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WATER **QUALITY** RESEARCH PROGRAM

BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Recreational Water Research Projects Update

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U.S. Environmental Protection Agency
Office of Research and Development

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Presentation Overview

- History and Background
- Epidemiology Studies
- Sample Stability Studies
- Indicators and Methods
- Sources
- Quantitative Microbial Risk Assessment
- Beach Management/Modeling Studies
- Recent Publications

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Research in Perspective

- In 2000, Congress passed the Beaches Environmental Assessment and Coastal Health Act (BEACH Act), which required the EPA to issue new or revised recreational water quality criteria by October 2005.
- In August 2006, the NRDC filed a federal lawsuit in Los Angeles against the EPA for failing to protect beachgoers from waterborne illnesses. Intervenors are the Los Angeles County Flood Control District and the National Association of Clean Water Agencies.
- EPA reached an understanding with the plaintiffs in 2008, and is required to complete specified research and science by December 2010 that is needed to develop new or revised criteria by October 2012.
- The first progress report was submitted to the Court in July 2009, with the next progress report due in January 2010. No projects have been completed to date.

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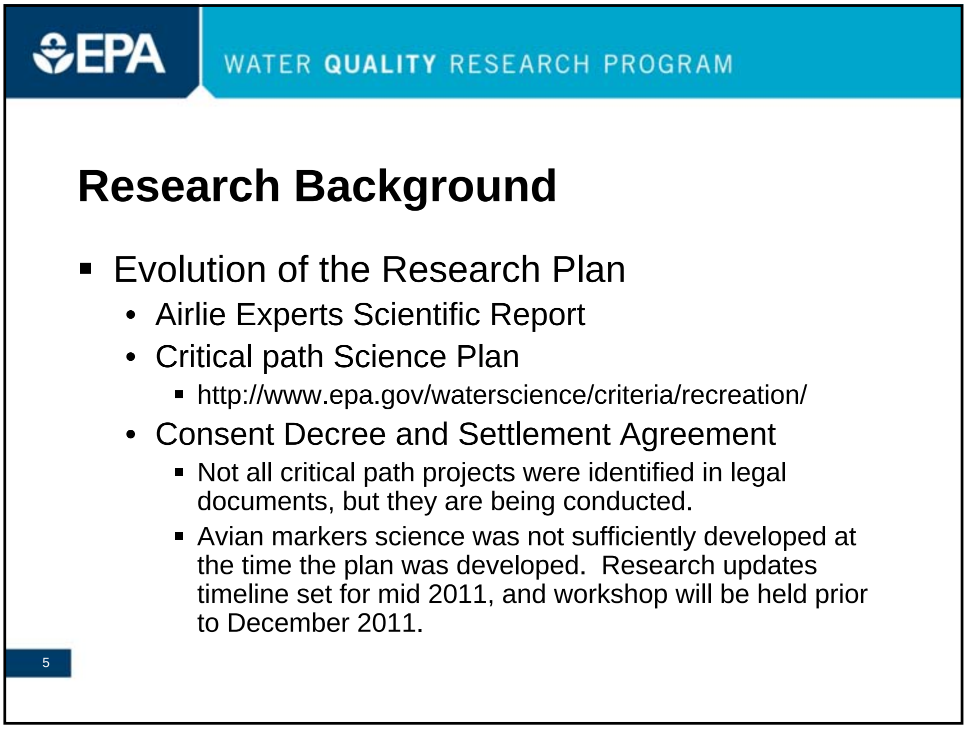
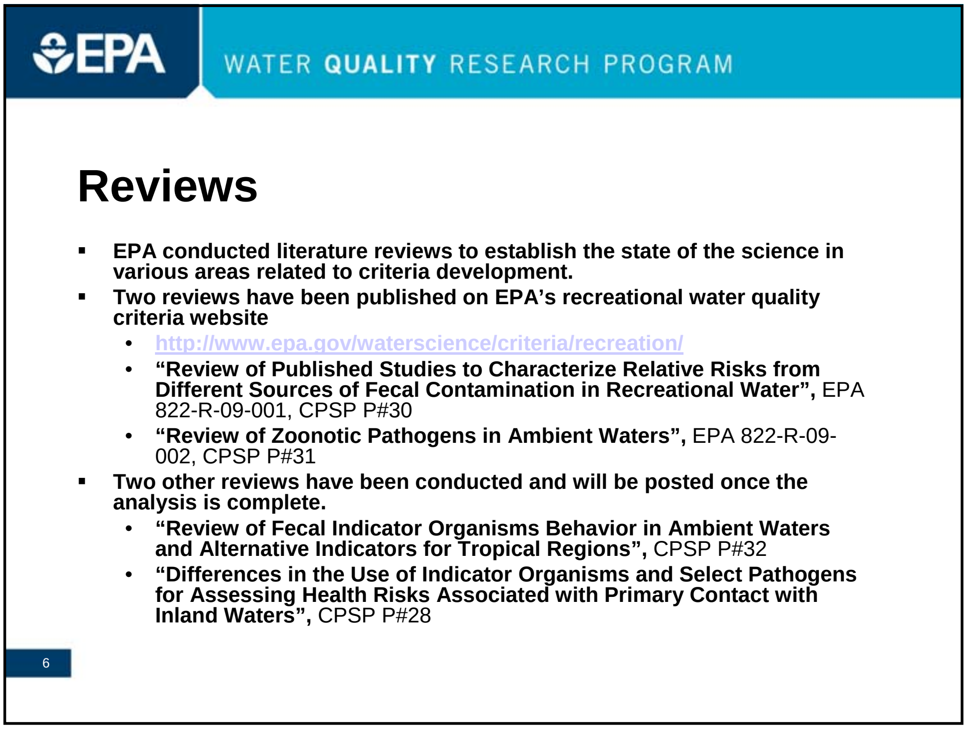
Research History

- Prior to 2008, EPA had conducted research to identify new and improved indicators for protection of human health in recreational waters, including:
  - Development and evaluation of a qPCR (quantitative Polymerase Chain Reaction) methodology as a rapid and efficient option for monitoring recreational waters for indicators of fecal contamination.
  - 4-fresh and 3-marine water epidemiological study sites establishing linkages between indicator/pathogen levels and health outcomes/risk levels in marine waters (note: the Biloxi dataset was incomplete due to hurricane Katrina).
- In 2008, five urban run-off beaches, identified during previous work assignment, were monitored as potential urban run-off sites for a 2009 epidemiologic study. Surfside SC was selected.



Research Background

- Evolution of the Research Plan
  - Airlie Experts Scientific Report
  - Critical path Science Plan
    - http://www.epa.gov/waterscience/criteria/recreation/
  - Consent Decree and Settlement Agreement
    - Not all critical path projects were identified in legal documents, but they are being conducted.
    - Avian markers science was not sufficiently developed at the time the plan was developed. Research updates timeline set for mid 2011, and workshop will be held prior to December 2011.



Reviews

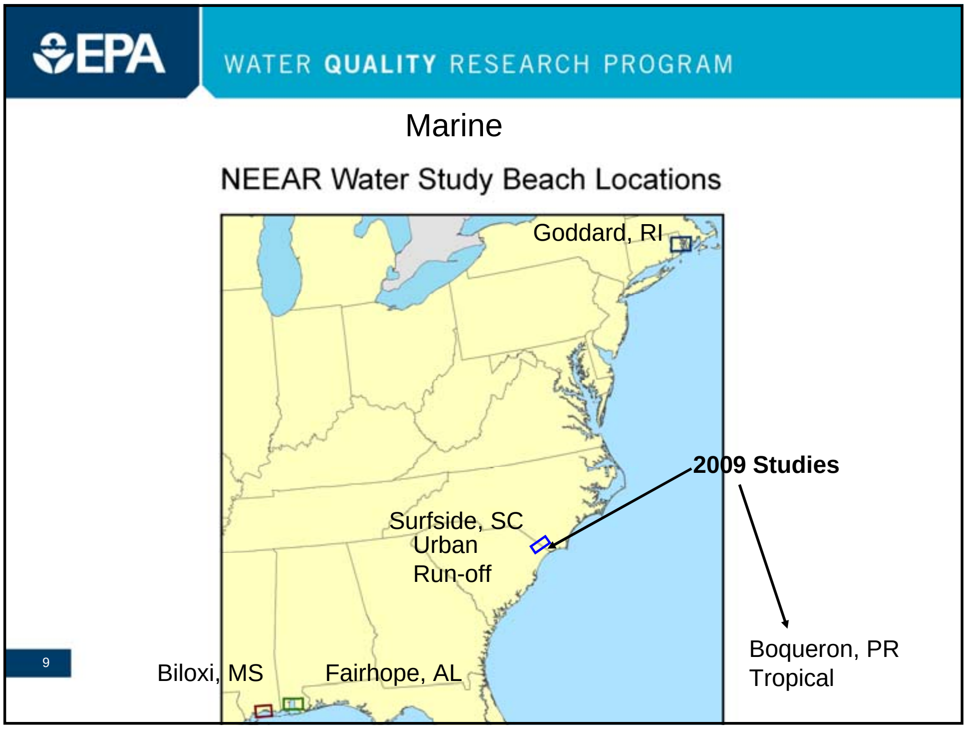
- **EPA conducted literature reviews to establish the state of the science in various areas related to criteria development.**
- **Two reviews have been published on EPA's recreational water quality criteria website**
  - http://www.epa.gov/waterscience/criteria/recreation/
  - **"Review of Published Studies to Characterize Relative Risks from Different Sources of Fecal Contamination in Recreational Water",** EPA 822-R-09-001, CPSP P#30
  - **"Review of Zoonotic Pathogens in Ambient Waters",** EPA 822-R-09-002, CPSP P#31
- **Two other reviews have been conducted and will be posted once the analysis is complete.**
  - **"Review of Fecal Indicator Organisms Behavior in Ambient Waters and Alternative Indicators for Tropical Regions",** CPSP P#32
  - **"Differences in the Use of Indicator Organisms and Select Pathogens for Assessing Health Risks Associated with Primary Contact with Inland Waters",** CPSP P#28

Epidemiologic Studies

- Freshwater Studies (4 in Great Lakes)
- Marine (Goddard, RI; Fairhope, AL; and Partial dataset from Biloxi, MS
- Technical Support for SCCWRP Studies (Avalon, Doheney, CA)
- Marine Source impacted by urban sources of pollution -- Study at Surfside, SC
- Marine Tropical waters influenced by effluent from a wastewater treatment plant -- Study at Boqueron, PR

Urban Run-off Beach Selection

- Contractor Report provided preliminary list of beaches. *Search Effort for Beach Site Locations Impacted by Urban Runoff*.
- Factors used for selection of beaches:
  - They all meet State or local water quality standards for recreational beach water
  - Have a minimum exceedance rate of 15 percent of samples
  - Source of contamination is primarily from runoff
  - Can provide raw monitoring data for fecal coliform or enterococci for 2006 and 2007
  - The beach is subjected to a minimum of one rain event per month, and both rain frequency and magnitude can be readily documented.
  - The swimming season > 90 days
  - The attendance is > 300 beachgoers per weekend day
  - Beach is not included in the list of beaches studied under the NEEAR beach study
  - Beach is located in a county with population density > 100/sq mi



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Marine

NEEAR Water Study Beach Locations

Goddard, RI

2009 Studies

Surfside, SC
Urban
Run-off

Boqueron, PR
Tropical

Biloxi, MS

Fairhope, AL

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Surfside, SC

Surfside, SC - 2009

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Surfside, SC

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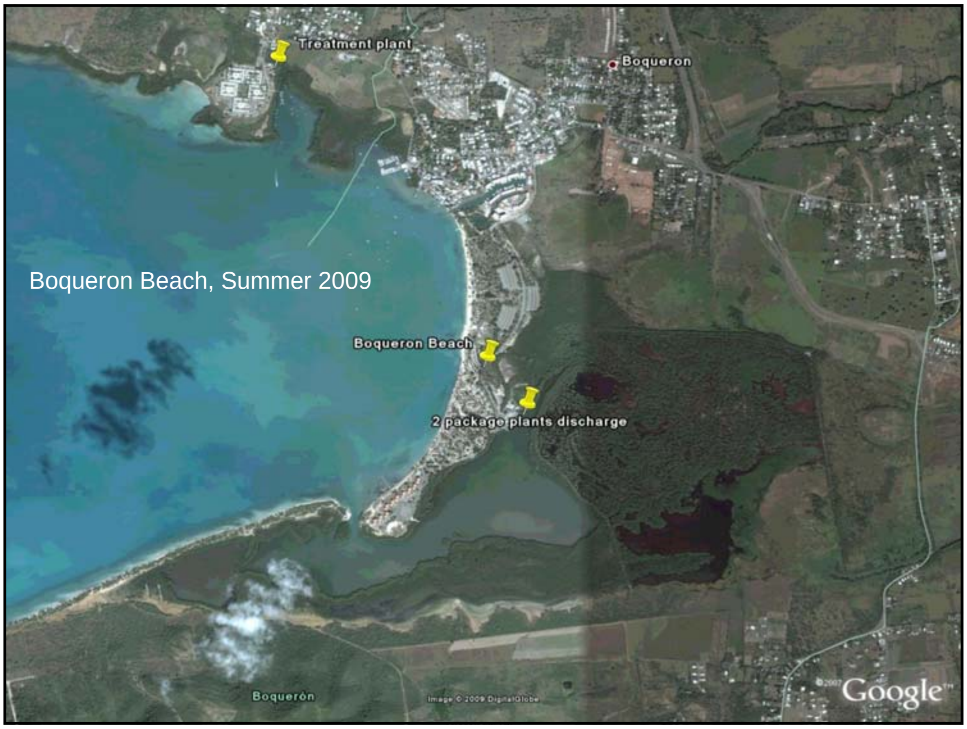

Boqueron Beach, Summer 2009

Treatment plant
Boqueron
Boqueron Beach
2 package plants discharge
Boquerón
Image © 2009 DigitalGlobe
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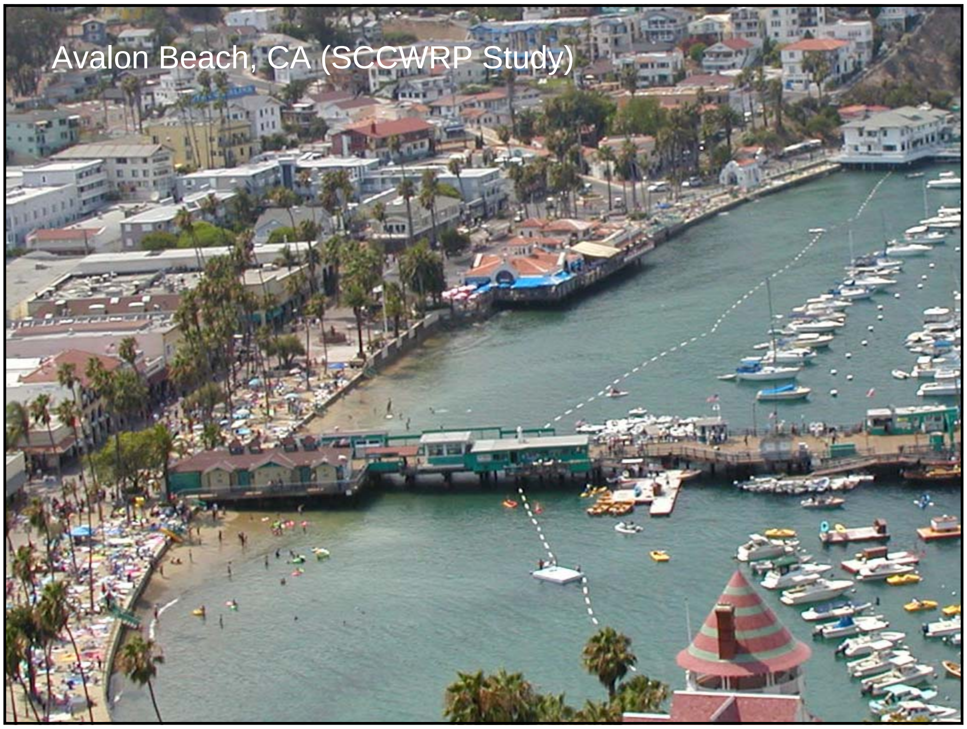
Boqueron Beach, Summer 2009

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Boqueron, PR - 2009

Boqueron, PR - 2009



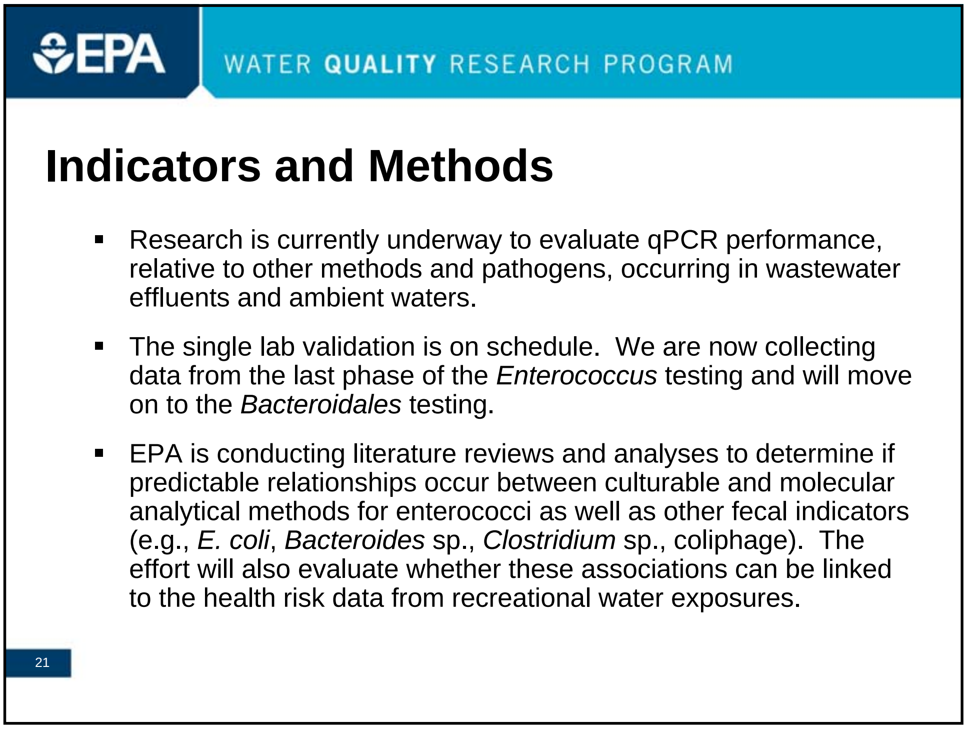
Avalon Beach, CA (SCCWRP Study)

Sample Stability Studies

- Sample Holding Time
    - Unfrozen surface water
    - Frozen filter stability
- Re-analysis of Archived Samples

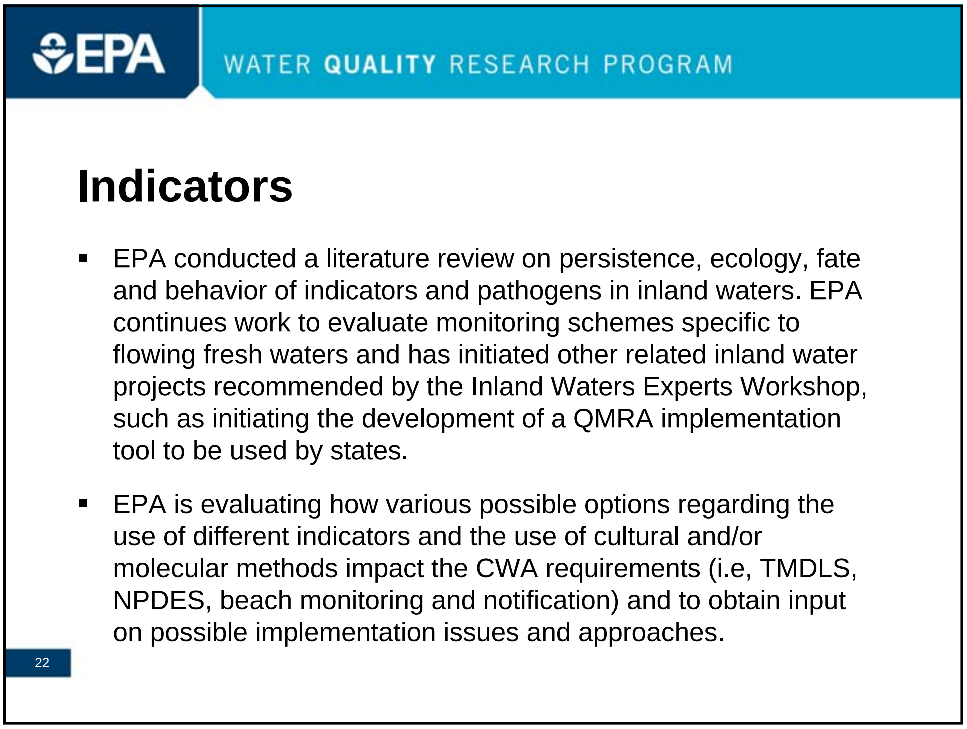
Additional Analyses

- EPA determined that it cannot complete a study comparing 1986 Bacteria Criteria recommendations to NEEAR studies as EPA was unsuccessful in its search for the raw individual data points needed to conduct the analyses. Some of the data were stored on magnetic tapes that had degraded. Because there are no other sources within EPA, or outside of EPA, that is likely to have the data, EPA has determined that it is unable make comparisons to the 1986 criteria.
- The analysis of epidemiologic study data continues to evaluate risks to children separately and as part of the entire population. These analyses are incomplete as the 2009 study data are not yet available.



Indicators and Methods

- Research is currently underway to evaluate qPCR performance, relative to other methods and pathogens, occurring in wastewater effluents and ambient waters.
- The single lab validation is on schedule. We are now collecting data from the last phase of the *Enterococcus* testing and will move on to the *Bacteroidales* testing.
- EPA is conducting literature reviews and analyses to determine if predictable relationships occur between culturable and molecular analytical methods for enterococci as well as other fecal indicators (e.g., *E. coli*, *Bacteroides* sp., *Clostridium* sp., coliphage). The effort will also evaluate whether these associations can be linked to the health risk data from recreational water exposures.



Indicators

- EPA conducted a literature review on persistence, ecology, fate and behavior of indicators and pathogens in inland waters. EPA continues work to evaluate monitoring schemes specific to flowing fresh waters and has initiated other related inland water projects recommended by the Inland Waters Experts Workshop, such as initiating the development of a QMRA implementation tool to be used by states.
- EPA is evaluating how various possible options regarding the use of different indicators and the use of cultural and/or molecular methods impact the CWA requirements (i.e, TMDLS, NPDES, beach monitoring and notification) and to obtain input on possible implementation issues and approaches.

Avian Markers

- By July 2011 determine if fecal source assays can be developed, and if feasible evaluate sensitivity and specificity.
- In 2011, hold Experts Scientific Workshop on what future science might improve understanding of potential human health risks from exposure to fecal contamination from avian wildlife and wildlife in coastal recreational waters.

Source Characterization

- Evaluate bovine and human host specific markers as PCR assays for indicators of cattle or human fecal pollution. Evaluate regional differences, seasonality, fate and transport, relationships with other fecal indicators and methods.
- Multiple case studies are being conducted at fresh and marine water sites to evaluate both human specific and animal markers at known animal and human sources of contamination.
- Efforts include mesocosm fate and transport studies and surveys of national rivers and streams.

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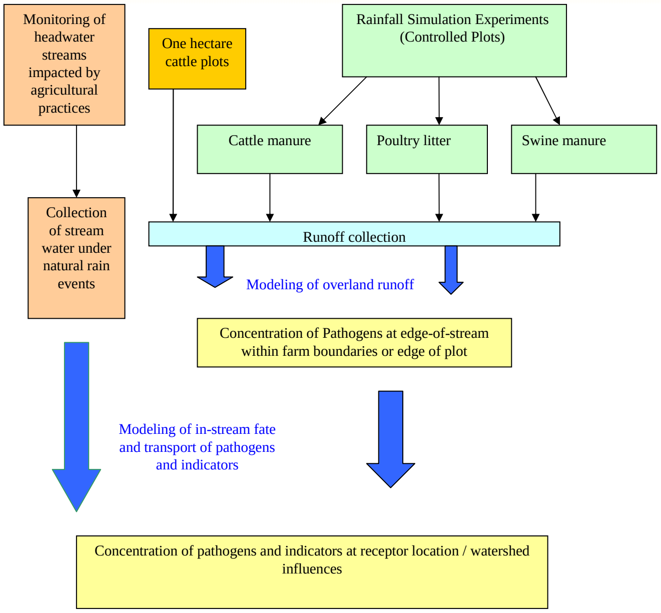
Sources



Monitoring of headwater streams impacted by agricultural practices

One hectare cattle plots

Rainfall Simulation Experiments (Controlled Plots)

Cattle manure

Poultry litter

Swine manure

Collection of stream water under natural rain events

Runoff collection

Modeling of overland runoff

Concentration of Pathogens at edge-of-stream within farm boundaries or edge of plot

Modeling of in-stream fate and transport of pathogens and indicators

Concentration of pathogens and indicators at receptor location / watershed influences

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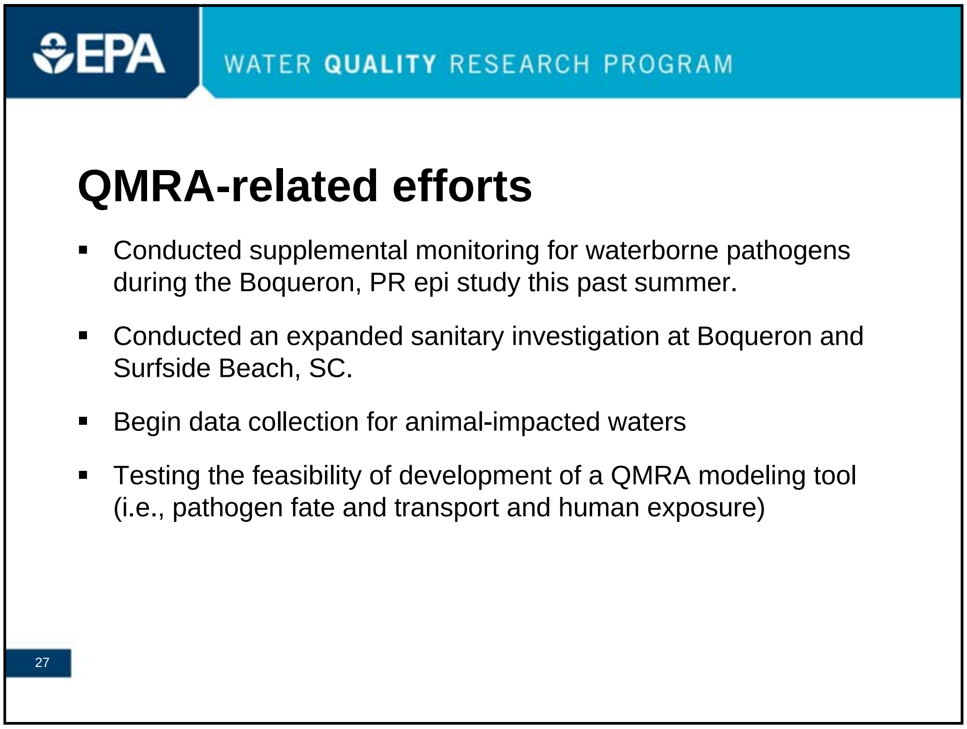
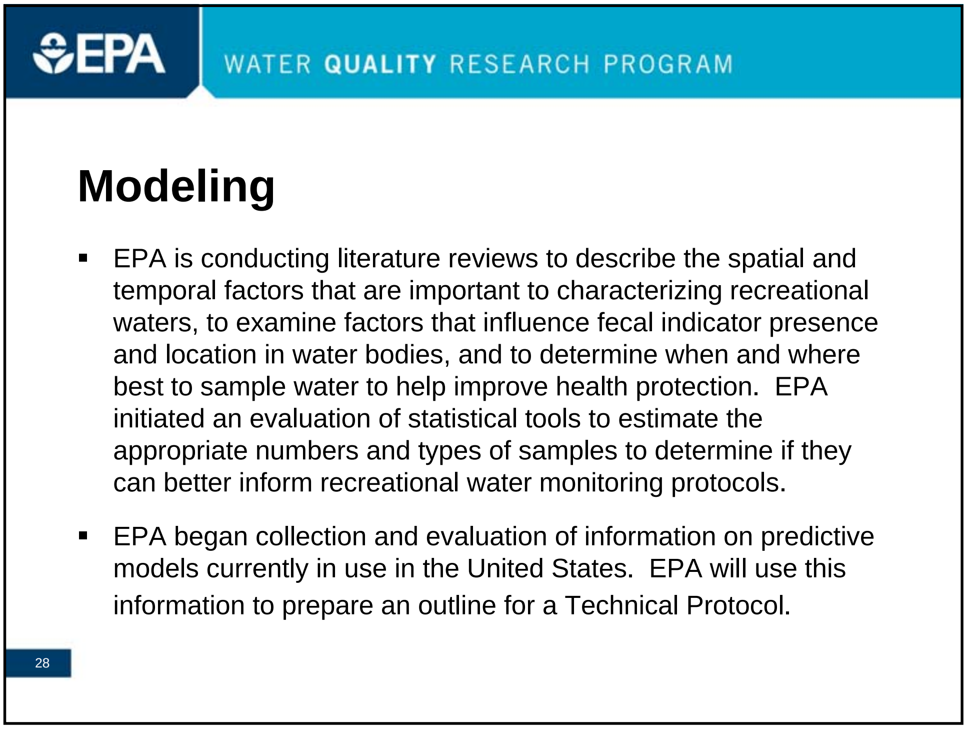
QMRA-related Efforts

- **Two main drivers for developing potential QMRA approaches in recreational waters**
  - Investigate the potential risks of human exposure to pathogens (e.g., animal-impacted waters)
  - Investigate a scientifically sound and defensible framework for potentially evaluating and developing flexible approaches for WQS implementation.
- **Specific goals:**
  - Better understand which pathogens likely cause illnesses from specific sources of fecal pollution.
  - Evaluate the degree to which risks of illness depends on and varies with the source(s) of contamination.
  - Facilitate WQS implementation via additional flexibility.



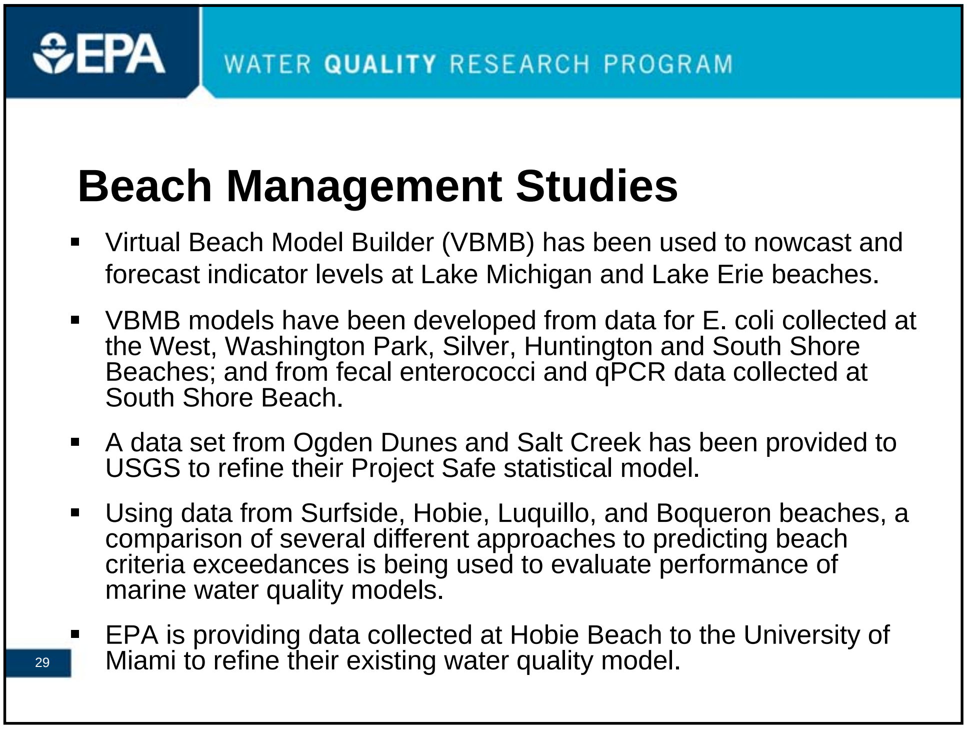
QMRA-related efforts

- Conducted supplemental monitoring for waterborne pathogens during the Boqueron, PR epi study this past summer.
- Conducted an expanded sanitary investigation at Boqueron and Surfside Beach, SC.
- Begin data collection for animal-impacted waters
- Testing the feasibility of development of a QMRA modeling tool (i.e., pathogen fate and transport and human exposure)



Modeling

- EPA is conducting literature reviews to describe the spatial and temporal factors that are important to characterizing recreational waters, to examine factors that influence fecal indicator presence and location in water bodies, and to determine when and where best to sample water to help improve health protection. EPA initiated an evaluation of statistical tools to estimate the appropriate numbers and types of samples to determine if they can better inform recreational water monitoring protocols.
- EPA began collection and evaluation of information on predictive models currently in use in the United States. EPA will use this information to prepare an outline for a Technical Protocol.



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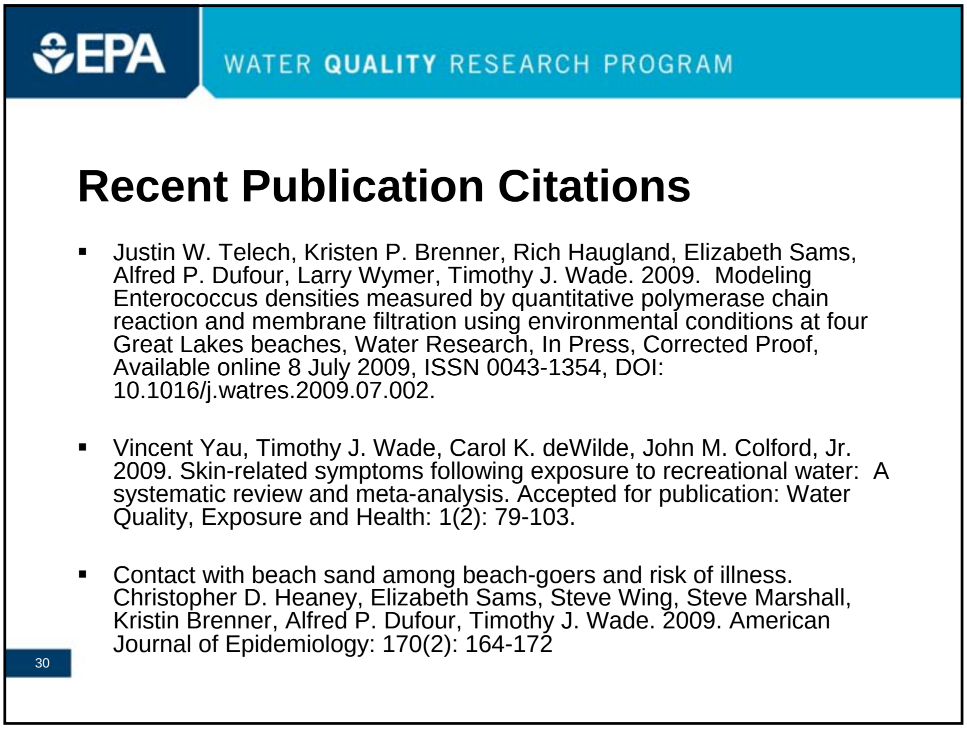
Beach Management Studies

- Virtual Beach Model Builder (VBMB) has been used to nowcast and forecast indicator levels at Lake Michigan and Lake Erie beaches.
- VBMB models have been developed from data for E. coli collected at the West, Washington Park, Silver, Huntington and South Shore Beaches; and from fecal enterococci and qPCR data collected at South Shore Beach.
- A data set from Ogden Dunes and Salt Creek has been provided to USGS to refine their Project Safe statistical model.
- Using data from Surfside, Hobie, Luquillo, and Boqueron beaches, a comparison of several different approaches to predicting beach criteria exceedances is being used to evaluate performance of marine water quality models.
- EPA is providing data collected at Hobie Beach to the University of Miami to refine their existing water quality model.



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Recent Publication Citations

- Justin W. Telech, Kristen P. Brenner, Rich Haugland, Elizabeth Sams, Alfred P. Dufour, Larry Wymer, Timothy J. Wade. 2009. Modeling Enterococcus densities measured by quantitative polymerase chain reaction and membrane filtration using environmental conditions at four Great Lakes beaches, Water Research, In Press, Corrected Proof, Available online 8 July 2009, ISSN 0043-1354, DOI: 10.1016/j.watres.2009.07.002.
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Recent Publication Citations

- Wade T.J., Calderon R.L., Brenner K.P., Sams E., Beach M., Haugland R., Wymer L., and Dufour A.P. High sensitivity of children to swimming-associated gastrointestinal illness: results using a rapid assay of recreational water quality. Epidemiology 2008: 19(3): 375-383.
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- Schoen, M.E. and Ashbolt, N.J. (2009) QMRA as a compliment to epidemiologic studies estimating bather risk at recreational beaches. In American Public Health Association Annual Meeting, November 7-11, 2009. Philadelphia, PA: American Public Health Association.
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Recent Publication Citations

- Shanks, O.C., C. Kelty, M. Sivaganesan, M. Varma, and R.A. Haugland. Quantitative PCR for genetic markers of human fecal pollution. (2009) Applied and Environmental Microbiology 75:5507-5513.
- Lee, Y, M. Molina, J.W. Santo Domingo, J.D. Willis, M. Cyterski, D.M. Endale, and O.C. Shanks. A temporal assessment of cattle fecal pollution in two watersheds using multiple host-specific PCR assays. (2008) Applied and Environmental Microbiology. 74:6839-6847.
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- Sivaganesan, M., S. Seifring, R.A. Haugland, and Orin C. Shanks (2008). A Bayesian method for calculating real-time PCR calibration curves using absolute plasmid DNA standards. BMC Bioinoformatics 9:120.

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- Frick, W. E., Z. F. Ge, R. G. Zepp (2008). Nowcasting and forecasting concentrations of biological contaminants at beaches: A feasibility and case study. *Environmental Science & Technology* 42(13): 4818-4824.
- Ge, Z.; W.E. Frick (2008) Time-frequency Analysis of Beach Bacteria Variations and its Implication for Recreational Water Quality Modeling. *Environmental Science & Technology* 43(4): 1128-1133
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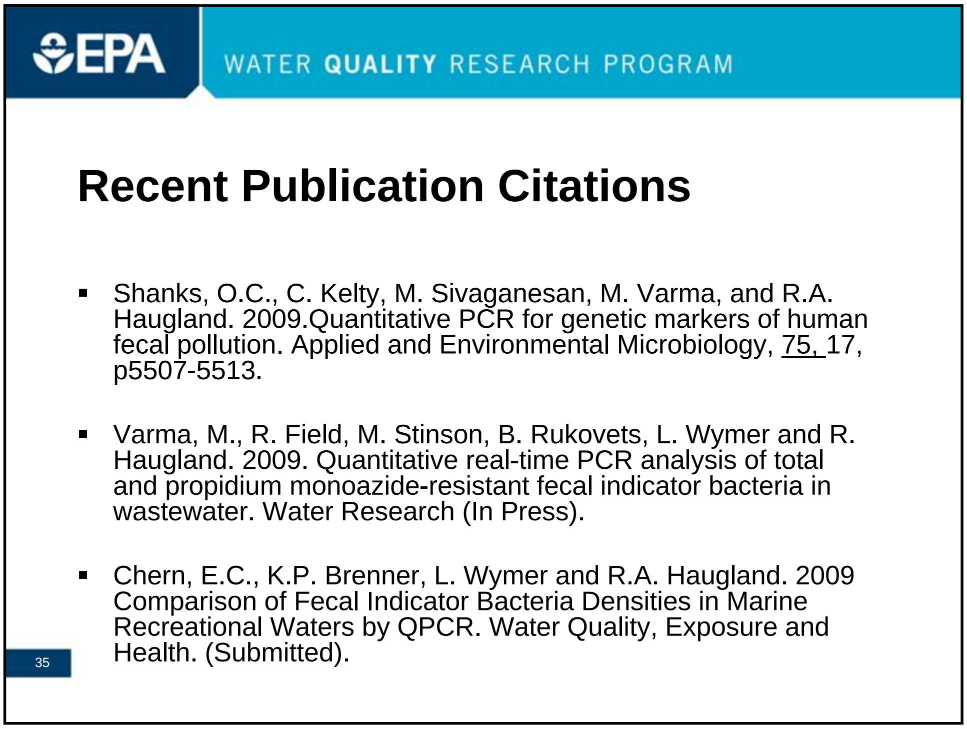

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- Varma, M., R. Field, M. Stinson, B. Rukovets, L. Wymer and R. Haugland. 2009. Quantitative real-time PCR analysis of total and propidium monoazide-resistant fecal indicator bacteria in wastewater. Water Research (In Press).
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