North Beach, Racine, Wisconsin

Located just north of Racine's harbor, North Beach (Figure 1) is among the most popular beaches on the Great Lakes and has been the focus of a long-term applied research program that has resulted in a series of innovations in the testing, management, and restoration of recreational water quality. These innovations have resulted in dramatic improvements in water quality over the past decade, reduced public health risk, and fewer beach closures. Since 2004, North Beach has been certified as a Blue Wave beach by the national Clean Beaches Council, the first beach in Wisconsin and second on the Great Lakes to be so recognized.

Figure 1. *North Beach, Racine, Wisconsin.*

Racine's Parks, Recreation, and Cultural Services Department maintains North Beach and is responsible for daily beach grooming, beach improvements, and lifeguard services throughout the summer. Based on daily counts by lifeguards in 2010 and 2011, total annual visits to North Beach are estimated at between 70,000 and 90,000. Major annual events include the two-day "Spike 'n Splash," which generates 200 hotel room stays, and the Ironman Racine Triathalon, which attracts 2,000 athletes from around the country. The city administration has estimated that these activities, coupled with regular visitation, generate as much as $5 million each year for the local economy[1].

[1] Garret, Ronnie. 2012. "A Day at the Beach." *Corporate Report Wisconsin*. 2623(August). Available online: http://crwmag.com/issue/august-2012/article/a-day-at-the-beach.

Responsibility for monitoring water quality falls with the Racine Health Department, which sends monitoring personnel to collect samples five days per week (Monday through Friday) at four fixed stations along 1,980 ft. of shoreline (Figure 1). Samples are composited and tested for the bacterium *E. coli* in the health department's laboratory. Tests include both the standard 18-hour, colilert analysis and a 2-hour, quantitative polymerase chain reaction (qPCR) analysis. Racine is the only jurisdiction to date approved by the U.S. EPA to use qPCR for operational water-quality testing. Racine is also the first jurisdiction to employ a standardized beach sanitary survey to identify likely sources and pathways of microbial contamination. Sanitary surveys entail intensive spatiotemporal sampling of water quality and measurements of associated nearshore, onshore, and hydro-meteorological conditions over the course of one or more beach seasons.

In 2004, North Beach was posted with 21 swim advisories and three beach closures. By 2010, there was just one advisory and in 2011 there were only three. Sanitary surveys have informed several beach improvements and best management practices contributing to these reductions, including beach re-grading, improved grooming practices, dune stabilization, and the redesign of the English Street stormwater outfall. During most rainfall events, stormwater flowing into the redesigned system is routed through two "vorceptors" (which settle debris and particulates) followed by a series of wetland cells before discharging into the lake via an outlet at Zoo Beach to the north. During large rainfall events, excess stormwater bypasses the bio-filtration system and discharges into the lake at the northern extent of the beach (Figure 1). Depending on the speed and direction of the nearshore current, large rainfall events can cause high *E. coli* levels at the beach.

Nowcast Models

Separate nowcast models were developed for North Beach for the 2011 and 2012 beach seasons, respectively. The 2011 nowcast model was built by the Wisconsin DNR using *Virtual Beach 2.1* with input and suggestions provided by beach monitoring staff at the Racine Health Department. The finished model was provided as a *Virtual Beach* model (.VBMX) file, for operation using that software. For the 2012 nowcast, Wisconsin DNR staff conducted data assembly, formatting, and model set-up, while Racine Health Department staff took the lead on building the model from a shared *Virtual Beach* project (.VBPX) file. The full process of data assembly, model set-up, and model-building is described in detail in the report *Building Operational "Nowcast" Models for Predicting Water Quality at Five Lake Michigan Beaches*[2].

The 2011 North Beach nowcast model was specified as:

LN(*Ecoli*) = 0.3824 - 0.116*(PROD(*Rain24*,*Rain48*)) + 0.6694*(SQUAREROOT(*Rain48*)) - 10.72*(PROD(*Rain48*,*CurrentEast*)) + 4.062*(PROD(*Rain48*,*CurrentNorth*)) + 0.000448*(PROD(*Discharge*,*Cloudy*)) - 0.4114*(*Sunny*) + 0.4737*(*WaveHeight_ft*) - 0.1971*(PROD(*Rain24*,*WaveHeight_ft*)) + 0.03915*(*WaterTemp_F*) - 0.7231*(*ClearWater*) - 2.886*(PROD(*CurrentNorth*,*ClearWater*)) + 0.9655*(QUADROOT(PROD(*Rain24*,*Pre_June21*))) + 0.1446*(QUADROOT(PROD(*Discharge*,*June21_July15*))) + 1.32*(QUADROOT(PROD(*Rain24, July16_Aug10*))) + 0.3075*(QUADROOT(PROD(*WaterTempF*,*Post_Aug10*)))

[2] Mednick, A.C. 2012. *Building Operational "Nowcast" Models for Predicting Water Quality at Five Lake Michigan Beaches.* PUB-SS-1098. Bureau of Science Services, Wisconsin Department of Natural Resources, Madison.

The 2012 North Beach nowcast model was specified as:

LOG10(*Ecoli*) = -4.377 + 0.2074*(*July16_Aug10*) - 0.1271*(*Sunny*) - 0.312*(*ClearWater*) - 0.3463*(*AlgBch_None*) + 1.257e-06*(SQUARE(*Gulls*)) - 136.4*(INVERSE(*DOY*,59.5)) + 0.7114*(POLY(*RRAIN24*,1.2171673,0.048945098,-0.00066772263)) + 2.949*(POLY(*Q168*,1.3845188,-0.00012402325,8.6777287e-08)) + 1.376*(POLY(*Q504*,1.3083821,0.00075025842,-7.3351447e-07)) - 23.84*(INVERSE(*Qmax672*,19.5)) + 0.7337*(*WaveO_comp*(WVHT,WVDIR,-17.35))

Where:

Ecoli = *E. coli* (MPN/ 100mL) — Measured by the Racine Health Dept.
AlgBch_None = Algae on beach? (n=0/ y=1) — Measured by the Racine Health Dept.
Cloudy = Sky condition (y=1/ n=0) — Measured by the Racine Health Dept.
ClearWater = Water "clear"? (y=1/ n=0) — Measured by the Racine Health Dept.
CurrentEast = Surface Water Velocity towards 90° (meters/sec) — GLCFS, NOAA
CurrentNorth = Surface Water Velocity towards 0° (meters/sec) — GLCFS, NOAA
Discharge = Root River Discharge, instantaneous (ft^3/sec) — USGS Gage
DOY = Day of year (1-365)
Gulls (count of birds) — Measured by the Racine Health Dept.
June21_July15 = Between these dates? (y=1/ n=0)
July16_Aug10 = Between these dates? (y=1/ n=0)
Post_Aug10 = After to August 10^{th}? (y=1/ n=0)
Pre_June21 = Prior to June 21^{st}? (y=1/ n=0)
Q168 = Root River Discharge, 7-day mean (ft^3/sec) — USGS Gage
Q504 = Root River Discharge, 21-day mean (ft^3/sec) — USGS Gage
Qmax672 = Root River Discharge, 28-day max (ft^3/sec) — USGS Gage
RAIN24 = Rainfall, 24 hours (in) — Racine Batten Airport
RAIN48 = Rainfall, 48 hours (in) — Racine Batten Airport
RRAIN24 = Rainfall, 24 hours (mm) — Radar Est. from the North Central River Forecasting Center, NOAA
Sunny = Sky condition (y=1/ n=0) — Measured by the Racine Health Dept.
WaveHeight_ft = Wave Height (ft.) — Estimated by the Racine Health Dept.
WaveO_comp = Onshore Waves (meters) — Derived from:
  Significant Wave Height (meters) — GLCFS, NOAA
  Wave Direction (from 0-360 deg.) — GLCFS, NOAA
WaterTemp = Water Temperature (deg. F) — Measured by the Racine Health Dept

And where:

LOG10 = logarithm, base 10
LN = natural logarithm
POLY = polynomial transformation ($a + bX + cX^2$)
PROD = *X1* * *X*2
QUADROOT = $X^{1/4}$
SQUARE = X^2
SQUAREROOT = $X^{1/2}$

Nowcast Model Operation

Figure 2. *Measuring water temperature during sample collection.*

Racine Health Department staff members operate the North Beach nowcast. The process of running the nowcast generally takes the operator five minutes or less on top of daily beach monitoring and public notification activities. Nowcast model runs are conducted after monitoring personnel return to the health department lab from collecting water samples and taking routine sanitary survey measurements at the beach (Figure 2). In some cases the nowcast operator will have conducted the field work. On most days, however, other staff members conduct the field work and provide the nowcast operator with the needed input values recorded on standardized paper forms. During the 2011 beach season, routine sampling and sanitary surveys took place around 11:00 a.m. During the 2012 beach season, these activities were moved forward to around 07:00 a.m., in order to allow time for samples to be returned to the lab, prepped for qPCR analysis, and run through the 2-hour process before posting an advisory (if deemed necessary based on the results) by mid-morning (In previous years, sampling was conducted at noon, with the aim of getting samples to the lab in time to conduct the standard 18-hour culture method to post advisories by mid-morning *the next day*.)

Figure 3. *Opening a Virtual Beach model (.VBMX) file.*

In 2011, the procedure for running the nowcast was for the operator to open the *Virtual Beach* model (.VBMX) file on their PC (Figure 3) and manually enter the day's input values into the *Virtual Beach* "MLR Prediction" tab. This was often done at, or around, the same time as the day's sanitary survey measurements and lab results were uploaded to the *Wisconsin Beach Health* website. Manually entered data included measurements that had just been taken in the field: *WaterTemp* (degrees F), *WaveHeight_ft* (estimated feet), *ClearWater* (1 if water "clear", 0 if not), *Sunny* (1 if sky "sunny"…), and *Cloudy* (1 if the sky "cloudy"…), as well as stage-of-season markers: *Pre_June21* (1 if before June 21st…), *June21_July15* (1 if between these dates…), *July16_Aug10*, and *Post_Aug10*. Input data also included *RAIN24* and *RAIN48* (inches of rain recorded at Batten Airport over the 24 and 48 hours prior to 07:00 a.m.), as well as *CurrentEast* (Velocity of surface water movement towards [+], or away from [–], 90° due East, estimated by NOAA-GLCFS) and *CurrentNorth* (Velocity of surface water movement towards [+], or away from [–], 0° due North…). The nowcast operator accessed these last four data inputs via the web, using beach-specific links posted on the *Wisconsin Beach Health* website (Figure 4), and copied the values into the MLR Prediction tab. Once all of the input values were entered, the operator executed the model.

Real-Time Data Links for:
North Beach
Racine County EPA ID: WI721390

Weather Conditions: http://glos.us/obs/station/11-190.html (Default time zone is GMT. Can change to CDT.)
RACINE/JOHN H BATTEN

24-hr. Rainfall: http://www.crh.noaa.gov/product.php?site=MKX&product=HYD&issuedby=MKX (Search for: " RAC ")
RACINE/JOHN H BATTEN

Lake Level: http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9087057 Milwaukee, WI&type=Great+Lakes+Water+Level+Data
MILWAUKEE

Surface Current and Waves: http://michigan.glin.net:8080/glcfs/glcfsps.glos?lake=michigan&i=-87.76109&j=42.74095&v=uc,vc,wvh&h=1&latest=3&tzf=-5&f=rss&u=m&pv=1&order=dec
Nearest GLCFS Cell
Lat: 42.74095
Lon: -87.76109

Tributary Discharge: http://waterdata.usgs.gov/nwis/uv?cb_00060=on&format=html&period=1&site_no=04087240
ROOT RIVER AT RACINE, WI

Note: The Web links listed above represent the nearest stations that regularly report real-time data. Distances between the beach and stations varies from site to site. "Surface Current and Waves" are model estimates from the Great Lakes Coastal Forecast System (GLCFS): www.glerl.noaa.gov/res/glcfs/

Return to Wisconsin Beach Health main page

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Figure 4. *Real-time data links for North Beach, posted on the Wisconsin Beach Health website* (http://www.wibeaches.us/real_time_data_links/RTD_Racine_North.html).

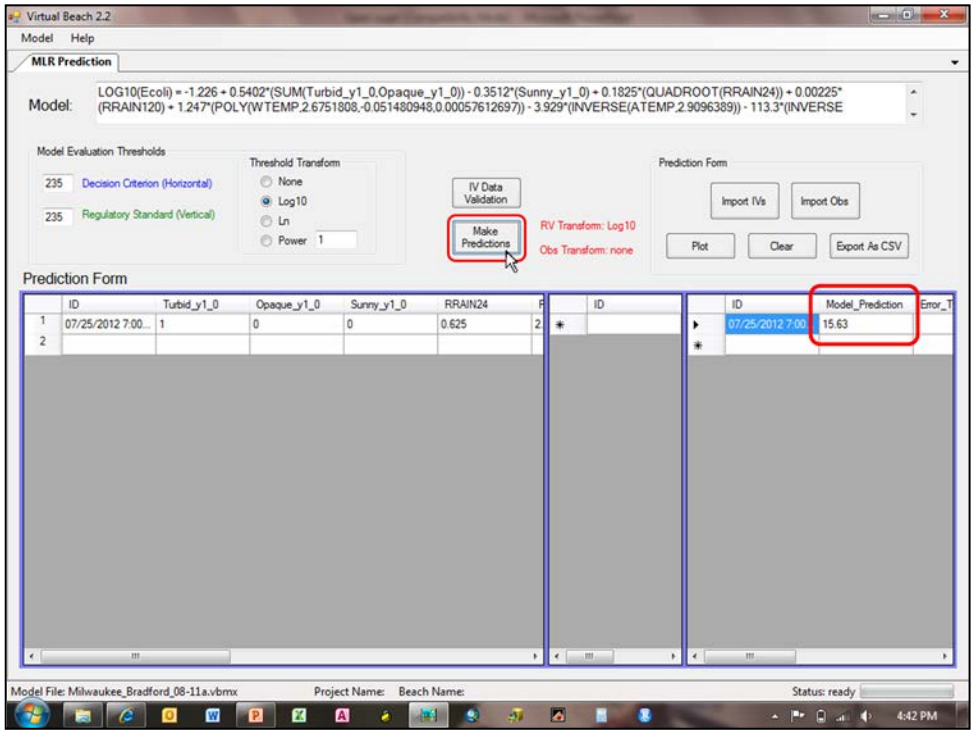

Figure 5. *Virtual Beach's "MLR Prediction" tab.*

The procedure for running the 2012 nowcast model was somewhat different, allowing for additional "automated" data inputs via the U.S. Geological Survey's *Environmental Data Discovery and Transformation* (ENDDAT) system[3]. The operator used a custom ENDDAT web URL (developed by Wisconsin DNR staff) to download a one-row table of the most recent values of several model inputs, including: *Q168* and *Q504* (7-day and 21-day average Root River discharge, ft^3/sec mean), *Qmax672* (28-day maximum Root River discharge, ft^3/sec), *RRAIN24* (millimeters of rain estimated by radar over the past 24 hours), and *Significant Wave Height* (meters) and *Direction* (0-360 degrees), as well as *DOY* (day of year, 1-365). The daily ENDDAT table was then imported into the *Virtual Beach* MLR Prediction tab, leaving the operator to manually-enter the remaining values: *AlgBch_None* (1 if there is any algae on the beach, 0 if none), *Gulls* (estimated number of gulls present), *ClearWater* (1 if water "clear"…), *Sunny* (1 if sky "sunny"…), and *July16_Aug10* (1 if between these dates…). Once all of the input values were entered, the operator executed the model to make a prediction (Figure 5).

Outputs of the nowcast included the estimated concentration of *E. coli*, as well as the statistical probability of exceeding the 235 CFU/100 mL water-quality standard. Health department staff used these outputs together with qPCR and sanitary survey results as multiple lines of evidence for determining whether or not to post a water-quality advisory or close the beach. The nowcast was generally conducted while qPCR analysis was in progress. Whereas the process of conducting the nowcast takes five minutes or so, the process of conducting qPCR typically takes two hours, including sample preparation, system operation, and output interpretation (Figure 6). As they are completed, nowcast predictions, 18-hour lab results, and qPCR are displayed alongside one another for daily comparison and validation (Figure 7).

Figure 6. *Conducting qPCR analysis. clockwise from top left: sample preparation (A-B), setting-up a qPCR run (C), and displayed results (D).*

[3] http://cida.usgs.gov/enddat/

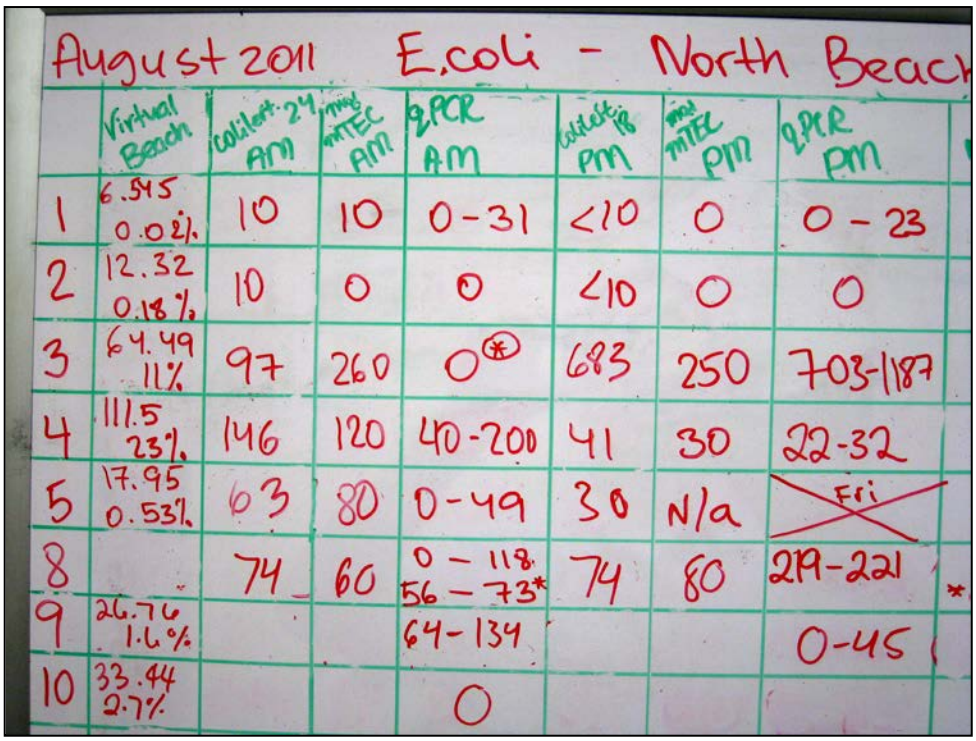

Figure 7. *Daily comparison of Virtual Beach results to standard lab and qPCR results.*

Nowcast Results

The 2011 North Beach nowcast was operated from June 10 through September 6. During that period, the model correctly predicted *non*-exceedances on 2 days when North Beach would otherwise have been posted, based on the previous days' 18-hour lab results. Both of these decisions were confirmed by qPCR results. For the 2012 beach season, the Racine Health Department was granted special permission by the U.S. EPA to use qPCR results for regulatory purposes; i.e. posting swim advisories or issuing beach closures. The 2012 nowcast was operated simultaneously with qPCR from June 28 through August 31. Rather than using nowcast-predicted concentrations of *E. coli* as the basis for posting advisories, the health department used model-estimated exceedance probabilities in conjunction with qPCR results – and in some cased, field-observed beach conditions such as strong onshore winds following rainfall – as multiple lines of evidence for posting advisories. On two occasions during the summer of 2012, nowcast exceedance probabilities indicated that qPCR results were incorrectly in exceedance of 235 CFU/100 mL advisory threshold. This was confirmed by secondary qPCR analysis and the following days' 18-hour lab results. This combined approach resulted in the posting two swim advisories and one beach closure that otherwise would have been missed, two *avoided* advisories that otherwise would have been posted, and one *avoided* closure that otherwise would have been issued.

Beach Water-quality Nowcast Model Case Study

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