capacity and any rainfall in excess of 1 - 2 cm flows concurrently through the outfall proper, partially bypassing the Vortechs System® and directly entering Lake Michigan. The goal of this study was to determine whether or not the re-designed outfall was effective in reducing bacterial contamination. For a period of 15 weeks during the summer of 2003, once weekly samples were collected from pools of standing water at the termini of the original outfall and the infiltration/evaporation beds in order to determine if the re-designed portion of this storm sewer system was more effective at filtering storm water than the original design. The concentration of *Escherichia coli* was determined using a chemical substrate method (Colilert-18®, IDEXX Laboratories, Inc., Westbrook, ME). Groundwater and rainfall event samples were also collected and analyzed in the same manner. Rainfall event samples indicated that the system was functioning as proposed. The concentration of *E. coli* was threefold higher in the storm water exiting to the infiltration/evaporation beds when measured within 30 minutes of initial rainfall. *E. coli* was not detected in groundwater samples ruling these samples out as potential sources of contamination. The concentration of *E. coli* collected weekly from the terminus of the infiltration/evaporation beds was significantly less than that collected from the terminus of the outfall proper ($p=0.029$). Of note, during the course of this study it was observed that when an exchange occurred between the outfall pool and Lake Michigan surface water quality was adversely impacted. This exchange occurred during rainfall events but also due to wave action and changing lake levels indicating that this site may be source of pollution in wet as well as dry weather. Conversely, at the terminus of the infiltration/evaporation beds, surface water quality appeared to be impacted only when the capacity of these beds were exceeded. It may be that vegetation, planted for aesthetic value, can act as an effective filter for the removal of microorganisms and that similar remediation steps at the site of the original outfall terminus may reduce the potential for bacterial contamination. The environment surrounding bathing beaches must be continually assessed for non-apparent sources of bacterial contamination in order to significantly reduce recreational water quality advisories.

GIS-Based Hydrologic Modeling of a Watershed that Drains into Lake Michigan: Example from the Watershed of the East Little Calumet River

G. C. Korinek[1, 2, 3], G. A.Olyphant[2, 3]
[1]United States Geological Survey, Lake Michigan Ecological Research Station, Porter, IN.; [2]Department of Geological Sciences, Indiana University, Bloomington, IN.; [3]Indiana Geological Survey, Bloomington, IN

The goal of this study was to develop a model that could simulate *E. coli* concentrations and water discharge within a large, heterogeneous watershed that flows directly into Lake Michigan, the East Little Calumet Watershed. A computer model was developed using hydrologic routing equations for discharge and a time-dependent mixing equation to estimate the concentration of *E. coli* bacteria in the individual reaches of the drainage

network. The physical and hydrological aspects of the target watershed were determined through the use of a Geographical Information System (GIS). Weighted average of storm runoff coefficients and bacterial loading factors were developed for each of the individual interfluve areas. Shreve's (1966, 1967) method of stream ordering was used to develop a hierarchical network coding technique for efficient routing of water and bacteria through the drainage network. The model was initially calibrated to fit known baseflow and stormflow conditions. Subsequent simulations using synthetic rainfall data showed that the amount of *E. coli* discharged into Lake Michigan exceeds 10^8 colony forming units.

A National Summary of State Beach Programs under the BEACH Act

C. Kovatch
U.S. Environmental Protection Agency, 1200 Pennsylvania Ave. NW, MC-4305T, Washington, DC 20460

In an effort to protect public health and improve beach monitoring and public notification, Congress passed the Beaches Assessment and Coastal Health (BEACH) Act in October 2000 to amend the Clean Water Act. The BEACH Act authorizes EPA to award grants to eligible coastal and Great Lakes States, Territories, and Tribes to develop and implement their beach monitoring and public notification programs. The Act also requires EPA to develop and maintain a public right-to-know database to store and display state collected beach monitoring and notification data. This presentation will discuss State progress developing their beach monitoring and public notification programs and EPA's development of a national database and interactive website.

Now in the third year of the BEACH Act Grant program, EPA published the National Beach Guidance and Required Performance Criteria for Grants document and over three years, awarded $21.9 million in BEACH Act Grants to 35 eligible coastal and Great Lakes States and Territories. In 2003, EPA awarded BEACH Act grants to state governments for implementation of programs to monitor beach water quality and notify the public of health risks posed by microbial pathogens. Now in the implementation of beach programs, the responsibility to monitor beaches, close beaches, notify the public, and report data requires state and local environmental and public health agency cooperation. This session will provide information to State and Local public health practitioners about: current funding and policies; understanding the grant requirements, the national state of beach programs, and developments in EPA data technology.

Great Lakes BeachCast: A Regional Beach Reporting System

C. Manninen and K. Yam
Great Lakes Commission, Eisenhower Corporate Park, 2805 S. Industrial Hwy, Suite 100 Ann Arbor, MI 48104-6791

The Great Lakes Commission, in cooperation with U.S. EPA and state beach program managers, is leading an effort to enable the Great Lakes states to reach three goals: 1) coordinated beach monitoring data collection and storage, 2) development of a regional, public reporting system, and 3) streamlined data transfer to meet the EPA BEACH Program requirements. A prototype is currently being developed for the states of Illinois, Indiana and Ohio. This partnership will enable data to be housed on individual state "nodes" but mirrored for broad public access on BeachCast, part of the Great Lakes Information Network (GLIN) [www.great-lakes.net/beachcast].

Report for U. S. Environmental Protection Agency's Great Lakes Beach Monitoring Program 1998-2002

D. Rockwell
Great Lakes National Program Office, 77 West Jackson Blvd, Chicago, Illinois 60604.

The U.S. EPA and the Great Lakes National Program Office, support a long term, beach closure and advisory survey of beaches on the Laurentian Great Lakes. Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. EPA has recommended the use of E. Coli as an indicator for human health. U.S. EPA's bacteria criteria recommendations for E. coli are a geometric mean of 126 colony forming units per 100 ml. Monitoring levels have increased after 1999 with observed increases in the number of beach advisories and closings. Variability in the data results from changing beaches being reported, expanded monitoring, and seasonal weather conditions, and may not be solely due to actual increases or decreases in levels of microbial contaminants. Monitoring practices, closures and advisories will be presented for 1998-2002.

Seasonal Persistence of *Escherichia coli* and Enterococci in Backshore Sand at the Groundwater Table of Two Lake Michigan Beaches

D. A. Shively, R. L. Whitman, M. B. Nevers, M. N. Byappanahalli
Lake Michigan Ecological Research Station, United States Geological Survey, Porter, Indiana 46304

High densities of *Escherichia coli* and enterococci occur in the surface sand, but their occurrence and persistence in the backshore beach has received little attention. We studied the landward and seasonal distribution of *E. coli* and enterococci at two southern Lake Michigan beaches. Mid-winter, backshore (20 m) sand was initially sampled to avoid

ambient contamination from the lake and wildlife, and monthly sampling continued for one year. Quadruplicate samples taken at 5-m intervals from shore to 40 m landward failed to show significant differences in bacteria concentrations (p=0.252). Further, *E. coli* or enterococci counts between the two beaches over the study period were not significantly different (p = 0.750 and 0.885), and neither *E. coli* nor enterococci counts were correlated between the two beaches (p = 0.535 and p = 0.263). Backshore beach bacteria persisted through winter and early spring, followed by a rapid mid-spring depletion and early summer rebound. In laboratory experiments, *E. coli* readily grew in sand supplemented with lake plankton, suggesting *in situ* multiplication potential under suitable conditions. The long-term persistence of these bacteria independent of pollution events further complicates their use as indicator organisms. Further, backshore sand at the water table may act as a reservoir for these bacteria and potentially for human pathogens.

Escherichia coli Source Detection on Lake Michigan Swimming Beaches in Lake County, Illinois

W.J. Soucie[1] and M. Pfister[2]
Central Lake County Joint Action Water Agency, Lake Bluff, IL 60044[1] Lakes Management Unit, Lake County Health Department, Waukegan, IL[2]

This study seeks to identify the most likely *Escherichia coli* (*E. coli*) sources in beach water on three Lake County, IL beaches from July 8 through August 29, 2003. When beaches were closed due to high *E. coli* counts, *E. coli* isolates from the contaminated beach water and from potential local sources were ribotyped at the University of Washington.

A comparison between the known and unknown isolates provides some indication as to the *E. coli* source on these closed beaches. The results of this study and a comparison with a similar study performed in 2002 will be presented.

Determining *E. coli* densities in Suspended Sediment

P. S. Struffolino[1], D. F. Dwyer[1], D. S. Francy[2], and A. M. Gifford
[1]University of Toledo, [2]United States Geological Survey

A common problem of beaches is high levels of bacteria, specifically total coliform bacteria, which inhibit recreational activities. Current methods of testing require 18 to 24 hours to determine if beach waters are safe for recreational use. In addition, the source of bacteria is not always easily determined. In an attempt to create a model for predicting beach closings and to determine sources contributing to high densities of fecal coliform bacteria in the southwestern portion of Lake Erie, Maumee Bay, a joint study between the University of Toledo and the United States Geological Survey is being conducted.

Bottom sediment, water, and suspended sediment were collected from rivers and ditches draining into the Maumee Bay throughout the 2003 recreational season. Ten traps for suspended sediment were placed close to the mouths of several drainage ditches and rivers flowing into the Bay. The traps consist of five sets of 2 collection cylinders. Periodically, one set was analyzed for densities of *E. coli*; the removed cylinders were replaced with clean cylinders. In addition, bottom sediment and a water samples were analyzed for densities of *E. coli*. Water turbidity values also were determined.

Samples were collected during the months of June, July and August. Sediment samples were analyzed for densities of *E. coli* using the Colilert Quantitray method (data as Most Probable Number per gram dry weight sediment, g dws); water samples were analyzed using Modified mTEC (Colony forming units per 100 ml). The data were analyzed for two purposes: to determine if *E. coli* were being re-suspended from bottom sediment as a result of wind and/or wave action, and to observe any correlations between the densities of *E. coli* in sediment and *E. coli* in the water column.

During the 2003 sampling period, densities of *E. coli* in the sediment traps were significantly higher than in the bottom sediment or in the water column. The highest levels of *E. coli* in the traps at one sampling location were 1104 (MPN per g dws); levels in the bottom sediment were <1 (MPN per g dws) and in the water column densities were 156 (CFU per 100 ml). The lowest E-coli densities in sediment traps at another site were 66 MPN per g dws compared to 8.9 MPN per g dws and water <1 CFU/ 100ml. A positive correlation existed between *E. coli* densities in the water column and turbidity values. The suspended sediment material from the collection cylinders had significantly higher levels of *E. coli* than were observed in bottom sediments, suggesting that *E. coli* observed on the beaches were from sediment that newly entered the Bay versus sediment that was re-suspended from the lake's bottom.

Thus, we feel that the *E. coli* observed on the beaches are newly input into the Bay, instead of derived from a source of *E. coli* occupying the bottom sediments. Continued sampling will occur through 2003-2004 to focus on identifying the proximate sources of *E. coli* entering the Bay.

Social Dimensions of Water Quality Monitoring and Public Notification at Wisconsin Great Lakes Public Beaches under the 2000 Federal BEACH Act

B. J. Vail
Wisconsin Department of Natural Resources, PO Box 7921, 101 S. Webster St, WT/2
Madison, WI 53707

While developing a policy for public notification about beach water quality issues in Wisconsin in 2002, it became clear that there were no state-wide data about public beach visitors' knowledge, attitudes and behavior regarding water quality issues. A social survey was developed and administered at public beaches on Wisconsin's Lake Michigan and Lake Superior coastlines. The results contributed to the design of public notification

methods implemented during beach season 2003. A follow-up social survey was conducted in 2003 to measure the effects of the Wisconsin beach monitoring program and measure change over time in beach user's knowledge, attitudes and behavior regarding water quality. The surveys found significant variation in patterns of beach users by geographic location around the state, allowing beach authorities to tailor public notification efforts to different public needs and demands while designing general notification plan to ensure statewide consistency.

Protecting Lake Michigan Water Quality: Addressing Beach Issues In 2003

J. T. Zmuda, Z. Abedin, and B. Sawyer
Metropolitan Water Reclamation District of Greater Chicago
Lue-Hing R&D Complex, 6001 W. Pershing Road, Cicero, IL 60804-4112
james.zmuda@mwrd.org, (708) 588-4224

The Metropolitan Water Reclamation District of Greater Chicago (District) undertook this analysis to determine if its operations were responsible for the increased number of beach closings at Lake Michigan beaches observed from 1998 through 2002. Bacterial beach monitoring data collected from 23 beaches in Chicago (2000 through 2002) and 26 beaches in the suburbs north of Chicago (2000 through 2001) were compiled. Basic statistics were computed from the data. The number of violations of the Illinois Bathing Beach Code (Code) at all of the beaches studied was determined from the compiled data. The basic statistics and the violations of the Code were used to assess, on a semi-quantitative or qualitative basis, water quality at the beaches in the study area.

As part of its normal operations the District maintained records of discharges of combined sewer overflow (CSO) to the Lake and collected rainfall data for Chicago and the suburbs north of Chicago. The number of violations of the Code coinciding with discharges of CSO to the Lake was computed from the data. Statistical models were developed to predict *Escherichia coli* (EC) or fecal coliform (FC) concentrations at each beach studied. The following conclusions were drawn from this study.

1. Water quality at the Jackson/63rd Street Beach in Chicago was the poorest of all the beaches studied while the water quality at the beaches in Evanston was the best.
2. Water quality at the Calumet, Rainbow, South Shore, 57th Street, 31st Street, 12th Street, Montrose, Hollywood/Osterman, Thorndale, and Jackson/63rd beaches was poorer than that at the rest of the beaches in Chicago.
3. Water quality at North Point Marina Beach was the poorest of all the beaches in Lake County.
4 There was no difference in water quality at Illinois Beach State Park (IBSP) – North, IBSP – Sailing, Lake Bluff Park District, Lake Forest Park District, Moraine Park, Park Avenue, and Rosewood, and the water quality at these beaches was better than that at all of the other beaches in Lake County.
5. Comparison of the total number of violations of the Code to the number of violations coinciding with discharges of CSO to the Lake demonstrated that these discharges to

the Lake are not responsible for the steady increase in the number of beach closings and advisories observed in the last several years.

6. EC and FC densities at the Lake Michigan beaches were found to correlate weakly with a function of rainfall expressed by the equation:

$$\text{Ln EC (or ln FC)} = kI^{1/7}$$

where I = inches of rainfall and k = a constant peculiar to each beach. This simple regression model was found to be superior to auto regressive models (developed using the ln of EC or FC concentrations from the three previous days), as judged by Akaike's Information Criteria.

7. R^2 values for the simple regression models developed to predict EC and FC concentrations as a function of rainfall at the Lake Michigan beaches in Chicagoland range from 0.14 to 0.34 with an average value of 0.27.
8. Operations of the District are not the main cause of beach closings in the Chicagoland area.