EPA Region 1 and ORD Merrimack River Projects

This project summary provides an overview of the work EPA Region 1 and the EPA Office of Research and Development (ORD) have done for the Merrimack River in the Lawrence, Massachusetts area from 2015 to 2019. EPA produced several deliverables during this time and collected data sets for research use. Below is a discussion about the project history and data sets that EPA collected.

Background of EPA Work on the Merrimack River

The Merrimack River is the source of drinking water for approximately 600,000 people in New Hampshire and Massachusetts. The river begins in Northern New Hampshire and flows into the Atlantic Ocean in Newburyport, Massachusetts. EPA has been involved in projects on the Merrimack River for several decades.

In 2015, EPA began working directly with the City of Lawrence, Massachusetts and other partners as part of the regional "Making a Visible Difference in Communities" project. Lawrence is the farthest downstream of five Massachusetts communities along the Merrimack River which use the river as their only source of drinking water. The other Massachusetts communities using the Merrimack River for drinking water are Methuen, Andover, Tewksbury, and Lowell.

The Merrimack River is a critical, but threatened resource. In addition to providing drinking water, it also receives the discharge of wastewater treatment effluent, combined sewer overflow, and stormwater discharges, many of which are from communities upstream of Lawrence. EPA learned more about the community's priorities by hosting stakeholder meetings from 2015 -2017 with City of Lawrence officials, citizens, planning agencies, non-profit organizations, and state agencies. Priorities included addressing water quality concerns and improving the resiliency of the drinking water treatment plant.

In 2015, staff from ORD, based in Cincinnati, visited Lawrence to see and learn about some of the city's water quality and flooding issues. As part of EPA Region 1's "Making a Visible Difference" project in Lawrence, EPA ORD staff were able to offer technical assistance to the City of Lawrence. One outcome of ORD's visit was to assist the community in developing a "comprehensive water strategy" for the river. This included conducting research to assess the issues and possible solutions.

EPA worked closely with Lawrence water officials, Groundwork Lawrence, the Merrimack River Watershed Council, and the U.S. Army Corps of Engineers as a research plan was developed. EPA's research focused on three objectives:

- Flooding Vulnerability
- Water Quality
- Environmental Justice

Lawrence's drinking water treatment plant is vulnerable to flooding, as it is in the 100-year flood zone. One component of the water strategy was to develop a climate and flooding vulnerability assessment of the Lawrence drinking water treatment plant, situated along the Merrimack River. The water strategy also included mapping and analyzing water quality data to advance the community's priorities. EPA captured local community knowledge of sensitive sites and locations where Lawrence residents go boating, swimming, and fishing to identify potential exposure locations. Collaborating with the stakeholders, EPA gathered historical water quality data and information on point source discharges (e.g., sewer overflows) to map against social vulnerability metrics and identified exposure points. EPA mapped and analyzed flood zones, using an updated analysis of precipitation data. EPA developed a mapping tool for the watershed, bringing together interactive data to visualize the watersheds greatest challenges and attributes. The Merrimack mapping tool can be found in the mapping section of the EPA Merrimack River webpage (www.epa.gov/merrimackriver). This tool also allows users to add their own data, enabling those who do not have access to GIS tools to create maps to analyze multiple data layers.

To support these efforts, EPA gathered additional water quality data from two monitoring stations in the river. The stations were funded by ORD (https://www.epa.gov/merrimackriver/basic-information-about-lower-merrimack-river-monitoring-station) and operated by the EPA Regional Laboratory. Water quality monitoring data were used to characterize the variability of river conditions and to develop predictive models of contamination levels impacting its use. EPA collected real-time water chemistry measurements as well as grab samples for microbial analysis during wet and dry weather. These data allowed ORD to evaluate the potential for nowcasting water quality using real-time monitoring, observed meteorological information, and river flow data. Nowcasting is a short time forecasting of water quality.

Data Collected
During the environmental monitoring and research, EPA both produced original data sets and gathered data from other sources to complete their analyses.

EPA deployed two real-time monitors that collected data every 15 minutes, from December 2016 to 2019. The preliminary data were displayed in near real-time on EPA's public website (https://www.epa.gov/merrimackriver).

Measurements are available on EPA's website and included the following:

- Temperature
- Dissolved oxygen
- Specific conductance (conductivity)
- pH
- Turbidity
- Chlorophyll
- Phycocyanin

Additional water quality parameters were collected every 15 minutes at each station. These parameters were not transmitted to EPA's web page because these data are considered preliminary due to the experimental nature of operating this equipment in the field. EPA scientists and water quality managers used data from these two stations to assess and understand water quality conditions. The experimental research data that were collected included:

- Total organic carbon (TOC)
- Fluorescent dissolved organic matter (FDOM)
- Nitrate
- Phosphate

The above datasets have not been published or QA/QC reviewed.

Lastly, from 2016 – 2018, EPA conducted seventeen grab sampling events in the Lawrence area to examine bacteria levels. EPA tested for presence of *Escherichia coli* and nutrients at six sites during dry and wet weather conditions. These data have gone through EPA's internal review and clearance, and are available upon request.

EPA also gathered additional secondary datasets to use in their analyses:

- Merrimack River water level data for the USGS stations
- Precipitation datasets for Lawrence and Lowell, MA
- Lowell CSO event dates and discharge volumes

Analyses Conducted

- **Flooding Analysis:** A detailed flooding analysis was conducted for Lawrence. The results pertain to the probability of flood levels overtopping the protective berm of the Lawrence drinking water plant located at the northern side of the river. Also, the flooding risk in Spicket River was analyzed to determine the potential impact on Lawrence water supply and wastewater collection systems. The results and datasets include:
    - Hydraulic profiles related to the river and water treatment plant
    - River flow and stage modeling
    - Areal precipitation and river stage variations in hydrological modeling
    - Flooding recurrence interval and design river stages in hydrological analysis
    - Datasets for both Lawrence and Lowell

  - Reconstruction of the historical 2006 flooding map for Lawrence
  - Flooding risk and water stages for Spicket River developed for small-probability floods
- **Indicators of Pathogen Levels:** River water quality nowcasting (models) and analyses were conducted based on datasets from the sensor monitoring data, river flow data, CSO discharge data, and other hydrological datasets. The results are in a summary presentation that is available upon request. Datasets from the nowcasting analysis include:
  - Nowcasting equations and methods for estimating *E. coli* in the river water based on real-time sensor monitoring results, CSO data in Lowell, and area precipitation
  - River water turbidity nowcasting using river flow and water turbidity variations, and their correlations
  - Datasets for identifying flow-contaminant events using coupled sensor stations, and river stage data

Through modeling and preliminary engineering analysis, EPA found that the changes in precipitation, watershed hydrology, and aged water infrastructure are the major factors affecting water quality and water supply resilience. EPA presented its research to the City of Lawrence in 2017 to help the city understand risks to their water supply in the event of extreme flooding or power loss.

Future Areas of Research

This work could lead to further investigation by Merrimack River stakeholders. Below are potential research questions and technical support needs that could be further explored.

Nowcasting models of fecal indicator bacteria could be used to develop a real-time notification system for recreational activities on the Merrimack River. Such a system would color-code water quality conditions via a web app or flagging system to inform the public about anticipated contamination levels that exceed acceptable thresholds. These thresholds could be based directly on recreational water quality criteria for *E. coli*, or on pathogen infection risks predicted using quantitative microbial risk assessment (QMRA). QMRA would: use the fecal indicator concentrations to model likely pathogen levels based on their respective densities in wastewater (a worst-case assumption) and the fate and transport of each; combine these with reported water ingestion rates to estimate exposure doses during various recreational activities; and then use pathogen-specific dose-response relationships to quantify associated infection risks for comparison against defined acceptable rates.

While this modeling introduces additional uncertainty through its assumptions, it has the benefit of relating contamination events to explicit risk-based conclusions. In doing so, the different levels of risk associated with swimming or non-contact recreation (e.g., boating or fishing) could be differentiated, informing which types of activities are suitable under current water quality conditions. However, because water quality sensors used to develop the nowcasting model are no longer in place, and if they cannot be replaced, new correlations using readily accessible data sources (e.g., precipitation levels and CSO reporting) would need to be developed in order to implement the notification system.

Additional monitoring would be needed to support future research involving modeling water quality conditions. Monitoring could be conducted to support model development or validation. A monitoring plan would be developed as part of the research needs.

Disclaimer

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