
Summary: This report describes grant-funded work undertaken by the Wisconsin Department of Natural Resources in close collaboration with the U.S. Geological Survey's Center for Integrated Data Analytics and the U.S. Environmental Protection Agency's Office of Research and Development to facilitate the continued expansion of beach water-quality nowcasts in Wisconsin. We made several enhancements to the *Wisconsin Beach Health* website to better integrate local operation of nowcast models with routine monitoring and data reporting, to make it easier for centralized technical assistance providers to collaborate with local partners in building and maintaining nowcasts, and to improve public notification and awareness of nowcast-based advisories. Specific enhancements included: (1) customized web data-entry forms, (2) a downloadable *Nowcast Report*, (3) enhanced public notification of swim advisories and beach closures, (4) model metadata, and (5) updated training materials. This report describes the work we undertook and documents the deliverables produced. This document also fulfills final reporting requirements for our grant agreement.

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Cover Illustration: Screen capture of *Wisconsin Beach Health* website showing download capability developed as part of the grant-funded work.

Editor: Dreux J. Watermolen

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**Enhancing the *Wisconsin Beach Health* Website
to Facilitate Water-quality Nowcasts**

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Introduction

Created in 2000 by the U.S. Geological Survey (USGS) Wisconsin Water Science Center, the *Wisconsin Beach Health* website (www.wibeaches.us) is a central component of Wisconsin's Great Lakes beach program. This program is a collaborative effort between the Wisconsin Department of Natural Resources (Wisconsin DNR), local health departments, and other partner organizations to reduce beach-goers' risk of exposure to water-borne pathogens. This is accomplished through water-quality monitoring and public notification, as well as active management and restoration. *Wisconsin Beach Health* was originally developed for local health departments in the Milwaukee area with funding from the U.S. Environmental Protection Agency (EPA) and the Wisconsin Coastal Management Program. The website was later expanded to accommodate coast-wide monitoring under the federal Beach Environmental Assessment and Coastal Health (BEACH) Act of 2000¹. The USGS continues to operate and maintain *Wisconsin Beach Health* under contract with the Wisconsin DNR. Both the website and the local monitoring and notification activities that it facilitates are funded currently by annual BEACH Act grants administered by the Wisconsin DNR.

Wisconsin Beach Health serves three primary functions. The first is to notify the public of any swim advisories or beach closures that are posted during the 15-week beach season: Memorial Day weekend through Labor Day weekend. Depending on the results of recent water-quality tests, or other conditions known to increase health or safety risks, a beach's status on a given day will be listed as either "open," "water-quality advisory," or "closed" (Figure 1). Health department personnel or contractors change beaches' status using secure data-entry forms accessed through a password-protected "internal" section of *Wisconsin Beach Health* (Figure 2). In addition to prominently-displayed signs at the beach, the public can view the current status of any of the state's 112 monitored beaches on the main (public) *Wisconsin Beach Health* page (Figure 3). Website visitors can also sign-up to receive email alerts for selected locations and copy automatically-refreshing RSS feeds to their web browsers. Beach statuses posted on *Wisconsin Beach Health* are also made available on mobile devices through the *myBeachCast* smartphone application (www.great-lakes.net/beachcast/).



Figure 1. Public notification signage used at beaches.

¹ See <http://water.epa.gov/lawsregs/lawguidance/beachrules/act.cfm>.

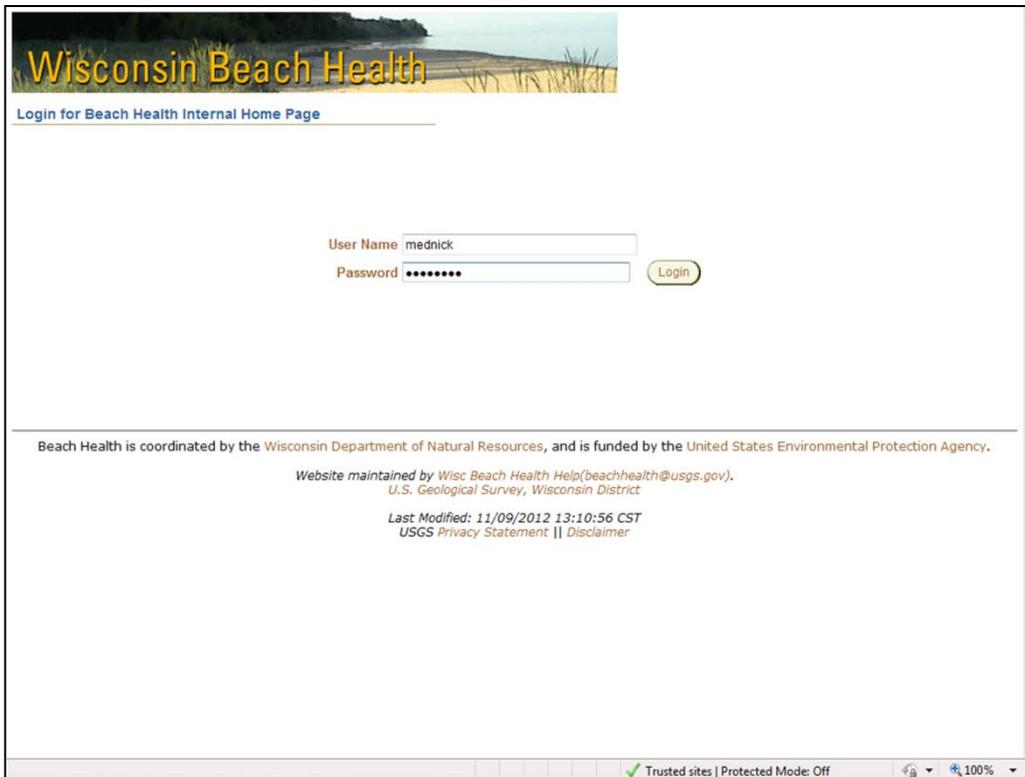


Figure 2. *Wisconsin Beach Health's "internal" page showing the password login screen.*

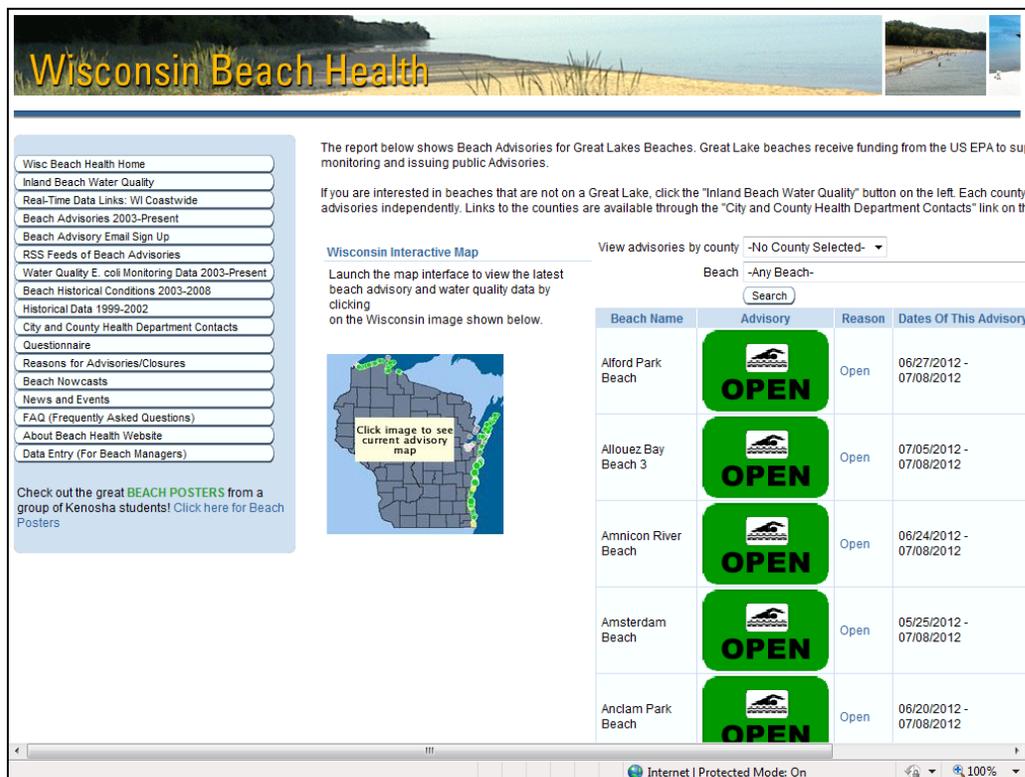


Figure 3. *Wisconsin Beach Health's main public page.*

The second major function of *Wisconsin Beach Health* is to provide local health departments and their contractors with a centralized system for reporting required data to the EPA. As a condition of Wisconsin's annual BEACH Act grant, all advisory- and water-quality data must be transmitted to the EPA's nationwide beach database. *Wisconsin Beach Health* serves as the state's data hub. As described above, local personnel post advisories and closures via password-protected web forms on the internal site. Separate web forms are used to also upload the results of water-quality lab tests. Depending on the beach, health department personnel or contractors will collect water samples one to five days per week and test them for the fecal-indicator bacterium *Escherichia coli* (*E. coli*). Swim advisories are posted when lab results show *E. coli* levels exceed the EPA recreational water-quality criterion of 235 colony-forming units (CFUs) per 100 mL. Beaches are closed when *E. coli* levels exceed the state guideline of 1,000 CFUs/100 mL.

Many beaches are also routinely surveyed for "sanitary" conditions, such as water clarity, gull concentrations, and tributary discharge, along with various hydro-meteorological conditions, using the EPA's *Routine On-site Sanitary Survey*². Data from sanitary surveys funded through the Great Lakes Restoration Initiative (GLRI) must be submitted to the EPA's GLRI Sanitary Survey database. Again, *Wisconsin Beach Health* serves as the hub for these data, including secure sanitary survey web forms corresponding to the paper forms used in the field. During the off-season, all three beach health datasets: advisories, water quality, and sanitary conditions, are electronically transmitted to their corresponding EPA databases.

Finally, *Wisconsin Beach Health* provides a readily-accessible, statewide archive of data that can be used for beach program analysis, research, and the development of real-time, predictive models. Data are organized into separate "reports" for advisories, water quality, and sanitary conditions. Site users can query these reports by date and location, with the results displayed as online tables (Figure 4) that can also be downloaded as comma-separated value (.CSV) files. The *Beach Advisory* and *Water Quality E. coli (Monitoring)* reports are available on both the internal and main *Wisconsin Beach Health* pages and include data for beach seasons dating back to 2003. The *Sanitary Data Report* is available only on the internal site and includes data dating back to 2007. For all three reports, data records (rows) include date and time, such that the downloaded .CSV tables can be temporally-matched in software packages such as MS Excel or Access. Downloaded .CSV tables are also compatible with the EPA's publically-available *Virtual Beach* software³.

Virtual Beach (Figure 5) is a critical component of efforts to develop and implement "nowcast" models for predicting real-time beach water quality at high-use beaches around the Great Lakes. Developed by the EPA's Office of Research and Development and enhanced with assistance and input from the Wisconsin DNR, USGS, and others, *Virtual Beach* guides users through the process of building, evaluating, and operating multivariate statistical models that can estimate current water quality based on readily measurable nearshore, onshore, and hydro-meteorological conditions. Typically, 100 or more concurrent measurements of *E. coli* and related sanitary and hydro-meteorological conditions, collected over two or more beach seasons, are needed to build a valid nowcast (Francy and Darner 2006). The existence of a centralized archive of these data is a pre-requisite for the widespread adoption of nowcasts in Wisconsin and around the Great Lakes (Mednick and Watermolen 2009).

² http://water.epa.gov/type/oceb/beaches/upload/2008_05_29_beaches_sanitarysurvey_survey-routine.pdf

³ www.epa.gov/ceampubl/swater/vb2/

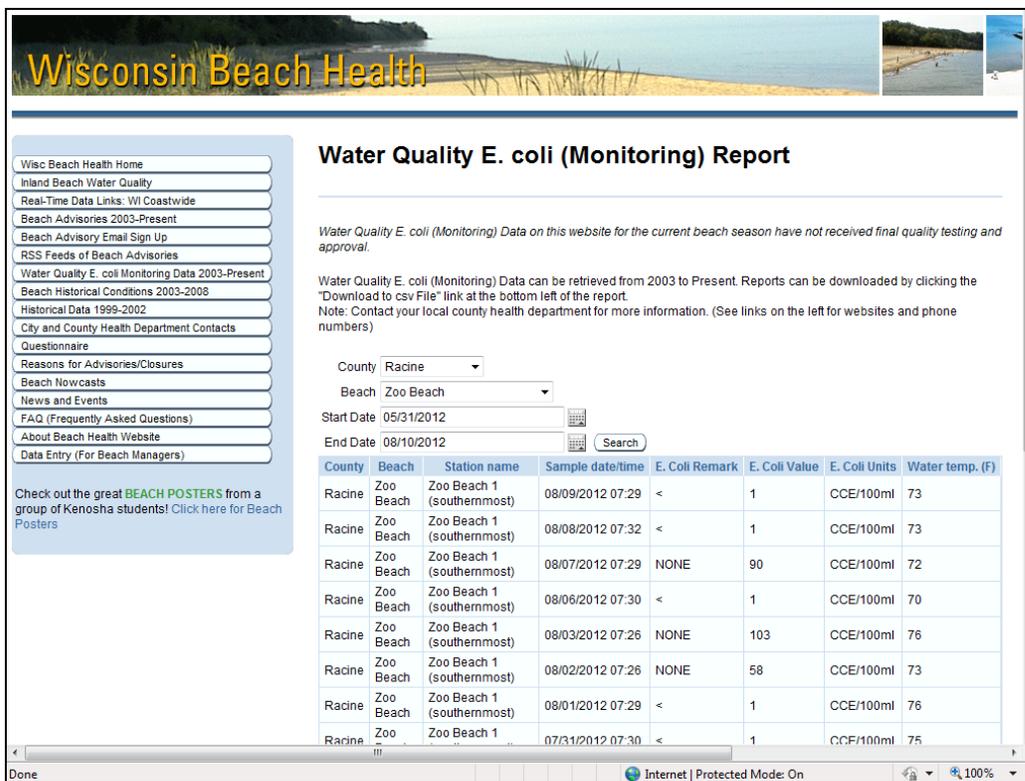


Figure 4. *Wisconsin Beach Health* query results for “Water Quality E. coli (Monitoring) Report”.

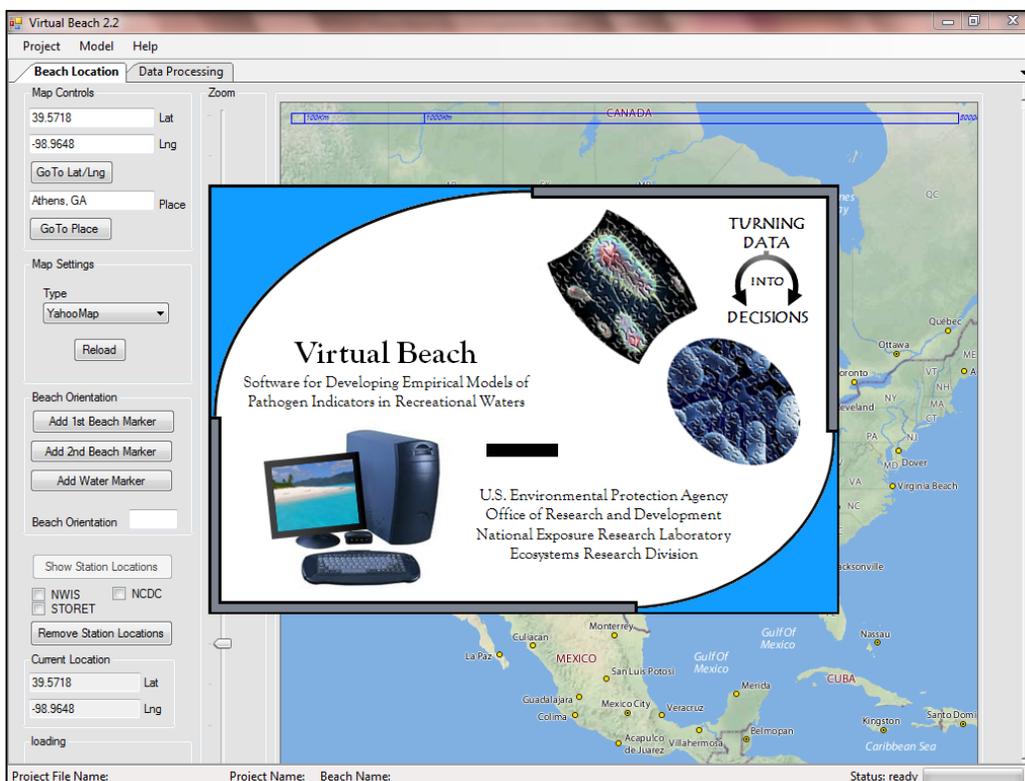


Figure 5. The U.S. EPA's *Virtual Beach* modeling and decisions-support software.

Nowcast models have been routinely demonstrated to be more accurate in estimating current water-quality conditions than traditional monitoring, which entails transporting samples to a lab and conducting 18-hour tests for *E. coli* (Nevers and Whitman 2005, Frick et al. 2008, Francy 2009). Using yesterday's *E. coli* to make today's decision frequently results in false exceedances (unnecessary advisories), as well as false non-exceedances (missed-advisories) (Whitman et al. 1999). Together, these errors increase beach-goers' exposure to potentially unhealthy conditions, while negatively impacting coastal economies. Using data archived on *Wisconsin Beach Health*, Mednick and Watermolen (2009) report that over 40% of advisories and 60% of closures posted in Wisconsin between 2003 and 2009 were unnecessary, while over 10% of non-advisory beach days should have been posted with an advisory or closure. Nowcast models may also present local health departments with a cost-effective alternative to sample-based monitoring at a time when beach health funding is declining at all levels (Mednick 2012a).

In order to facilitate the continued expansion of beach water-quality nowcasts in Wisconsin, the Wisconsin DNR contracted with the USGS Center for Integrated Data Analytics (CIDA) to make several enhancements to *Wisconsin Beach Health*. The objectives of this project were to better integrate local operation of nowcast models with routine monitoring and data reporting, to make it easier for the Wisconsin DNR and other centralized technical assistance providers to collaborate with local partners in building and maintaining nowcasts, and to improve public notification and awareness of nowcast-based advisories. Specific enhancements included: (1) customized web data-entry forms, (2) a downloadable *Nowcast Report*, (3) enhanced public notification of swim advisories and beach closures, (4) model metadata (descriptive information), and (5) updated training materials. These enhancements are described in the following section.

Notes

Enhancements

Customized Data-entry Forms

Using a flexible web platform implemented by USGS CIDA programmers, Wisconsin DNR staff created a series of customized data-entry forms (Figure 6) for uploading time-specific nowcast inputs (i.e. standard sanitary survey data plus additional predictive variables), outputs, and *E. coli* lab results to the *Wisconsin Beach Health* internal page and archive. The secure web forms allow local personnel to report water-quality data, sanitary conditions, and advisories, as well as additional nowcast inputs and outputs, via a single interface – as opposed to three or more separate forms. Also, rather than include space for all possible data that could be reported, the customized forms include only those variables that are routinely measured at the beach in question. For beaches with more than one water-quality monitoring station, the forms include a general beach tab plus separate tabs for each individual station. Since the forms can be edited, variables can easily be added, removed, or re-ordered to meet the needs of the local users.

The screenshot shows a web browser window displaying the USGS Wisconsin Beaches Sanitary Survey form for Zoo Beach. The form is titled "USGS - Wisconsin GL Beaches Sanitary Survey - Zoo Beach" and includes a "Logout mednick" link. The main content area is divided into several sections:

- Basic Information (EARLIEST sample Date & Time.):** Contains fields for "Date*", "Time (HH:MM 24-Hour Time)*", and "Surveyor*". A calendar for July 2012 is open, showing the 4th as the selected date.
- "Nowcast" Model inputs & Outputs. (Click on...):** A large text area containing a complex URL for automated data retrieval: `http://infotrek.er.usgs.gov/apex/?p=175:11:7981296501290243::NO:::...`
- Nowcast Est. Concentration (CFU/100mL):** An input field.
- Nowcast Probability of >235 CFU (%):** An input field.
- Post an Advisory. (Click on the URL below to go to WI Beach Health.):** A link to the advisory page.

The footer of the page includes "Accessibility", "FOIA", "Privacy", and "Policies and Notices" links, contact information for "gri_beach_help@usgs.gov", and the "FIRST GOV" logo.

Figure 6. Newly developed customized data-entry form for Zoo Beach, Racine, Wisconsin.

Prominent on the main tab is a lengthy URL, which provides direct online access to real-time hydro-meteorological data via the *Environmental Data Discovery and Transformation* (ENDDAT) portal⁴. Also created by the USGS CIDA, ENDDAT enables users to create custom URLs for accessing location-specific NOAA and USGS data, including radar-estimated rainfall, tributary stream flow, cloud cover, air and water temperature, and the magnitude and direction of wind, waves, and surface currents. ENDDAT URLs can be constructed to download either historical data needed to build nowcast models or real-time

⁴ <https://cida.usgs.gov/enddat/>

data needed to operate them. When launched from one of the web forms (Figure 7), the beach-specific URL downloads a one-row .CSV table of the most recent values for various nowcast model inputs. The tables are formatted to be imported directly into *Virtual Beach* models (Figure 8). For most models, some additional field-measured data must be manually entered (e.g., water clarity), after which the user clicks “Make Prediction,” to generate a point-estimate of the current *E. coli* concentration, plus a statistical probability of exceeding the 235 CFU/100 mL water-quality threshold (Figure 9).

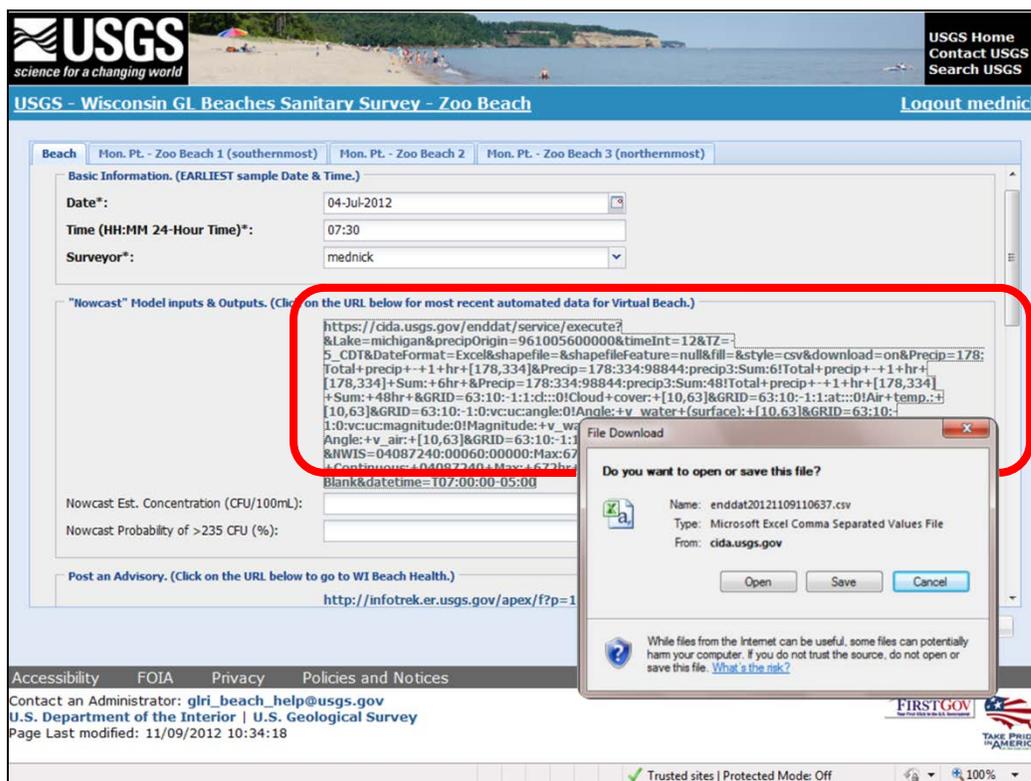


Figure 7. Clicking the custom URL downloads real-time hydro-meteorological data.

The process of downloading real-time data from the ENDDAT URL, importing them into a *Virtual Beach* model, and running the nowcast takes less than 5 minutes. Once this short process is completed, the user can enter any remaining routine data into the web form, starting with the just-completed nowcast results (Figure 10). If necessary, the user can also click on the link immediately below the nowcast results to post an advisory or closure. The remainder of the form includes spaces for entering general beach conditions (Figure 11), station-specific conditions (if needed), and water-quality results (for the previous day, unless a rapid lab method is used). When completed and submitted, the web form fulfills all of the data-reporting requirements of the BEACH Act and GLRI, while simultaneously uploading nowcast inputs and outputs.

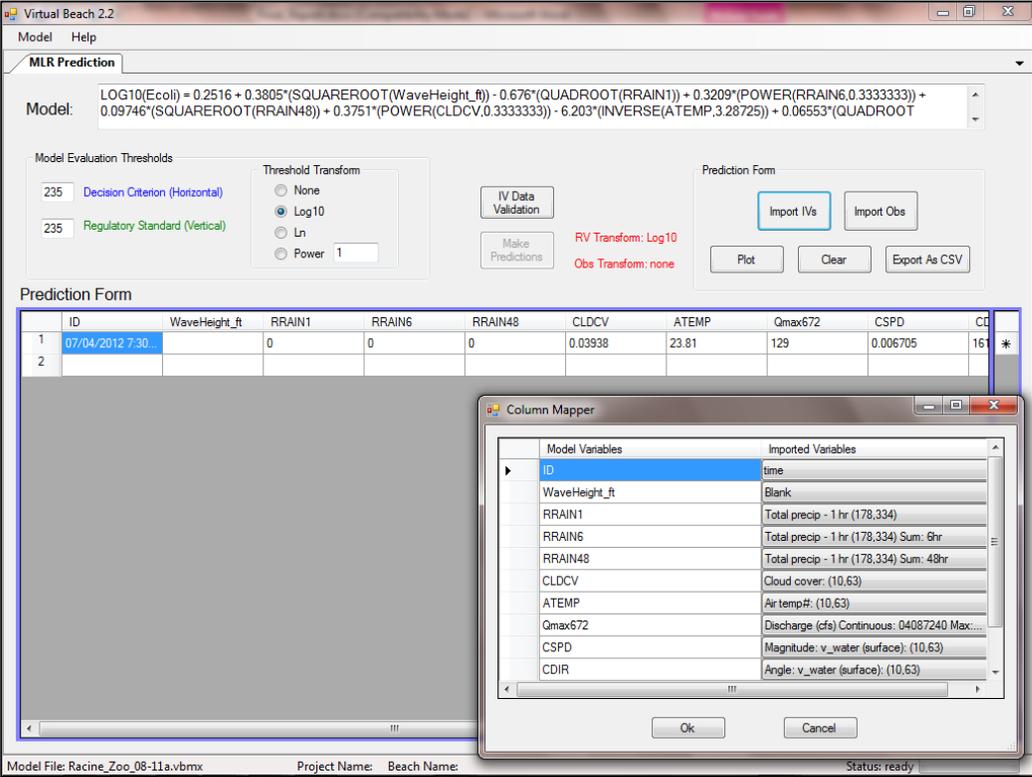


Figure 8. Importing current hydro-meteorological data into Virtual Beach.

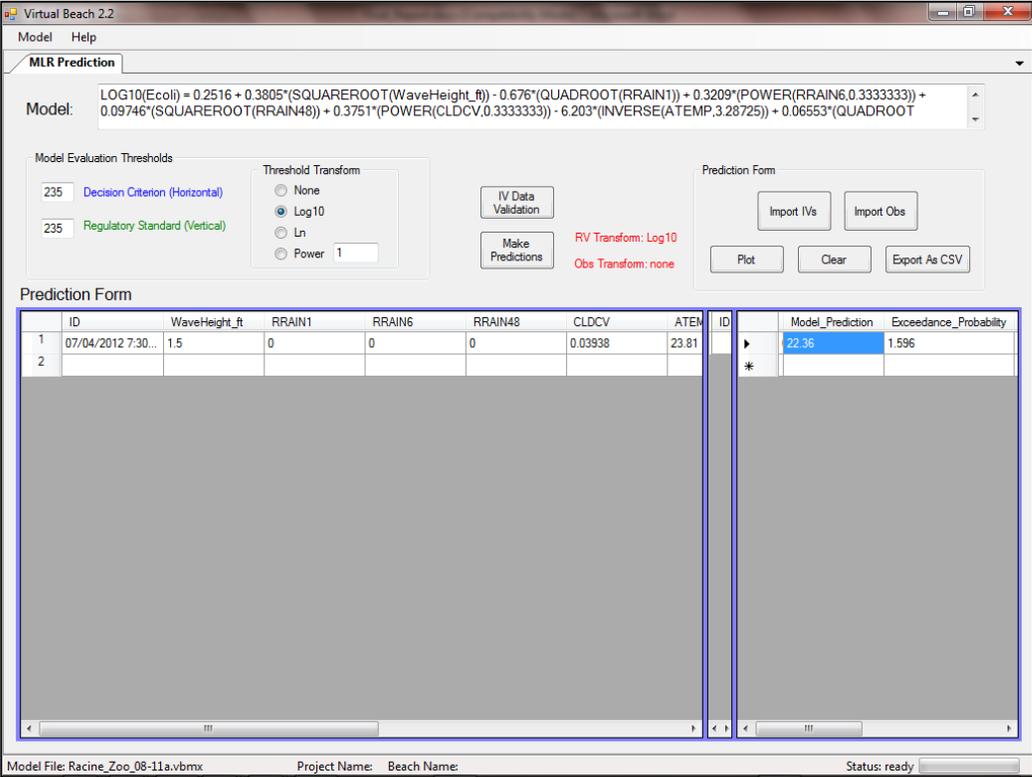


Figure 9. Making a nowcast prediction with Virtual Beach.

USGS
science for a changing world

USGS Home
Contact USGS
Search USGS

USGS - Wisconsin GI Beaches Sanitary Survey - Zoo Beach Logout mednick

Beach: Mon. Pt. - Zoo Beach 1 (southernmost) | Mon. Pt. - Zoo Beach 2 | Mon. Pt. - Zoo Beach 3 (northernmost)

Basic Information. (EARLIEST sample Date & Time.)

Date*: 04-Jul-2012
Time (HH:MM 24-Hour Time)*: 07:30
Surveyor*: mednick

"Nowcast" Model inputs & Outputs. (Click on the URL below for most recent automated data for Virtual Beach.)

Blank&datetime=T07:00:00-05:00

Nowcast Est. Concentration (CFU/100mL): **22.36**

Nowcast Probability of >235 CFU (%): 1.6

Post an Advisory. (Click on the URL below to go to WI Beach Health.)
<http://infotrek.er.usgs.gov/apex/f?p=175:11:7981296501290243::NO::>

Accessibility FOIA Privacy Policies and Notices

Contact an Administrator: gfri_beach_help@usgs.gov
U.S. Department of the Interior | U.S. Geological Survey
Page Last modified: 11/09/2012 10:34:18

FIRST GOV TAKE PRIDE IN AMERICA

Trusted sites | Protected Mode: Off

Figure 10. Entering nowcast results.

USGS
science for a changing world

USGS Home
Contact USGS
Search USGS

USGS - Wisconsin GI Beaches Sanitary Survey - Zoo Beach Logout mednick

Beach: Mon. Pt. - Zoo Beach 1 (southernmost) | Mon. Pt. - Zoo Beach 2 | Mon. Pt. - Zoo Beach 3 (northernmost)

Part I - General Beach Conditions

Air Temperature: 25
Air Temperature Units: Celsius Degrees
Wind Speed: 7
Wind Speed Units: mph
Wind Direction (° From N): 180
Hours Since Last Rain Event: > 72
Rainfall Measurement: 0
Rainfall Units: Inches
Rainfall Intensity:
Weather Conditions: Sunny (No Clouds)
Wave Height (ft)*: 1.5
Wave Intensity: Normal
Wave Direction: Calm
Lakeshore Current Direction (° From N): Normal
Rough

Comments / Observations - Part I:

Cancel Reset Submit

Accessibility FOIA Privacy Policies and Notices

Contact an Administrator: gfri_beach_help@usgs.gov
U.S. Department of the Interior | U.S. Geological Survey
Page Last modified: 11/09/2012 10:34:18

FIRST GOV TAKE PRIDE IN AMERICA

Done Trusted sites | Protected Mode: Off

Figure 11. Entering general beach conditions.

Downloadable Nowcast Report

Building on previously-created *Sanitary Survey* and *Water Quality* reports, USGS CIDA programmers created a new *Nowcast Report* on the internal *Wisconsin Beach Health* site. Like the other reports, the *Nowcast Report* is continuously updated with data entered via the password-protected web forms. The *Nowcast Report* can also be queried by date and beach, with the results displayed in online tables or downloadable .CSV files (Figure 12). A key difference is that the new report includes model outputs as well as inputs, plus lab results, in a single table. This avoids time-consuming data requests and data assembly, including the often tedious process of temporally matching data tables from multiple sources. Moreover, the data are formatted for direct import into *Virtual Beach*. Following requirements of that software, the left-hand column is the record identifier (date-and-time), followed by observed *E. coli* (the response variable), and then the various other data (potential explanatory variables). The report also pre-translates qualitative sanitary measures such as *Water Clarity* (field-reported as “clear,” “somewhat turbid,” “turbid,” or “opaque”) into quantitative ordinal variables (ranked values of 0-3) and binomials (presence-absence values of 1 or 0), so that they can be used in *Virtual Beach*. Together, these formatting elements significantly reduce the time and effort required to update historical datasets for model calibration during the off-season.

The screenshot shows a web browser window displaying the 'Nowcast Report' interface. At the top, there are navigation links for 'Internal Home' and 'Logout'. Below that, the 'Nowcast Report' title is followed by dropdown menus for 'Municipality/County' (set to 'Manitowoc') and 'Beach' (set to 'Neshotah Beach'). There are 'Search' and 'Cancel (Return to Main Menu)' buttons. The main content is a table with the following columns: DATETIME, ECOLI LAB, ECOLI_METHOD_UNITS, BEACH, COUNTY, NOWCAST_ECOLI, NOWCAST_PROB_235, NOWCAST_PROB_1000, and NOWCAST_ID. The table contains 20 rows of data. A 'File Download' dialog box is overlaid on the table, asking 'Do you want to open or save this file?'. The dialog shows the file name 'Nowcast_Report.csv', type 'Microsoft Excel Comma Separated Values File', and source 'infotrek.er.usgs.gov'. There are 'Open', 'Save', and 'Cancel' buttons. A security warning is also visible at the bottom of the dialog: 'While files from the Internet can be useful, some files can potentially harm your computer. If you do not trust the source, do not open or save this file. What's the risk?'. The browser's address bar shows the URL: 'http://infotrek.er.usgs.gov/apex/f?p=175:2:1551246227:'. The browser status bar indicates 'Trusted sites | Protected Mode: Off' and '100%' zoom.

DATETIME	ECOLI LAB	ECOLI_METHOD_UNITS	BEACH	COUNTY	NOWCAST_ECOLI	NOWCAST_PROB_235	NOWCAST_PROB_1000	NOWCAST_ID
08/29/2012 09:00	17.1	MPN/100 mL	Neshotah Beach	Manitowoc	10.66	.06		329
08/28/2012 11:30	35.9	MPN/100 mL						
08/27/2012 12:30	1	MPN/100 mL						
08/26/2012 18:55	58.8	MPN/100 mL						324
08/23/2012 12:00	33.2	MPN/100 mL						314
08/22/2012 08:48	7.1	MPN/100 mL						313
08/21/2012 11:00	7.3	MPN/100 mL						312
08/20/2012 10:50	12	MPN/100 mL						308
08/16/2012 11:00	225.4	MPN/100 mL						294
08/15/2012 10:00	12.2	MPN/100 mL	Neshotah Beach	Manitowoc	77.23	12.24		290
08/14/2012 10:00	35	MPN/100 mL	Neshotah Beach	Manitowoc	120.52	24.26		281
08/13/2012 13:15	129.6	MPN/100 mL	Neshotah Beach	Manitowoc	275.23	56.56		275
08/09/2012 09:30	144.5	MPN/100 mL	Neshotah Beach	Manitowoc	96.21	17.53		268
08/08/2012 12:30	34.5	MPN/100 mL	Neshotah Beach	Manitowoc	48.95	5.05		267
08/07/2012 12:35	28.8	MPN/100 mL	Neshotah Beach	Manitowoc	22.16	.68		263

Figure 12. “Nowcast Report,” web view and data download.

In addition to standard inter-year calibration (i.e. model rebuilds) conducted during the off-season, changes in climate and beach conditions underscore the importance of validating, and if necessary re-calibrating, models *during* the beach season. In 2012, this was illustrated by prolonged periods of extreme heat (air and water) and a number of dry-weather *E. coli* exceedances that initial nowcast models were unable to predict (Mednick 2012b). Without a central archive of model inputs, outputs, and lab results available through the *Nowcast Report*, it would be virtually impossible for centralized technical assistance providers at the Wisconsin DNR to validate and calibrate models operated by multiple local health departments. With the new report, pre-formatted .CSV tables can be readily downloaded and imported directly into *Virtual Beach* (Figure 13), which in turn can be used to quickly generate standard metrics and graphics of model performance. These include model sensitivity (correctly predicted exceedances), specificity (correctly predicted non-exceedances), and overall accuracy. Poorly performing models can then be re-calibrated using these metrics as the basis for optimization. Because it exists online, the *Nowcast Report* makes it easier for the Wisconsin DNR to coordinate this process with its local partners throughout the state.

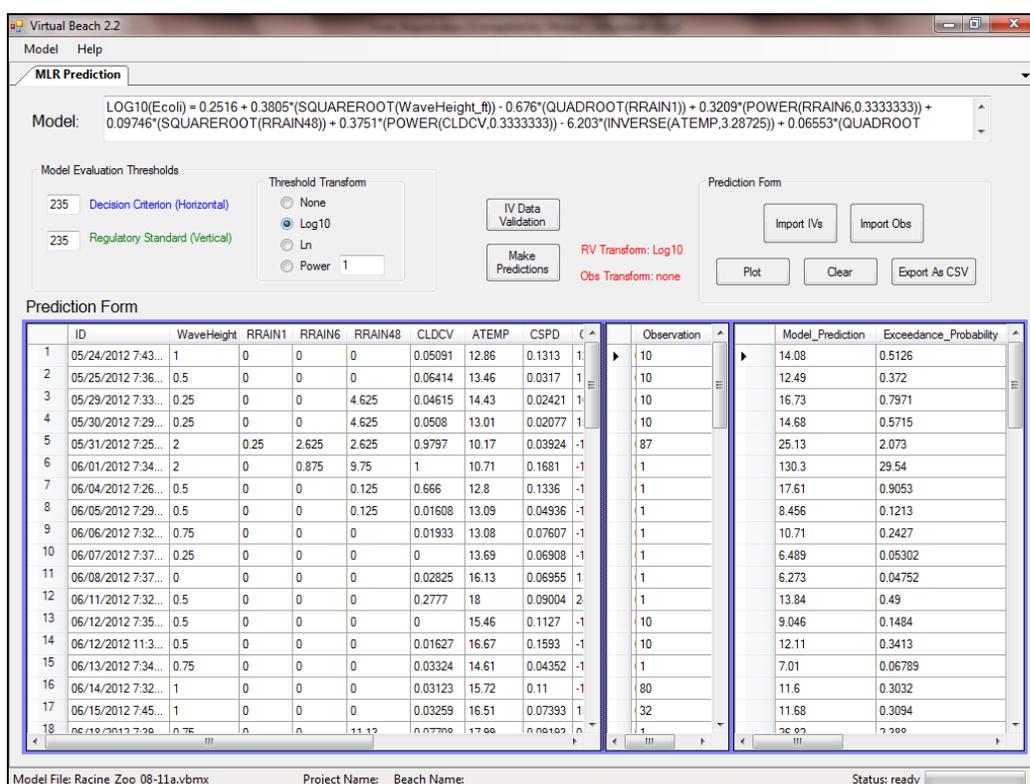


Figure 13. “Nowcast Report” imported into *Virtual Beach*, with validation results.

Enhanced Public Notification of Swim Advisories and Beach Closures

A key objective in updating the *Wisconsin Beach Health* website was to raise awareness of water-quality nowcasts. In 2010, the site received 1.8 million hits from 15,000 unique visitors; however, none of the posted swim advisories or beach closures included a reason for the decision (i.e. whether it was the previous day’s lab results, a nowcast, or some other consideration). Health department staff and contractors have always been required to report one of six standard reasons for posting an advisory (for EPA reporting purposes), but these were not included in the public postings. USGS CIDA programmers changed this so that the reason for any advisory is now listed in all electronic postings, including the main page (Figure 14), RSS feeds (Figure 15), email alerts, and the *myBeachCast* mobile application. A separate webpage was also created to provide more detailed explanations of the standard reasons (Figure 16). This additional page is launched from hyper-links embedded in each advisory and includes links to additional resources such as the Wisconsin DNR’s *Predicting Beach Water Quality* webpage⁵.

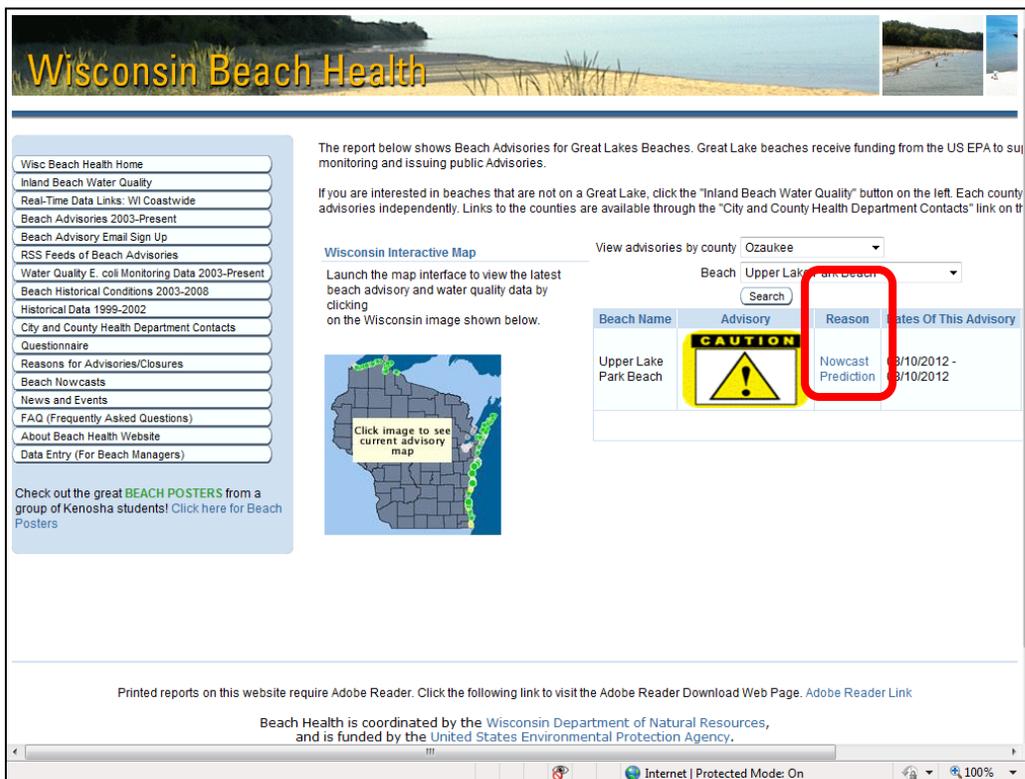


Figure 14. Posted swim advisory, August 10, 2012.

The explanation given for Nowcast Prediction-based advisories reads:

The results of a predictive model, based on historical observations, indicate a high probability that E. coli levels exceed recreational water-quality standards or guidelines. Nowcast predictions are based on a combination of factors correlated to water quality, such as rainfall, wave height, water clarity, nearby river discharge, and lake currents. The advisory or closure is preemptive, since lab results will not be immediately available.

⁵ <http://dnr.wi.gov/topic/beaches/predicting.html>

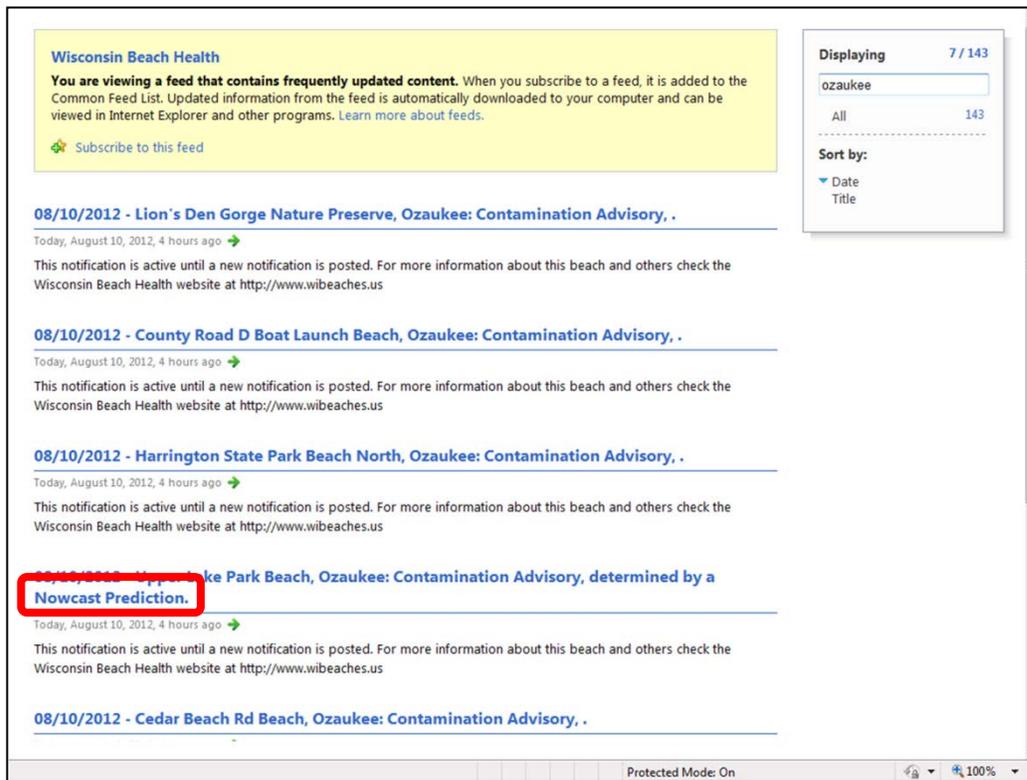


Figure 15. RSS feed showing swim advisories, August 10, 2012.



Figure 16. Web page with explanations of reasons for swim advisories and beach closures.

Model Metadata and Training Materials

To provide additional information on nowcast models to both the interested public and those tasked with building and operating them, USGS programmers created a new *Beach Nowcasts* section on the public *Wisconsin Beach Health* site (Figure 17). This page includes links to Wisconsin DNR's *Predicting Beach Water Quality* page, case studies of implemented nowcasts, model metadata, and illustrated training materials. Nowcast metadata (Figure 18) are short documents presenting key details of current and previous year models, such as the explanatory variables used, data sources, size and historical period of the training dataset, model statistics, dates of operation, and performance metrics. Metadata will be particularly important in the future as nowcasting is expanded to more beaches, as mid-season calibration becomes more common, and as locales begin to implement two-tiered nowcasts, including separate models for days when field data are collected and days when they are not.

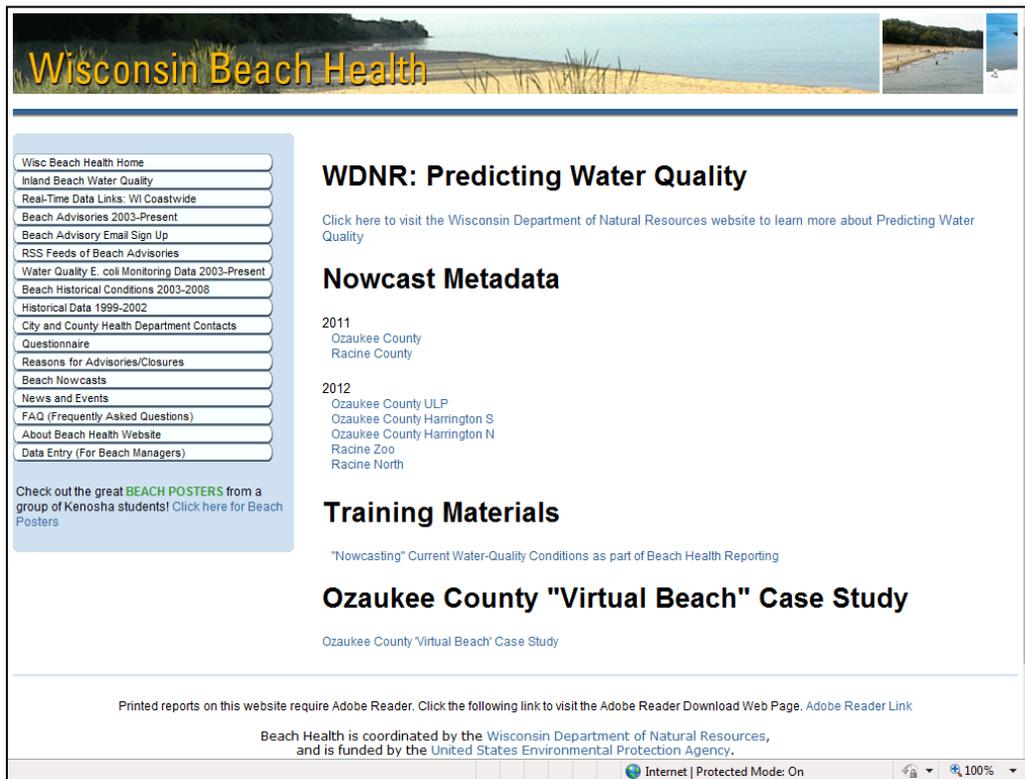


Figure 17. Newly developed “Beach Nowcasts” section of *Wisconsin Beach Health*.

Training materials include a step-by-step user guide titled “*Nowcasting*” *Current Water-quality Conditions as Part of Beach Health Reporting* (Figure 19). This illustrated guide provides users with instructions on how to operate a nowcast model in conjunction with routine beach health reporting, including the web data-entry form, using the ENDDAT URL to download and import current hydro-meteorological data into a *Virtual Beach* model, making a nowcast prediction and entering the results into the web form, posting advisories, completing and submitting the web form, querying the *Nowcast Report*, and importing query results into *Virtual Beach* for model validation. These instructions will be revised to reflect future updates to the *Virtual Beach* software.

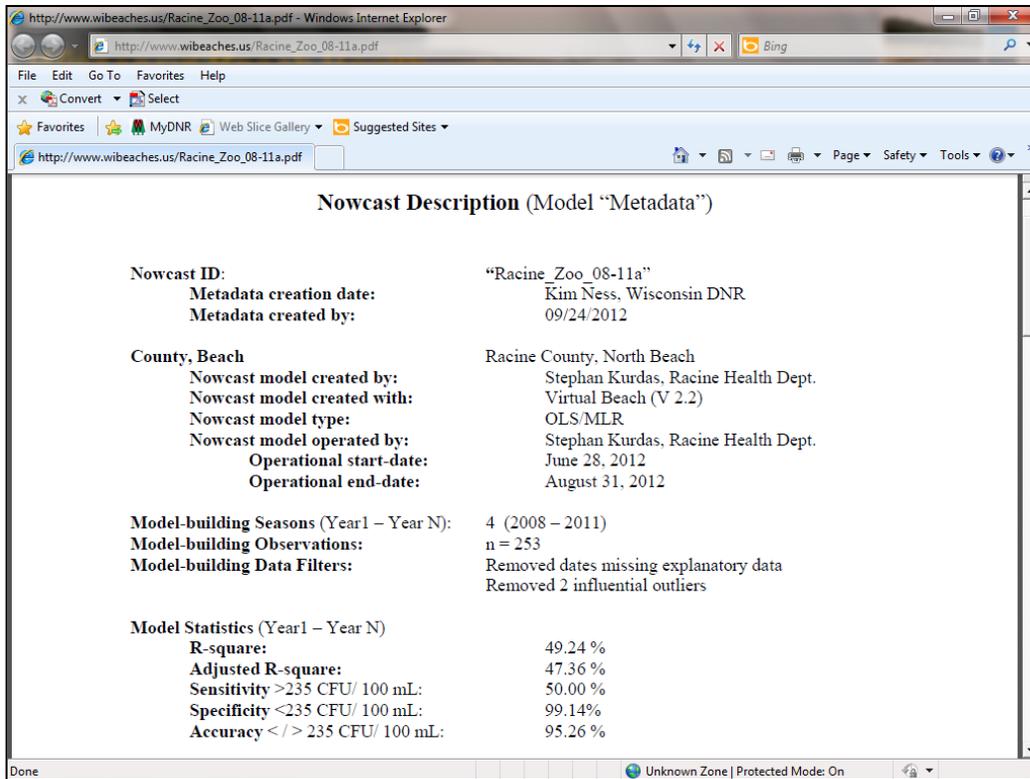


Figure 18. Nowcast metadata, example from Zoo Beach, Racine, Wisconsin.

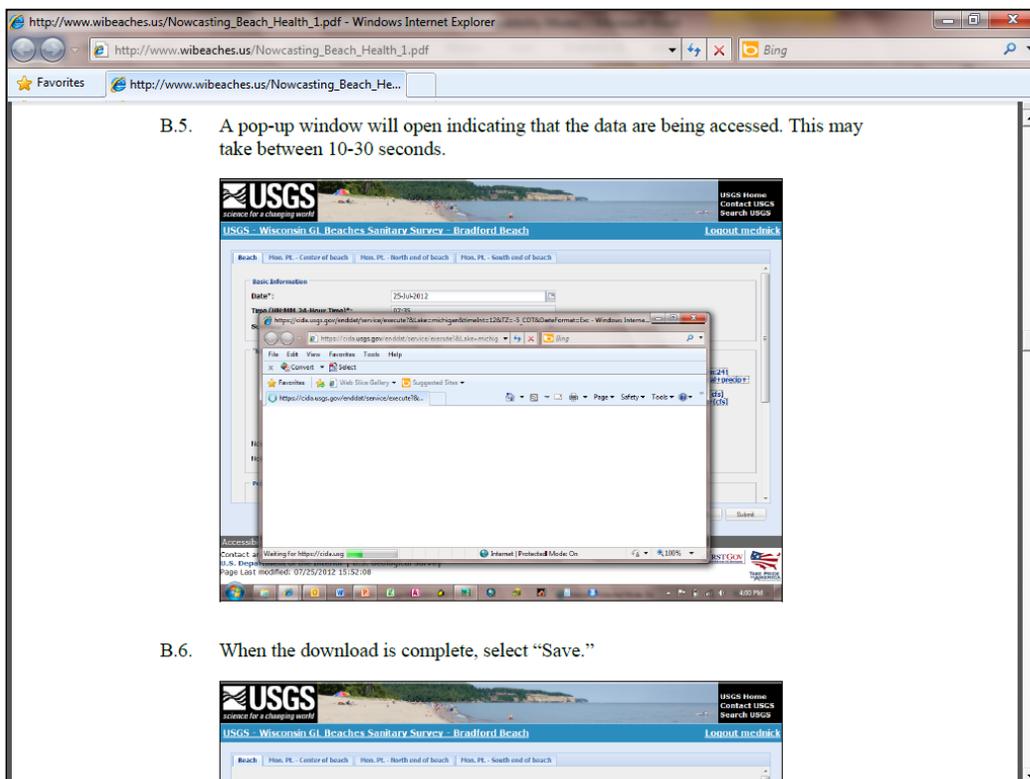


Figure 19. Illustrated user guide and training materials.

Literature Cited

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Abbreviations and Acronyms

BEACH Act – Beach Environmental Assessment and Coastal Health Act of 2000

CFU – colony-forming unit

CIDA – Center for Integrated Data Analytics, U.S. Geological Survey

.CSV – comma-separated values, a way of storing tabular data (numbers and text) in plain-text form

DNR – Department of Natural Resources, Wisconsin

ENDDAT – U.S. Geological Survey’s Environmental Data Discovery and Transformation system

EPA – Environmental Protection Agency, U.S.

GLRI – Great Lakes Restoration Initiative

mL – milliliter

NOAA – National Oceanic and Atmospheric Administration, U.S.

RSS – really simple syndication or rich site summary, a family of web feed formats used to publish frequently updated works

URL – universal resource locator or uniform resource locator, a specific string of characters that constitutes a reference to an Internet resource

USGS – United States Geological Survey

Notes

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