PhillyRiverCast: A Real-Time Bacteria Forecasting Model and Web Application for the Schuylkill River

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Abstract: The Philadelphia Water Department developed a unique, Web-based water quality forecasting system for the Schuylkill River called RiverCast. Based on real-time turbidity, flow, and rainfall data, it provides up-to-the-hour public service information on the estimated current fecal coliform concentrations in the river and the acceptable types of recreation based on those conditions. The system is designed to maximize accuracy while avoiding recommendations that suggest water quality is better than it is likely to be (avoidance of false positives). RiverCast can be reached on the Web at www.phillyrivercast.org.

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Introduction

As real-time environmental monitoring becomes more prevalent and cost effective, new approaches to public reporting of water quality have been developed that have merged with Web-based applications and algorithms that allow increased notification, response, and prediction of environmental events of significance. Currently this approach has emerged for early warning systems (EWSs) for drinking water supplies (Gullick et al. 2004; Coppola et al. 2006), public bathing beaches, and recreation. Though there are limited efforts under way in a handful of places nationally, many communities are struggling to develop systems to meet the demand for more real-time information on environmental conditions for a variety of activities. These range from major recreational events such as triathlons and beach swimming, to prediction and response to accidents, spills, or terrorist activities. Some communities are aware that knowledge of environmental conditions or the ability to forecast them can facilitate increased tourism and recreation. Water suppliers are aware of the value for routine water treatment operations. Developing a system that can accomplish these capabilities is still an area of developing and applied research.

The U.S. Geological Survey (USGS) developed models for predicting exceedance of the bathing-water standard for Escherichia coli (*E. coli*) at three Lake Erie beaches and one inland lake in Ohio. The statistical models were specific to each beach, and the best model for each beach was based on a unique combination of environmental and water-quality variables as explanatory factors. Results are posted on the USGS Website (Francy and Darner 1998, 2003; Francy et al. 2003; Francy and Lis 2006).

A survey done by the U.S. Environmental Protection Agency (USEPA) (USEPA 1999) revealed that only a few local agencies were experimenting with using predictive models for assessing recreational water quality (USEPA 2002b). Rasmussen and Ziegler (2003) describe the overall sanitary quality of surface water in selected Kansas streams, the relation between fecal coliform and *E. coli*, the relation between turbidity and bacteria densities (Rasmussen et al. 2006), and how continuous bacteria estimates can be used to evaluate the water-quality conditions in selected Kansas streams. USEPA (2005) reviews the state-of-the-art technologies and techniques for integrated EWSs for drinking water infrastructure, particularly for finished water supplies and distribution systems. USEPA (2002a) discusses case studies on monitoring, predictive modeling, and public notification.

In Massachusetts, the Charles River Watershed Association conducts a regular water quality monitoring and public notification program in the Charles River Basin during the recreational season to inform users of the river's health. Eleria and Vogel (2005) describe this program, as well as an overview of other programs in the United States. Listed publications include Ferguson et al. (1996), Christensen et al. (2000), Clark and Norris (2000), Francy et al. (2000), Crowther et al. (2001), and Rasmussen and Ziegler (2003), all of whom developed multiple linear regression models to relate bacteria concentrations to explanatory variables. Kelsey et al. (2004) found that stormwater runoff from urban land uses were the primary source of fecal pollution. They found that proximity to areas with septic tanks and rainfall prior to the sampling date are good predictors of fecal pollution.

What Is RiverCast?

The Philadelphia Water Department (PWD) has developed a Web-based water quality forecasting system for the Schuylkill River that has a number of unique qualities. The forecasting system, called PhillyRiverCast (found at www.PhillyRiverCast.org), provides up-to-the-hour public service information on the current fecal coliform concentrations in the river within Philadelphia and

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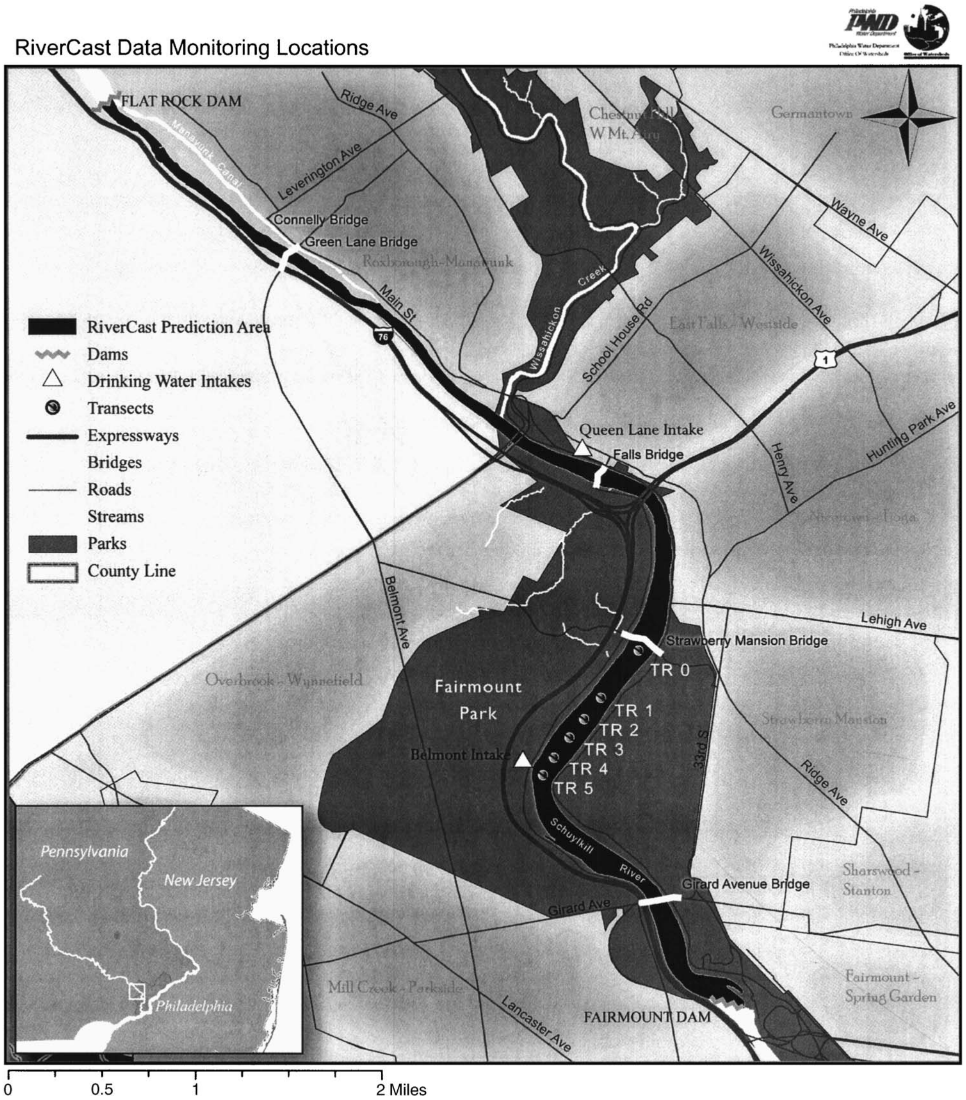

Fig. 1. Area of Schuylkill River covered by RiverCast

the acceptable types of recreation based on those conditions. RiverCast is based on empirically derived relationships between commonly available parameters and fecal coliform levels in the Schuylkill River. The Schuylkill River, with an average flow of 2,720 cubic feet per second (cfs), is the major source of water for over 1.5 million people, but is also becoming more heavily utilized as a recreational resource. With increased public activity and access comes increased public contact with the waterway, making the level of fecal coliform bacteria in the river an important health issue. Sampling of the Schuylkill River and its tributaries show that fecal coliform concentration can increase by a factor of over 100 during a storm event. Fecal coliform contamination presents a special problem for real-time systems because there is no fast and simple method to continuously determine fecal coliform counts. Sample results sent to the laboratory take at least 48 h, meaning that, at best, a system will post fecal coliform counts 2 to 3 days after the sample is taken, which is not very helpful to swimmers who wish to know if it is safe to swim that day. Since triathlons, kayaking, and rowing take place in the Schuylkill River, a real-time forecasting system was needed to inform swimmers and boaters about water quality conditions.

RiverCast went live in July 2005, covering the stretch of the river shown in Fig. 1. Its recommendations are based on draft federal regulations for recreational waters, and provide users with information about the suitability of the river for various recreational activities, not estimates of fecal coliform concentrations. The recommendations, however, are based upon predicted levels of bacteria in the river at a given time. The suitability of the water depends on the type of recreational activity and the extent of contact with the water. Direct contact recreation, referred to as primary recreation by state and federal authorities, includes any activity that is likely to cause immersion in the water. Secondary contact recreation is not likely to cause immersion in the water and is, therefore, less impacted by changes in water quality. Table 1 provides a summary of RiverCast water quality designations as they relate to specific recreational activities.

Development of RiverCast

RiverCast was developed in several steps. Initially, the most likely sources of fecal coliform in the river were identified to better understand patterns of high and low counts of fecal

J. Water Resour. Plann. Manage., 2007, 133(6): 542-549

Table 1. Summary of RiverCast Water Quality Designations

		RiverCast Recommendation		
Contact	Activity	Green	Yellow	Red
Primary	jet skiing wakeboarding water skiing kayaking swimming events wading	Suitable	May not be suitable	Not suitable
Secondary	canoeing sculling/rowing power boating fishing	Suitable	Suitable	May not be suitable

coliform, and to identify which variables are likely to be good predictors of fecal coliform concentrations. The next step involved graphical and statistical analyses to look at the relationship between parameters measured in real time and concentrations of fecal coliform. The intent was not to predict concentrations directly, but to develop a range-based (red-yellow-green) warning system. Available real-time data included flow, turbidity, and rainfall, all of which were associated with the primary sources of fecal coliform—stormwater discharges and combined sewer overflows. Once patterns of fecal coliform concentrations were identified and related to the real-time data, an algorithm was designed to generate a warning level based on incoming data and the results were posted on the Web at PhillyRiverCast.org.

Primary Sources and Fecal Coliform Count Patterns

Christensen et al. (2000, 2005) have published research correlating fecal coliform density to real-time data on several rivers in Kansas. One conclusion based on their work suggests that statistical patterns predicting fecal coliform density will vary, depending on sources, climate, and flow patterns. RiverCast is focused on the downstream portion of the Schuylkill River (Fig. 1), where most of the fecal coliform is believed to result from stormwater discharges, sanitary sewer overflows, combined sewer overflows, and instream sources such as geese. As such, seasonal changes are not likely to occur and fecal coliform concentrations can be estimated using some combination of rainfall, flow, and turbidity with the pattern expected to be similar during all seasons.

Available data were somewhat limited, but included 341 combined bacteria and water quality measurements from the locations shown in Fig. 1. Sampling data included:

- Belmont and Queen Lane Water Treatment Plant intakes, Connelly Bridge, Flat Rock Dam, and river transect sampling locations collected in various water quality studies from 1998 to 2000;
- Weekly grab samples at Queen Lane and Belmont Water Treatment Plant intakes from 1998 to 2003;
- Monthly wet weather pathogen sampling from a study at Connelly Bridge and Flat Rock Dam during 1998-99; and
- Weekly transect samples between Wissahickon Creek and Belmont Intake during 1999-2000.

Hydrological data were collected from the following locations and periods of record:

- USGS stream flow data from gauge 01474500, Schuylkill River at Fairmount Dam (15 min data, 1932–2004); and
- PWD rain gauge data from RG16 (15 min data, 1998–2000).

Flow data were first examined to define low and high flows and to look for possible break points in the flow data. The data indicated that flow of less than 1,000 cfs represents low flow conditions, and flow greater than 3,000 cfs represents relatively high flows. For the entire period of record, the average annual mean stream flow was 2,716 cfs at Fairmont Dam. A preliminary analysis of fecal coliform counts measured between 1998 and 2003 in the nontidal portion of the Schuylkill River within the city of Philadelphia suggests that the river has relatively low counts (less than 200 fecal coliform per 100 milliliter (mL) about 50% of the time, moderate levels (between 200 and 1,000 counts per 100 mL) about 30% of the time, and relatively high counts about 20% of the time.

Once a basic understanding was gained of the expected magnitude and distribution of flow, rainfall, turbidity, and fecal coliform readings, a series of regression analyses were performed to look for associations between parameters and to deepen our understanding of relationships between variables. The first sets of regressions using flow, turbidity, rainfall, and rainfall intensity were disappointing, with only weak correlations at best. These results would have been discouraging if the intent was to directly predict fecal coliform concentration. However, the intent was to design a practical warning system using ranges of fecal coliform concentrations based on reasonable cut-off values.

Establishment of Cut-Off Values

Successful regression analysis showing correlation between fecal coliform concentrations and any single variable was less important than an approach that could predict the correct warning level at a given moment. To do this only required the establishment of cut-off values for each relevant parameter associated with a health-based concentration of fecal coliform. Because the primary sources of fecal coliforms in the study area are related to stormwater, fecal coliform counts could be expected to be related closely to rainfall. Therefore, measured fecal coliform concentrations were examined as a function of the time as the last rainfall was registered at the rain gauge. The data showed a pattern of decreasing concentration with increasing time from the end of the rainfall. Fig. 2 shows that after 48 h of dry weather, fecal coliform counts are expected to be below 1,000 counts per 100 mL. Thus, a potential cut-off value or rule could be formulated to that effect. This was confirmed by plotting the fecal coliform counts at various flows for samples taken more than

J. Water Resour. Plann. Manage., 2007, 133(6): 542-549

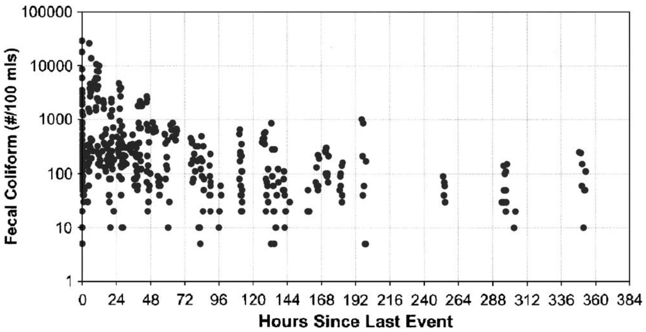

Fig. 2. Fecal coliform sample results distributed by hours since last rainfall event

48 h after a rain event. The results are shown in Fig. 3, which shows that after more than 2 days, at almost any flow, most if not all of the fecal coliform samples can be expected to be below 1,000 coliform per 100 mL.

Initial Warning Levels Based on Fecal Coliform Counts

The initial approach was to develop the red-yellow-green warning system based on fecal coliform counts. A minimum cutoff of 200 was selected based on the Pennsylvania water quality criteria for bacteria. A maximum cutoff of 1,000 counts per 100 mL was selected as another break point because 48 h after a rain event, almost 100% of the samples were less than 1,000 coliforms per 100 mL. From earlier analysis, it was noted that fecal coliform concentration was also correlated to turbidity, showed some rough relationship to high flows, and was very much related to the time since the last rainfall event ended. To this end, three sets of data were grouped and basic statistics calculated.

The first data set is the best case, where flows, bacteria, and turbidity values are assumed to be the lowest. Data were restricted to times when fecal coliform counts were less than 200 coliform per 100 mL. Table 2 shows the results, which not surprisingly indicate that these values are associated with a 4 to 5 day period of no rain and relatively low flows and turbidity. The second data set was restricted to samples taken more than 48 h since the last rainfall that exhibited coliform counts between 200 and 1,000 counts per mL. For values in this set, the time since the last rainfall was very similar to the first set, but flows were much higher, and turbidity was slightly higher. The third set restricted the data to samples taken within 2 days of the end of a rain event and fecal coliform counts above 1,000 per mL. Flows were much higher and turbidity values were elevated in comparison to the first and second sets.

Table 2. Rainfall, Flow, and Turbidity Statistics for Samples within Specified Ranges of Fecal Coliform Levels

	Mean	Median	Minimum	Maximum	Standard deviation
Fecal coliform samples less than 200 counts per 100 mL					
Days since last rainfall	5.07	4	1	15	3.73
Flow (cfs)	2,243	1,280	443	9,630	2,101
Turbidity (NTU)	5.74	3.56	0.884	37.7	6.78
Fecal coliform samples between 200 and 1,000 counts per 100 mL					
Days since last rainfall	5.16	4	3	15	2.86
Flow (cfs)	3,117	2,420	443	8,030	2,263
Turbidity (NTU)	9.51	4.45	1.31	34.1	8.67
Fecal coliform samples greater than 1,000 counts per 100 mL					
Days since last rainfall	1.34	1	1	2	0.48
Flow (cfs)	5,961	4,940	1,235	21,030	4,992
Turbidity (NTU)	43.2	19.3	2.39	388	73.6

Based on the insight gained from the above-presented analyses, a cutoff for rainfall was established at 2 days, or 48 h after the end of a rainfall event as one of the parameters in our system of categories. The data suggested that anytime during or within 48 h of a rain event, there is a strong likelihood that fecal coliform counts would be unacceptably high, and thus the flag should be set to "red" as a warning that recreational activities resulting in full immersion were not advisable. The remaining samples, those taken more than 48 h after the end of a rain event, needed to be further categorized based on flow and turbidity.

The plot of all samples taken more than 48 h after a rainfall event (Fig. 3) shows that at a flow of approximately 2,300 cfs or greater, the fecal coliform values tend to show increased scatter and higher counts. However, even at flows below 1,650 cfs, fecal coliform data showed that 13 out of 119, or 11%, of samples were greater than 200 fecal coliforms per 100 mL. By examining flows and turbidity data, gradually a pattern emerged for potential cutoff values useful in delineating green, yellow, and red warning levels. Green was initially defined for conditions where flow was less than 1,650 cfs and when more than 48 h had passed after a rain event. For greater flows, it appeared that adding a turbidity condition could also effectively define a green warning level. When flows are less than 2,300 cfs for this subset of data, the geometric mean of fecal coliform is 296 coliforms per 100 mL and average turbidity is 3 nephelometric turbidity units (NTU), with no values above 10 NTU. Thus, additional green instances might be defined when flows are between 1,650 and 2,300 cfs and turbidity is less than 10–15 NTU. Yellow warning levels would

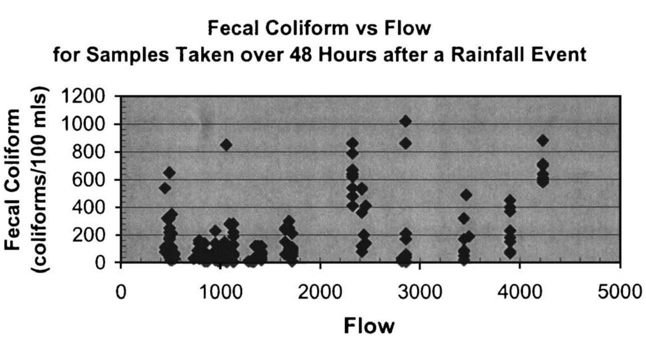

Fig. 3. Fecal coliform concentrations versus flow for samples taken more than 48 h after the end of rainfall

J. Water Resour. Plann. Manage., 2007, 133(6): 542-549

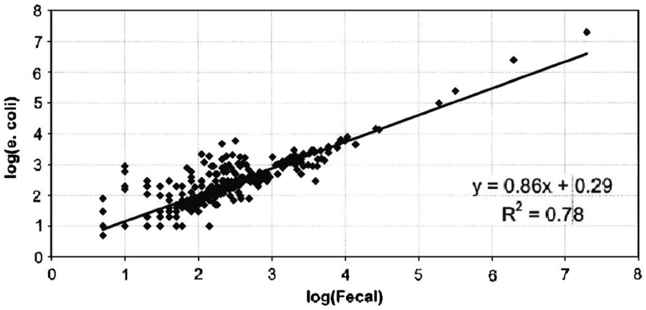

Fig. 4. Relationship between fecal coliform concentration and *E. coli* concentration

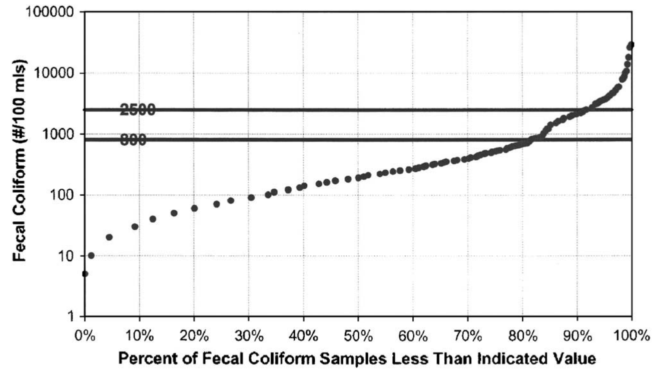

Fig. 5. Cumulative frequency distribution of fecal coliform samples compared to equivalent health-based *E. coli* standards

then need to be defined using combinations of turbidities above 10–15 NTU and flows greater than 1,650 cfs.

Finalizing Water Quality Standards to Be Applied

The above-described preliminary statistical analysis used Pennsylvania recreational standards regarding fecal coliform to create subsets of data. It was preferred to move to standards that were more directly related to the health issues that are key to the RiverCast system, and that could be related to a single sample. This implied moving to a standard based on *E. coli*. The USEPA has published a draft report titled "Implementation Guidance for Ambient Water Quality Criteria for Bacteria" (USEPA 2002a). This document identifies the maximum level of bacteria measured *in a single sample* that would be within acceptable illness levels for recreational activities that may involve complete immersion in the water. These appeared to be more relevant to the intent of RiverCast, and provided a means to better assess the health risks associated with the chosen warning levels. For heavily used beach areas and other popular recreational areas, USEPA recommends adopting criteria based on illness rates and use of the 75% confidence level as a single sample maximum value. The recommended bacteriological criterion based on the illness rates for fresh water is 14 illnesses per 1,000 swimmers.

With most of the samples and the majority of the statistical analysis focused on fecal coliform data, it was necessary to translate preliminary cut-off values to new assumptions based on *E. coli*. To this end, linear regression analysis was conducted to determine the relationship between *E. coli* and fecal coliform in the Schuylkill River. The log transforms of sampled *E. coli* and fecal coliform are plotted in Fig. 4. The results suggest that a reasonable factor to relate fecal coliform to *E. coli* is a multiplier of 0.71 (this value applies to data that have not been log transformed). Plotting the cumulative distribution of all the *E. coli* data collected indicated that using *E. coli* would produce slightly higher cut-off values than our preliminary work which focused on fecal coliform counts. Almost 80% of the sample values were less than the value associated with an illness rate of 8 per 1,000 (576 coliform per 100 mL). About 90% of the values were less than the illness rate of 14 per 1,000 (1,783 coliform 100 mL). Analysis of river flow data measured when *E. coli* samples were less than 576 coliform per 100 mL indicates that over 50% of the time flows are less than 1,650 cfs, which would qualify as green. Also, 60% of the samples had flows less than 2,300 cfs, but sample results are a mix of low, medium, and higher *E. coli* counts, which suggests at a minimum a yellow designation, possibly depending on turbidity values.

Applying the generalized factor (0.71) to translate the health-based *E. coli* ranges to the fecal coliform limits used in the initial regression analyses results in a health-based criteria range of 800–2,500 fecal coliform counts per 100 mL. These are higher values than the earlier assumption that 200 and 1,000 counts per 100 mL are appropriate cut-off values. As shown in Fig. 5, over 80% of the fecal coliform samples are less than 800 counts per 100 mL, representing the lower illness rate limit (8 per 1,000). Over 90% of the samples are less than the upper illness rate limit of 14 counts per 1,000, or 2,500 coliforms per 100 mL. Switching to the federal guidelines by using health based *E. coli* cut-off values resulted in an increase in the range of statistically comparable fecal coliform counts found to be acceptable for light use water contact.

Developing and Testing an Algorithm

For simplicity and ease of public use, the RiverCast system concept presents only three water quality categories: green (water quality is suitable for all recreational activities), yellow (water quality may not be suitable for activities involving direct contact with the river), and red (water quality is not suitable for activities involving direct contact with the river). Each color category is associated with a range of bacteria counts, determined according to draft federal regulations for *E. coli*. Using the insight gained from preliminary statistical analysis, a set of rules was developed that could serve as an algorithm using available real-time data to determine, at any given moment, what warning level should apply. Green was defined as *E. coli* predicted to be less than 576 counts per 100 mL or fecal coliform predicted to be less than 822 counts per 100 mL. Yellow was defined as *E. coli* predicted to be greater than or equal to 576 counts per 100 mL and less than 1,783 counts per 100 mL, or fecal coliform predicted to be greater than or equal to 822 counts per 100 mL and less than 2,547 counts per 100 mL. Red was defined as *E. coli* predicted to be greater than 1,783 counts per 100 mL or fecal coliform predicted to be greater than 2,547 counts per 100 mL. The following guidelines for determining accuracy of each algorithm were developed:

False Alarm: When the algorithm produces a red flag and fecal coliform is less than 2,547 counts per 100 mL (*E. coli* less than 1,783 counts per mL), or if the algorithm produces a yellow flag and fecal coliform is less than 822 counts per mL (*E. coli* less than 576 counts per mL).

True Result: When the algorithm produces a red, yellow, or

J. Water Resour. Plann. Manage., 2007, 133(6): 542-549

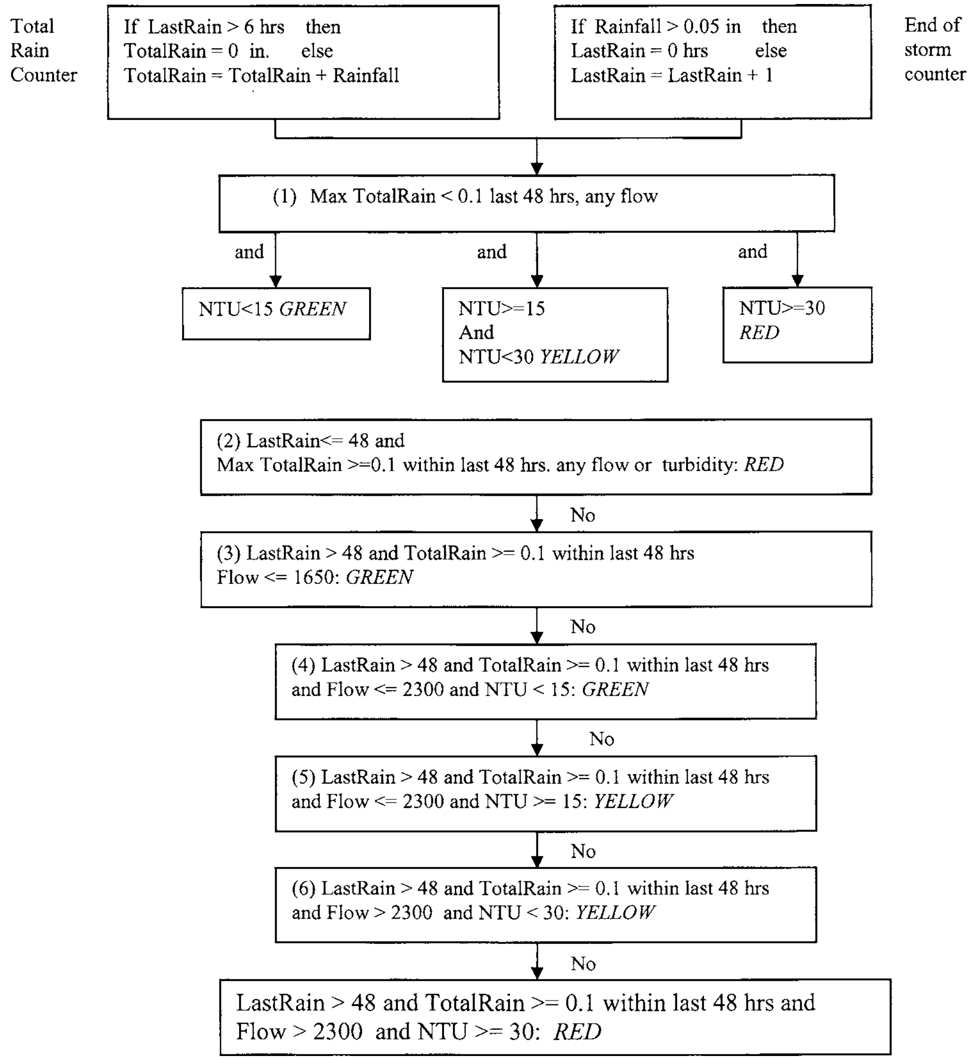

Fig. 6. RiverCast algorithm diagram

green flag and fecal coliform or *E. coli* sample results match the above-defined criteria.

False Positive: When the algorithm produces a green flag and the actual fecal coliform count is greater than 822 counts per 100 mL (*E. coli* count is greater than 576 counts per mL), or the algorithm produces a yellow flag and the actual fecal coliform count is greater than 2,547 counts per 100 mL (*E. coli* greater than 1,783 counts per mL).

Numerous experimental algorithms were developed and tested to compare predicted levels against the analytical results of actual bacteria samples taken from the river between January 2004 and April 2005 using the above-discussed criteria. Each algorithm was tested for its performance against the criteria with the following objectives in mind. Over the available testing period, no false positives would be allowed, false alarms would be minimized as much as possible, and the number of true results would be maximized. Eliminating false positives tends to increase false alarms, but this very conservative approach was taken with the initial roll out of RiverCast to protect public health.

Selected Algorithm

In order to use the precipitation parameter in the algorithm, a definition of rain had to be developed. Clearly, if too little rain falls, stormwater runoff never reaches the river, and *E. coli* concentrations remain unchanged. Practical definitions were established as follows:

- Cumulative rainfall amounts are recorded on an hourly basis. Rain continues to accrue to a storm event unless there is a 6 h gap between recorded rainfalls, in which case a new event is started.
- Hourly rainfall must be greater than 0.05 in., or it does not count as rainfall for that hour.
- Total rainfall for a rainfall event must be at least 0.1 in. to count as a rainfall event.

If the designated minimum amount of rain has fallen in the last 2 days, the resulting warning level is automatically red. Otherwise, the algorithm must sort through various combinations of flow and turbidity and assign a warning level. The logic that provided the best results is as follows (see Fig. 6).

- Green results if the total rain is less than 0.1 in. in the last 48 h at any flow, if turbidity is less than 15 NTU.
- Green results if the total rain is more than 0.1 in. in the last 48 h but the last rain fell more than 48 h ago, and flow is less than 1,650 cfs (this can occur because of the 6 h gap needed to end a rain event), at any turbidity reading.
- Green results if the total rain is greater than 0.1 in. in the last 48 h but the last rain fell more than 48 h ago. Flow can be

J. Water Resour. Plann. Manage., 2007, 133(6): 542-549

between 1,650 and 2,300 cfs, but turbidity must be less than 15 NTU.
- Yellow results if the total rain is less than 0.1 in. in the last 48 h at any flow and turbidity is between 15 and 30 NTU.
- Yellow results if the total rain is greater than 0.1 in. in the last 48 h, the last rain fell more than 48 h ago, flow is less than or equal to 2,300 cfs, and turbidity is greater than or equal to 15 NTU.
- Yellow results if the total rain is greater than 0.1 in. in the last 48 h, the last rain fell more than 48 h ago, flow is greater than 2,300 cfs, and turbidity is less than 30 NTU.
- Red results if total rain is greater than 0.1 in. in the last 48 h and the last rain counter is also less than 48 h for any flow or turbidity.
- Red results if the total rain is less than 0.1 in. in the last 48 h at any flow if turbidity is greater than or equal to 30 NTU.
- Red results if the total rain more than 0.1 in. within the last 48 h and the last rain fell more than 48 h ago, but flow is more than 2,300 cfs and turbidity is greater than or equal to 30 NTU.

Using the real-time turbidity, flow, and rainfall data from January 2004 through April 2005 to backcast warning levels, a check was made on the performance and ability of the algorithm to correctly predict warning levels. Based on this backcasting analysis, the algorithm would have resulted in a 54-9-37% split between green, yellow, and red during this period. When the algorithm results were compared to actual samples taken during this same period, the comparison showed that the RiverCast relationships are very conservative. The algorithm met the most important of the three objectives completely—there were no examples of predicted levels lower than the measured levels, or no false positives. The results indicate that the algorithm matched the expected result based on sample data for 65% of the samples. For 35% of the samples, the algorithm warned of a yellow condition when it should have been green, or a red condition when it should have been yellow or green.

Algorithm Verification

To verify that the algorithm was properly calibrated, RiverCast hourly output was compared with bacteria sample data taken at the Queen Lane and Belmont intakes for a period subsequent to the period used to develop the algorithm. The verification data spanned the period between May 23, 2005 and March 29, 2006, a 10 month period following the period of data used to develop the algorithm. Results indicated an almost identical split, with 66% of the samples corroborating the RiverCast prediction, and 34% of the predictions overestimating bacteria counts and providing an overly cautious warning level. Of the 56 samples taken, only one sample resulted in a false positive prediction.

Web-Based Implementation

With the algorithm tested, the system was ready for pilot implementation to make it available to the public via the Internet. Since July 2005, the RiverCast system has provided Web-based access to the current Schuylkill River water quality warning level and water flow and temperature information 24 h per day. The application can automatically start upon boot-up and is independent of any specific user being logged on at the time. It runs automatically, constantly generating RiverCast ratings. The RiverCast rating is calculated every hour, around the clock, using the selected algorithm to process real-time turbidity, precipitation, and flow data. The turbidity data are initially collected by a turbidimeter. Turbidity readings are generated at 15 min intervals and stored in a remote terminal unit (RTU) near the turbidimeter. The RTU has a built-in telephone modem that transmits the collected turbidity data to the RiverCast server each hour. The data are stored and transmitted in comma separated value (CSV) file format. The RiverCast system moves the data from the CSV file to a Structured Query Language (SQL) Server 2000 database, where it is aggregated into hourly averages.

The data for precipitation and river flow are collected from existing water-data stations owned and operated by the USGS. Every 1 to 2 h these stations transmit, via a satellite communications network, the water quality information they collect to a national database maintained by USGS. The RiverCast system automatically downloads the flow and precipitation data from the USGS Website (http://waterdata.usgs.gov/nwis) and stores the information in the RiverCast database. Each hour, prior to generating the rating, the RiverCast system checks for and downloads data for the Philadelphia station (01474500) and the Norristown station (01473500). Since the USGS data is reported in 15 min intervals, the RiverCast system aggregates precipitation into hourly totals and river flow into hourly averages. Once the data have been downloaded and aggregated, the RiverCast system uses the precipitation, flow, and turbidity data as computational elements in the predictive algorithm to generate a water quality rating.

Conclusions

A more timely and efficient method to make available public health information for recreational waters is clearly needed in many areas of the country. Based on the work performed by USGS in Kansas and PWD in Philadelphia, it is clear that such systems can be developed and implemented, but to be effective, design must be tailored to the local conditions and sources of bacteria specific to the water body. PWD's RiverCast system is an experiment that started in July 2005, and is currently under evaluation. Early indications are that it can be accurate, and when inaccurate, produce an overly cautious rating. Its water quality ratings are available for the lower, nontidal portion of the Schuylkill River in Philadelphia, and it has already been enthusiastically endorsed by residents and organizations that regularly use the river for organized recreational events. There are plans to review and improve the algorithm as more data become available, and to expand the system to include the tidal portion of the river in the near future.

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J. Water Resour. Plann. Manage., 2007, 133(6): 542-549