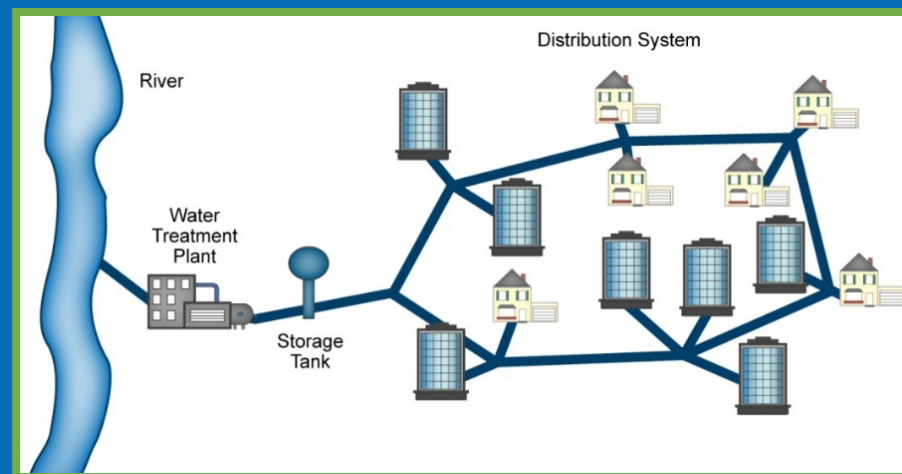


# EPA Tools & Resources Webinar: Drinking Water Models and Tools

Regan Murray, PhD

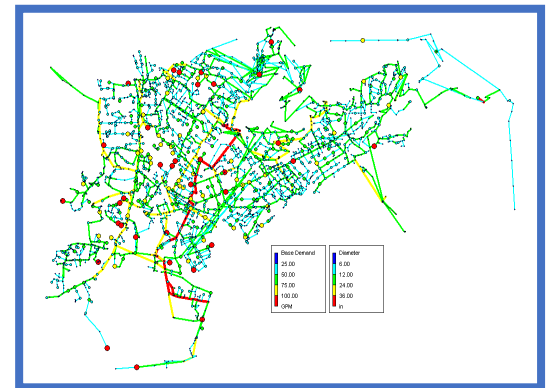
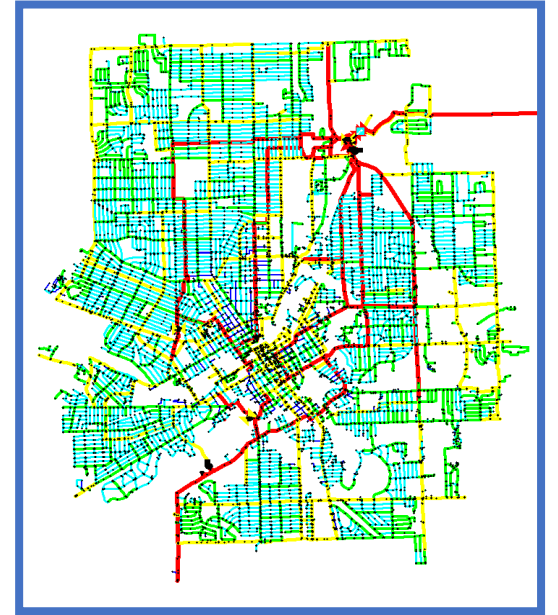
*US EPA Office of Research and Development*

November 18, 2020

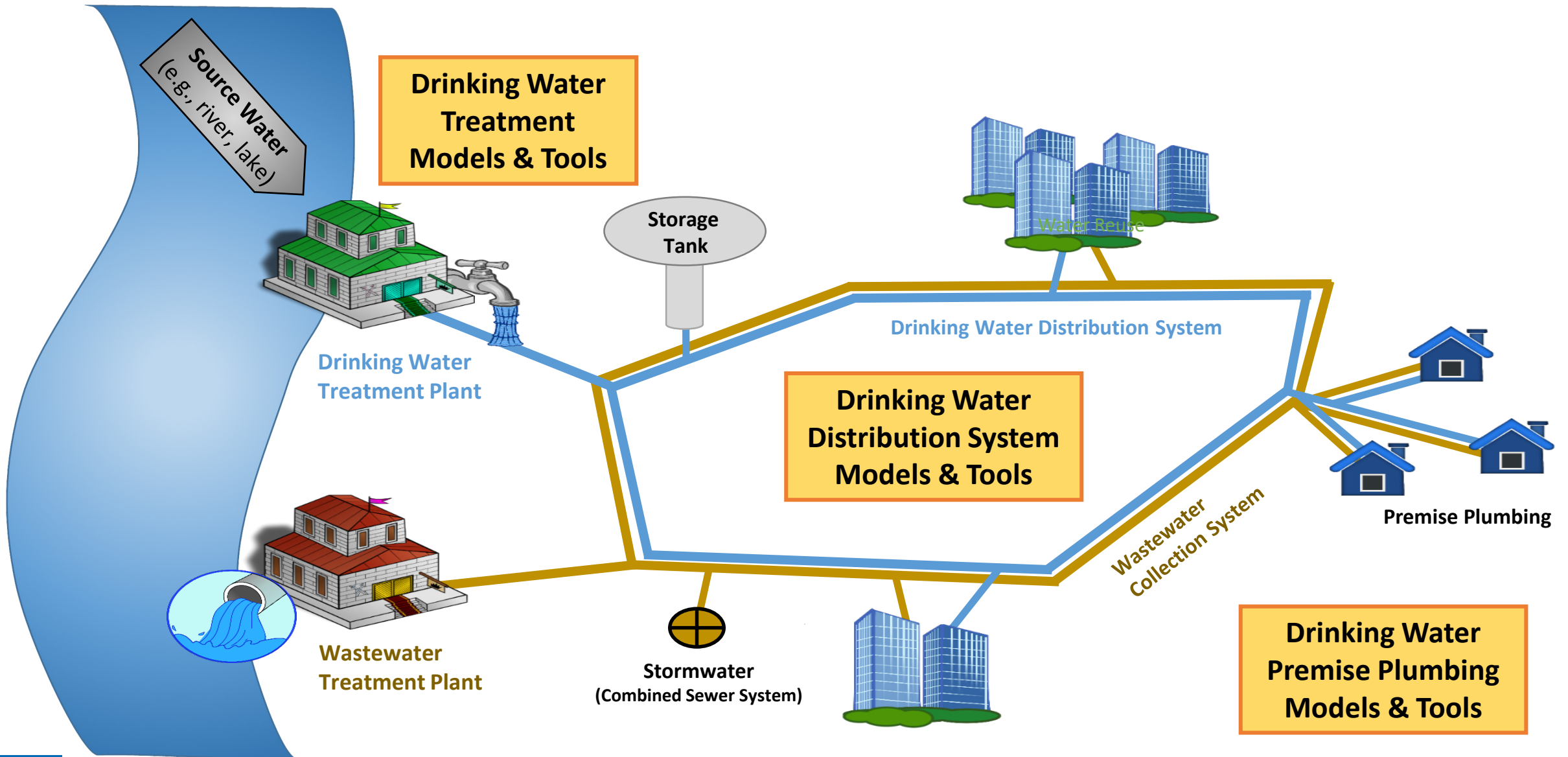


# Background and Motivation

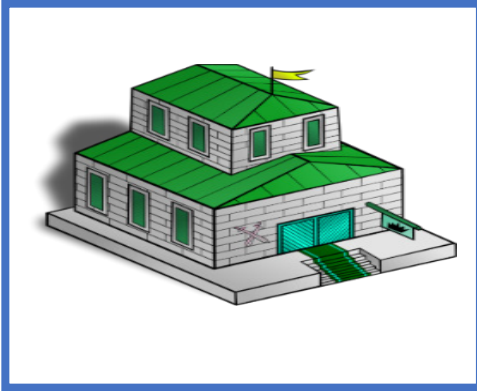
- 💧 Drinking water systems are typically large and complex.
- 💧 Changes to treatment processes or distribution systems can affect water quality downstream in unforeseen ways.
- 💧 Modeling is a powerful, cost-effective tool to predict results of changes prior to implementing them in the real system.



# Water Infrastructure

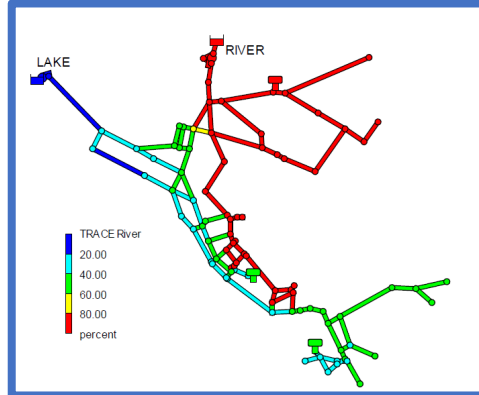


# Drinking Water Models and Tools



## Drinking Water Treatment Models & Tools

- CFD
- CBCS
- FCCAS
- FCEDTS
- WTM
- ETDOT
- Treatability DB



## Drinking Water Distribution System Models & Tools

- EPANET
- EPANET-MSX
- EPANET-RTX
- RTX:LINK
- TEVA-SPOT
- CANARY
- WNTR



## Drinking Water Premise Plumbing Models & Tools

- PPM Tools

Access these models and tools through EPA's [Science Models and Research Tools \(SMaRT\) Search](#)

# Distribution System Model: EPANET

- Simulates hydraulics within a water distribution network.
- Models decay/growth of a single substance.
- More than 50,000 downloads per year.
- Components utilized for multiple commercial software packages.
- Latest official release: version 2.2 in July 2020.

[epa.gov/water-research/epanet](https://epa.gov/water-research/epanet)

## EPANET

### *Application for Modeling Drinking Water Distribution Systems*

EPANET is a software application used throughout the world to model water distribution systems. It was developed as a tool for understanding the movement and fate of drinking water constituents within distribution systems, and can be used for many different types of applications in distribution systems analysis. Today, engineers and consultants use EPANET to design and size new water infrastructure, retrofit existing aging infrastructure, optimize operations of tanks and pumps, reduce energy usage, investigate water quality problems, and prepare for emergencies. It can also be used to model contamination threats and evaluate resilience to security threats or natural disasters.

#### Software, Compatibility, and Manuals

EPANET is public domain software that can be freely copied and distributed. It is a Windows®-based program that will work with all versions of Windows. Continued development and bug fixes are ongoing. Requests for more information or interested parties should contact the following guidelines:

- EPA's G

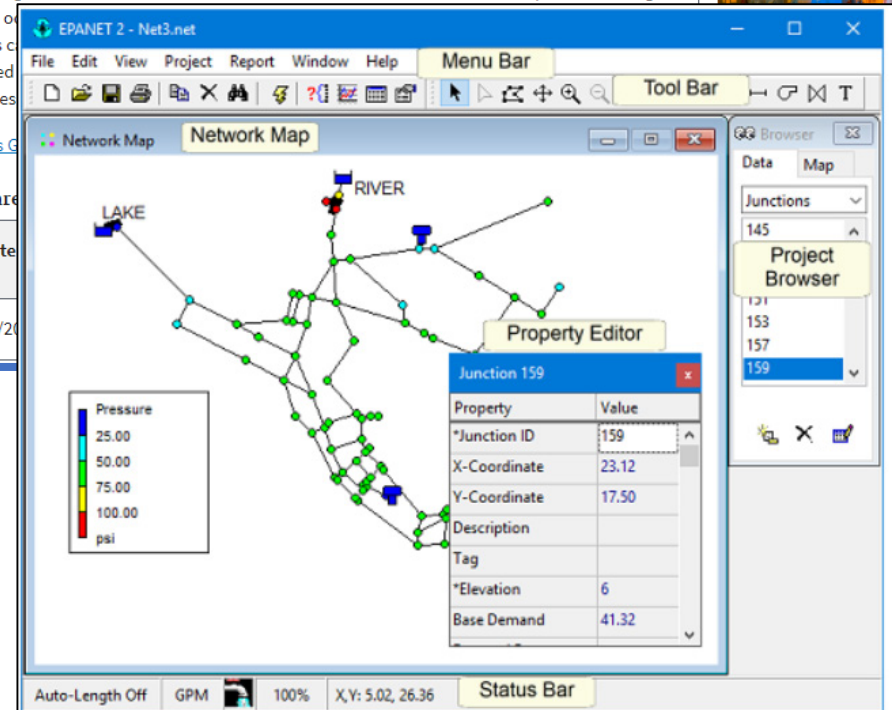
Software

Date

07/23/20

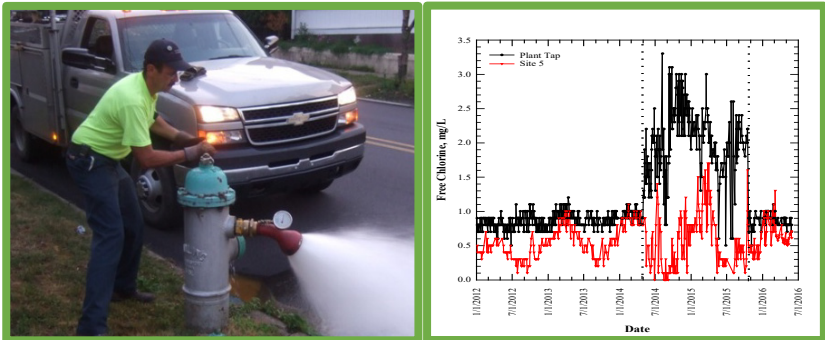
#### On this Page

- [Software, Compatibility, and Manuals](#)
- [Capabilities](#)
- [Applications](#)
- [Related Resources](#)
- [Technical Support](#)



# EPANET Typical Uses and Applications

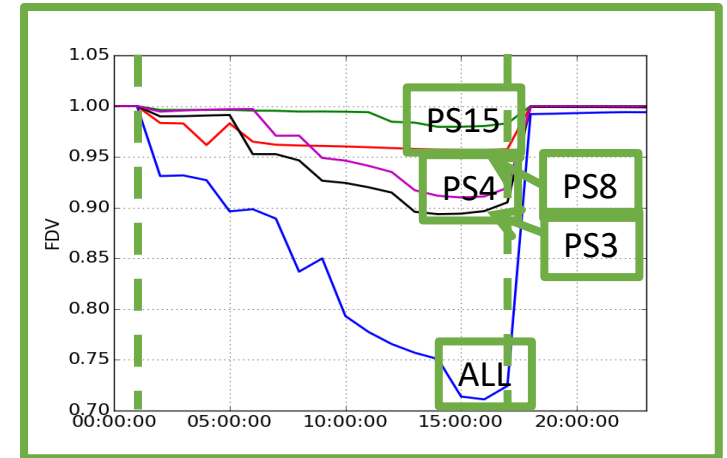
## Solving Regulatory Problems



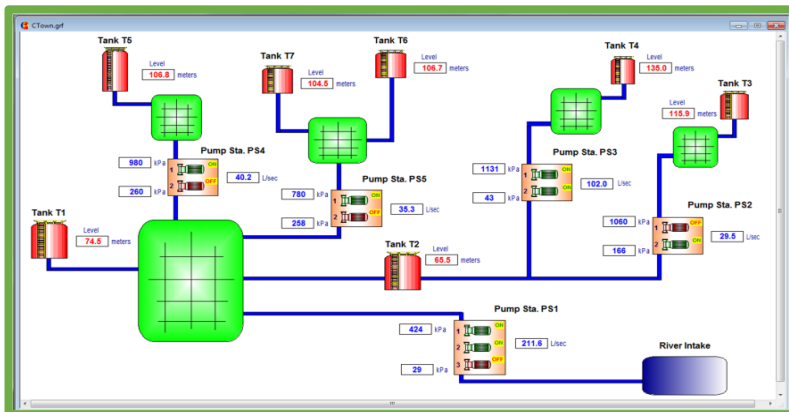
## Designing and Replacing Aging Infrastructure



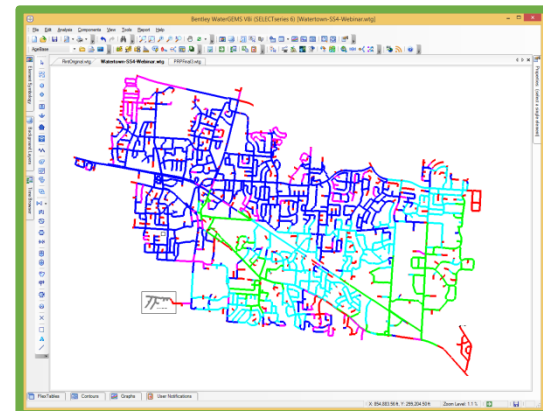
## Preparing for Emergencies



## Optimizing Operations to Improve Water Quality

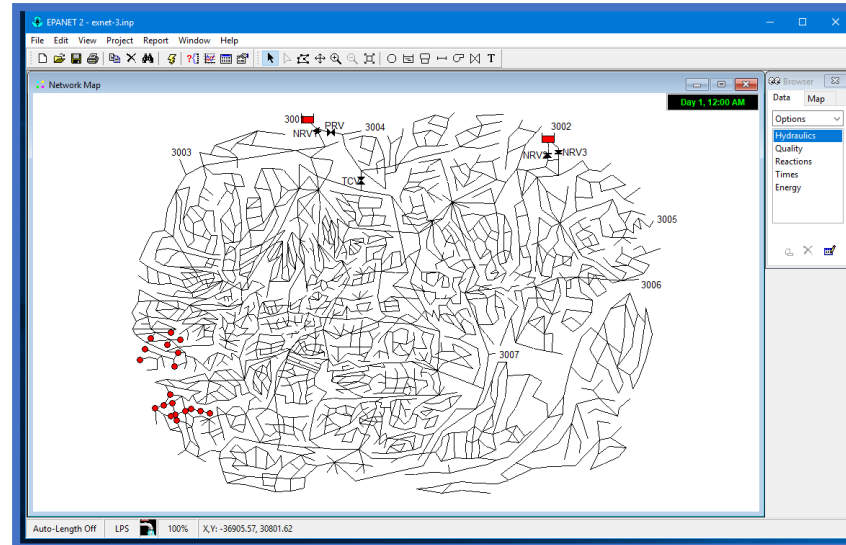
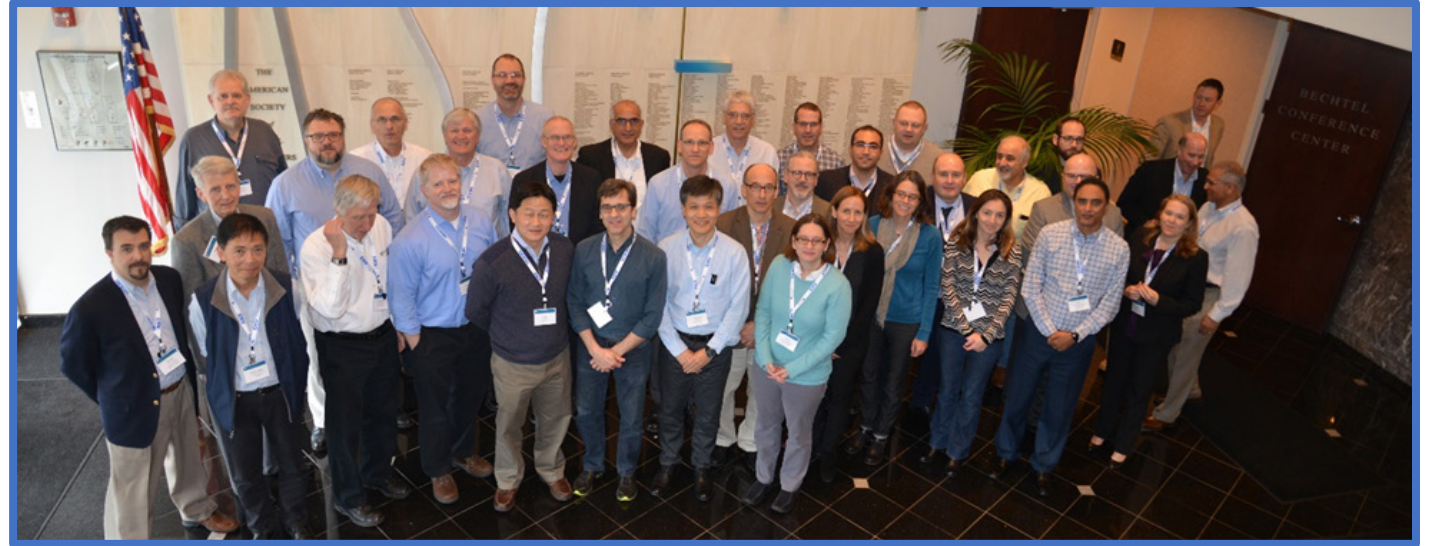


## Real-time Operations and Decision Making



# EPANET Recent Updates (*version 2.2*)

- 💧 Online User Manual
- 💧 Testing and QA
- 💧 User interface
- 💧 Improved solution performance and accuracy
  - Pressure dependent demand analysis
  - Water quality mass balance
  - Handling of low flows
  - Convergence criteria
- 💧 External contributors



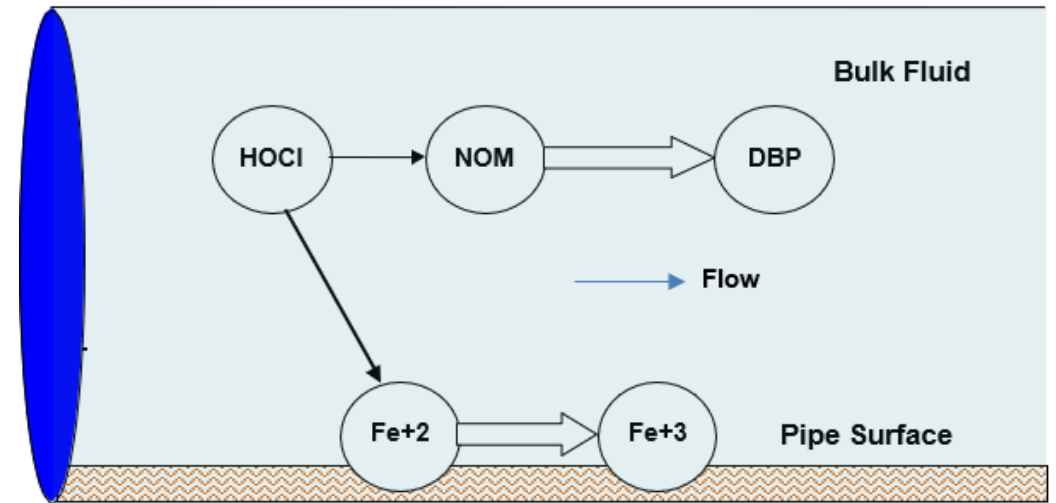
# Distribution System Model: EPANET-MSX

## 💧 EPANET-MSX can model the following:

- Adsorption/desorption on pipe walls
- Attachment to biofilms
- Chemical reactions
- Biological growth and decay

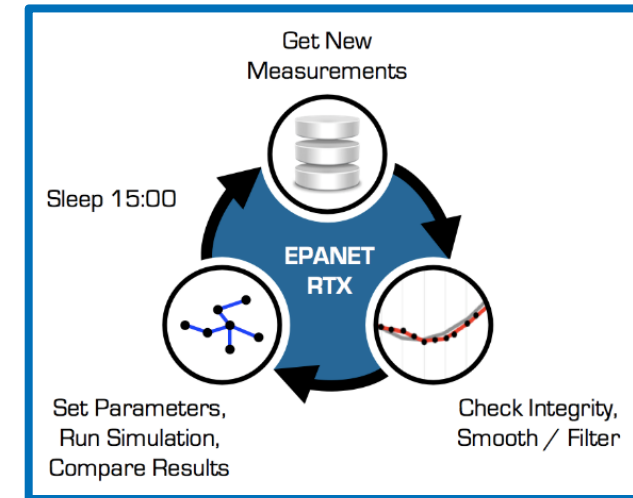
## 💧 Planned features:

- Graphical user interface
- Dispersion modeling
- Parcel tracking
- Built in contaminant fate and transport models

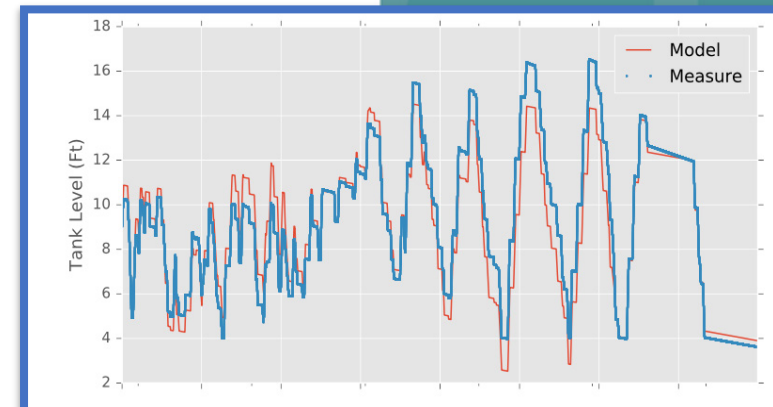


# Distribution System Model: EPANET-RTX

- 💧 EPANET in real-time.
- 💧 Suite of software libraries to integrate EPANET model with SCADA operational data.
- 💧 Real-time analytics for automated:
  - Forward cast (what will happen next?)
  - Hind cast (why did this happen in the past?)
  - Regular updates to model calibration
  - Simulate and compare operational decisions
- 💧 Continuous graphical data comparison and analysis between model and SCADA outputs allowing for more accurate predictions.



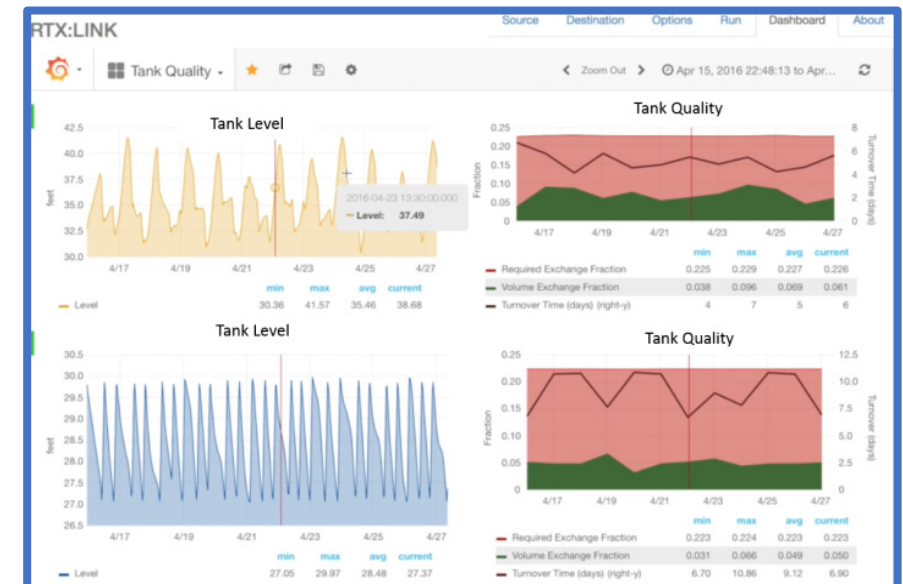
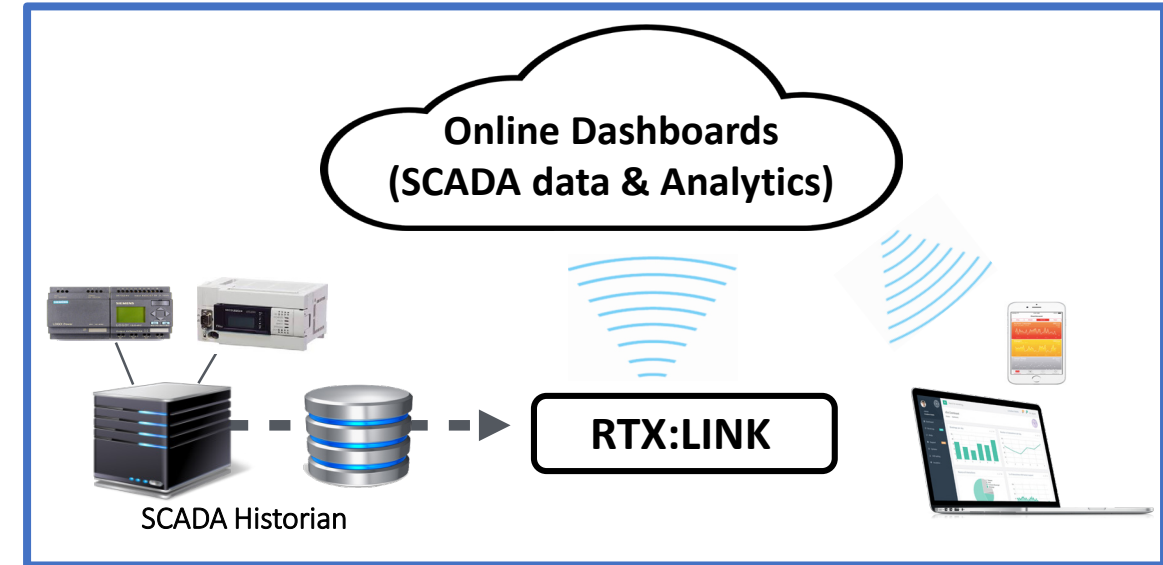
Water Utility Case Study of Real-Time Network Hydraulic and Water Quality Modeling Using EPANET-RTX Libraries



# Distribution System Tool: RTX:LINK

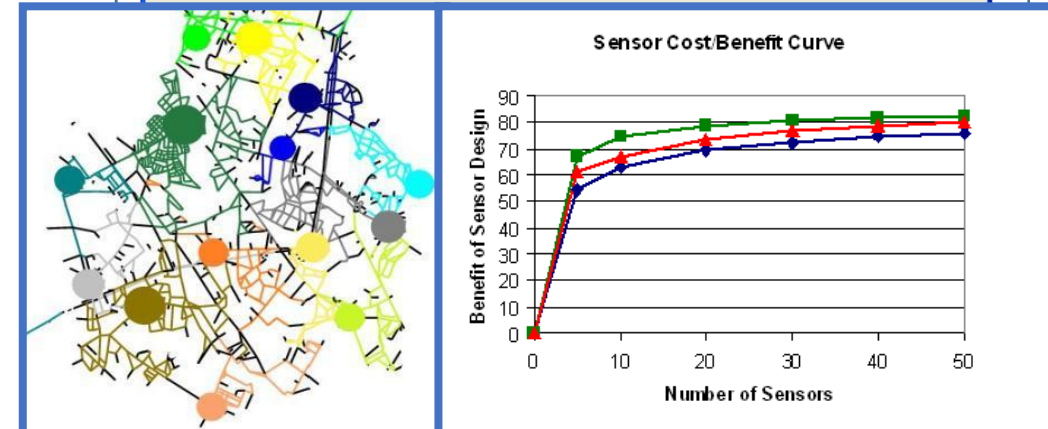
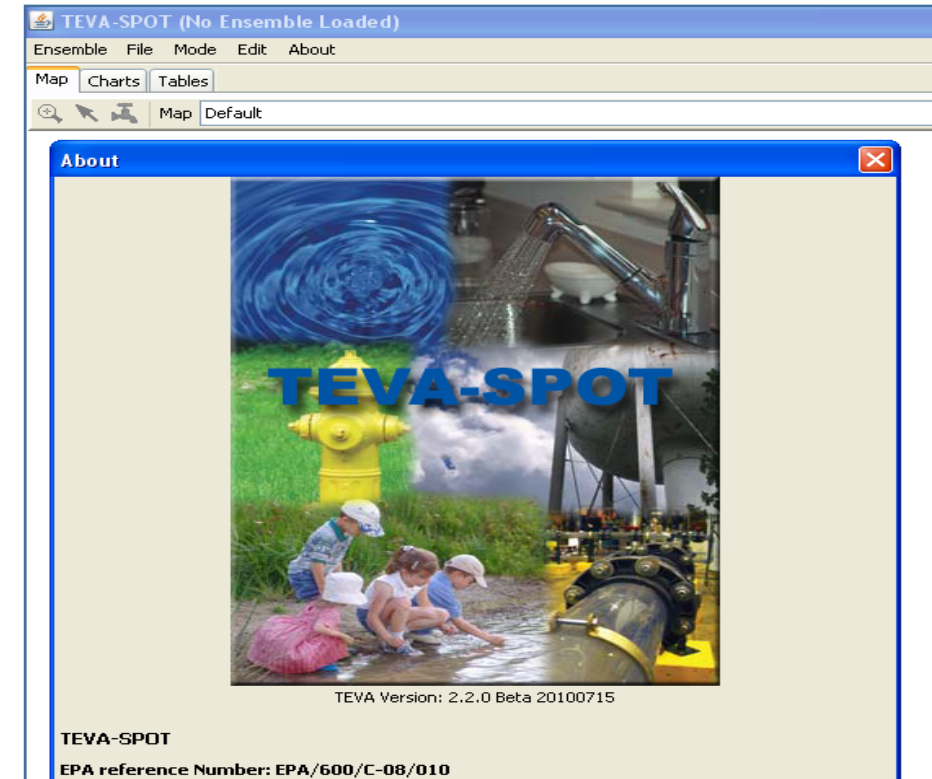
RTX:LINK provides the technology to view water system data and simple analytics on smart phones and mobile devices.

- Available for free on EPA's website.
- Shows real-time statistics and trends, water age, tank turnover time, tank degree of mixing, energy usage and system demand.
- Can alert based on min/max (set point) levels or other methods.
- Helps support rapid and accurate decision making at water utilities.



# Distribution System Model: Sensor Placement

- TEVA-SPOT:
  - Threat Ensemble Vulnerability Assessment
  - Sensor Placement Optimization Tool
- Assess impacts of contamination incidents.
- Optimize sensor network designs.
- Evaluate/compare the performance of different sensor layouts.
- Command line (research) and Graphical User Interface (end user) versions available.



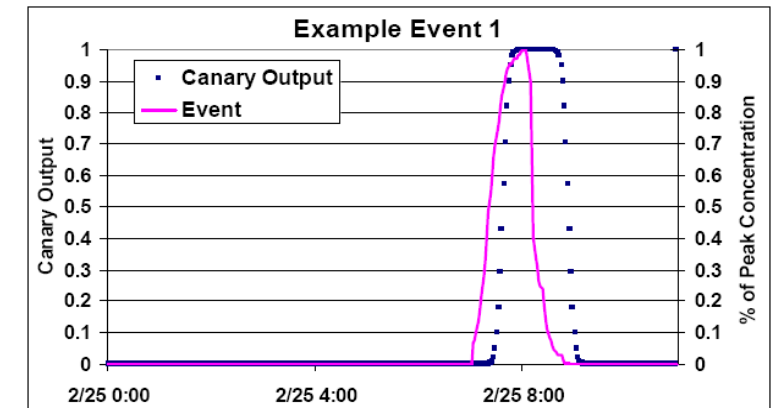
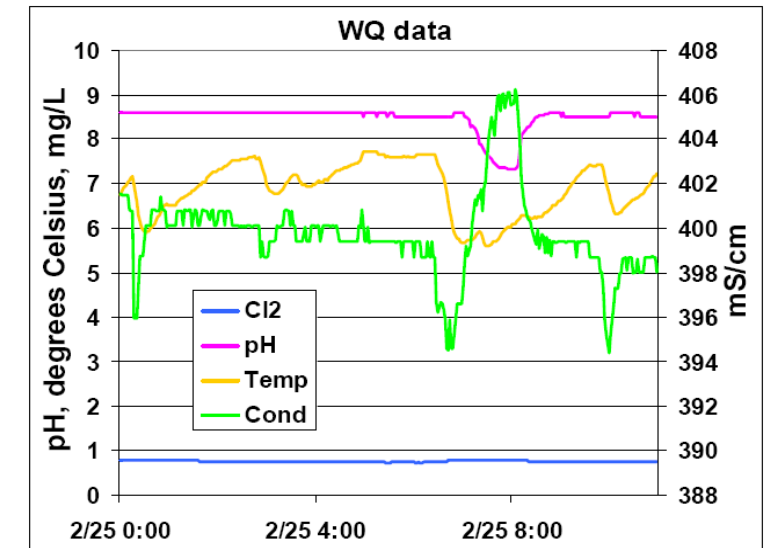
# Distribution System Tool: CANARY



CANARY is a water quality event detection software.

- **Monitors** water quality data at multiple sensor locations continuously.
- **Recognizes** recurring water quality patterns.
- **Ignores** data during periods of sensor malfunction or hardware alarms.
- **Analyzes** data using multiple statistical algorithms.
- **Alerts** during periods of anomalous water quality.
- **Produces** graphics for analysis.

<https://github.com/USEPA/CANARY/releases/tag/v4.3.3>

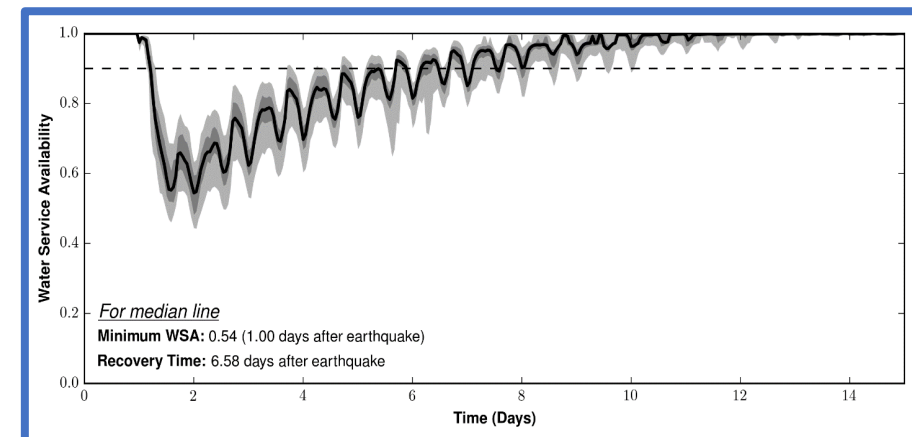
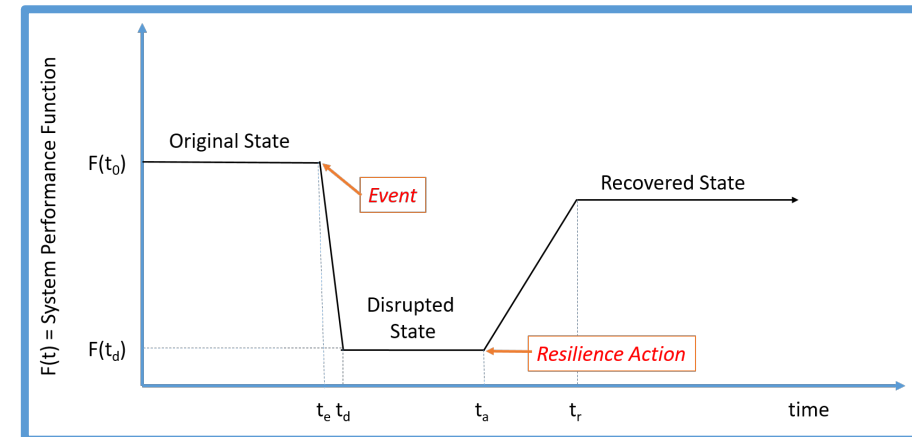


# Distribution System Tool: WNTR

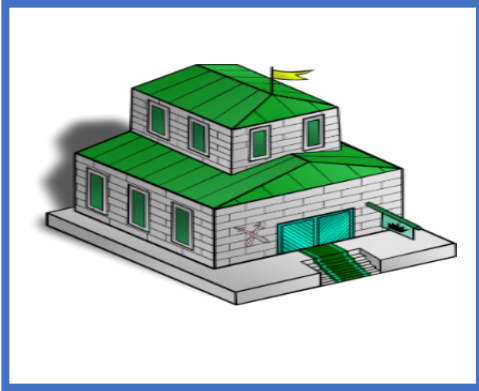
- Simulates disaster scenarios such as earthquakes, power outages, floods, contamination incidents, loss of access to infrastructure.
- Predicts damage to infrastructure.
- Calculates resilience metrics.
- Evaluates response and mitigation strategies to improve resilience:
  - Isolate and repair pipe breaks.
  - Change valve and tank operation to maintain water service
  - Install backup generation
  - Plan flushing or water conservation mandates
  - Evaluate fire fighting capacity



<https://github.com/USEPA/WNTR>

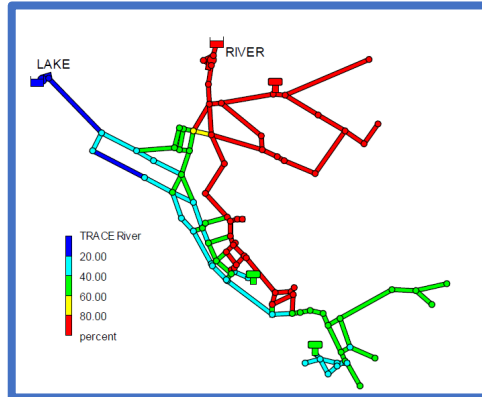


# Drinking Water Models and Tools



## Drinking Water Treatment Models & Tools

- CFD
- CBCS
- FCCAS
- FCEDTS
- WTM
- ETDOT
- Treatability DB



## Drinking Water Distribution System Models & Tools

- EPANET
- EPANET-MSX
- EPANET-RTX
- RTX:LINK
- TEVA-SPOT
- CANARY
- WNTR



## Drinking Water Premise Plumbing Models & Tools

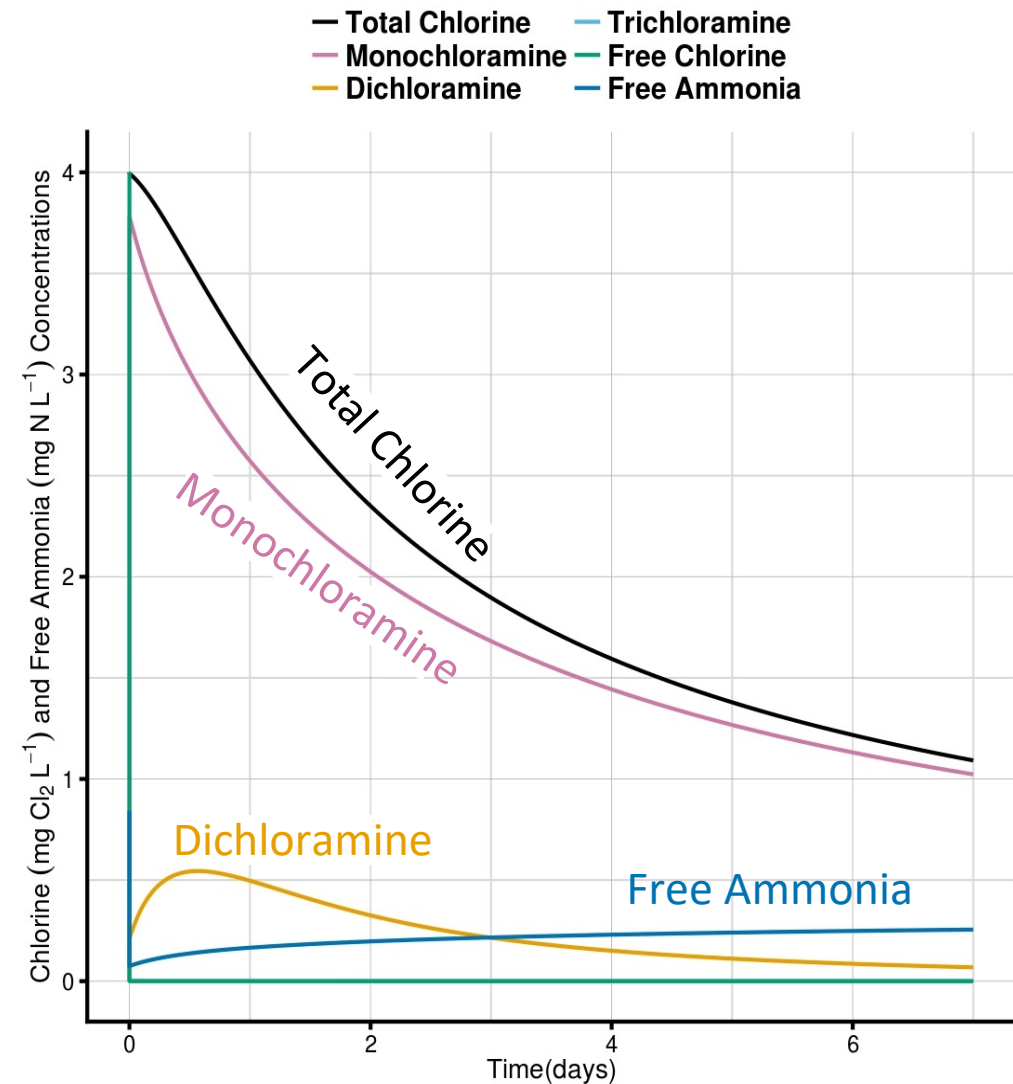
- PPM Tools

Access these models and tools through EPA's [Science Models and Research Tools \(SMaRT\) Search](#)

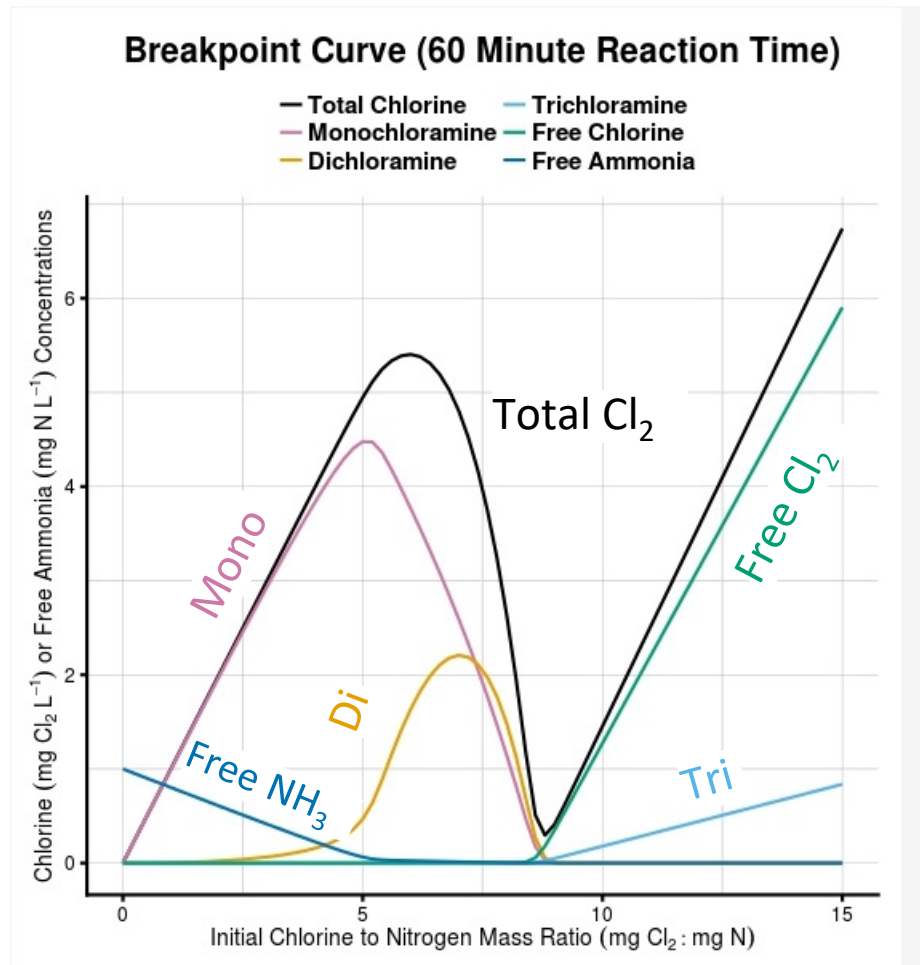
# Treatment Models: Chloramine Formation/Decay

- 💧 Chloramine formation and decay
- 💧 Batch (plug flow) reactor
- 💧 Allows comparison of input choices:
  - Free chlorine, free ammonia
  - pH, alkalinity, temperature, Total Organic Carbon (TOC)
  - Simultaneous addition, booster chlorination, or preformed chloramines

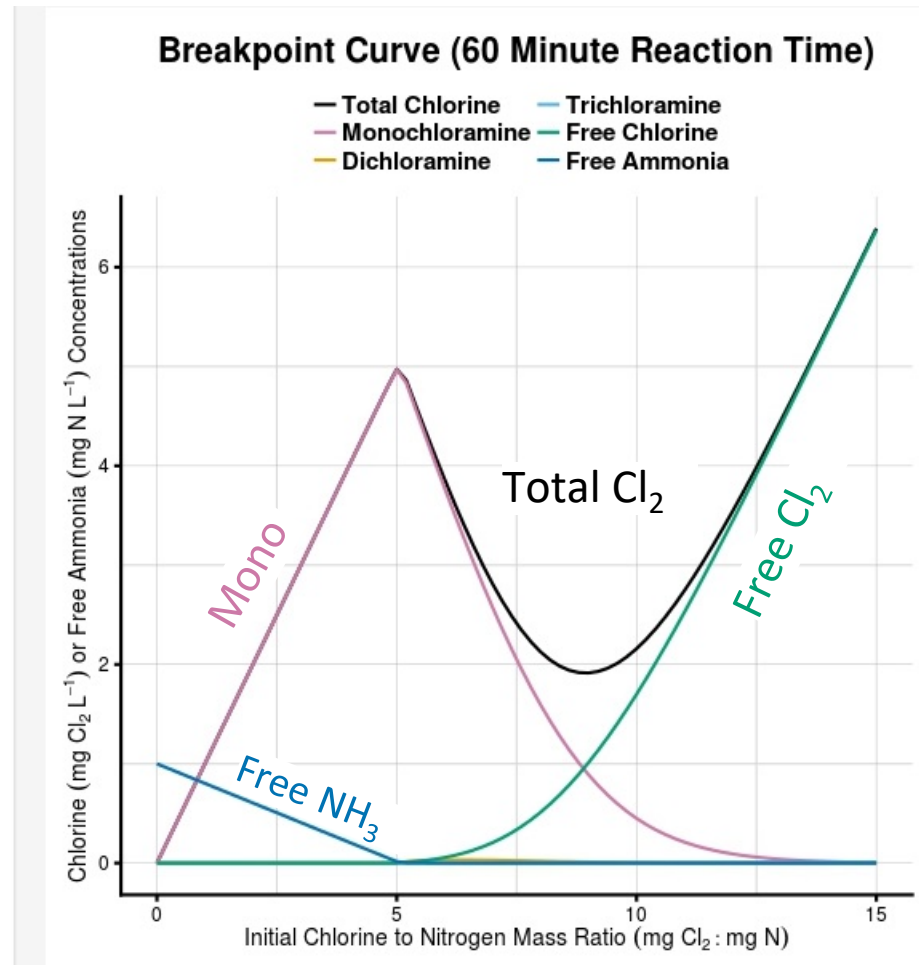
<https://shiny.epa.gov/cfd/>



# Treatment Models: Chlorine Breakpoint Curve



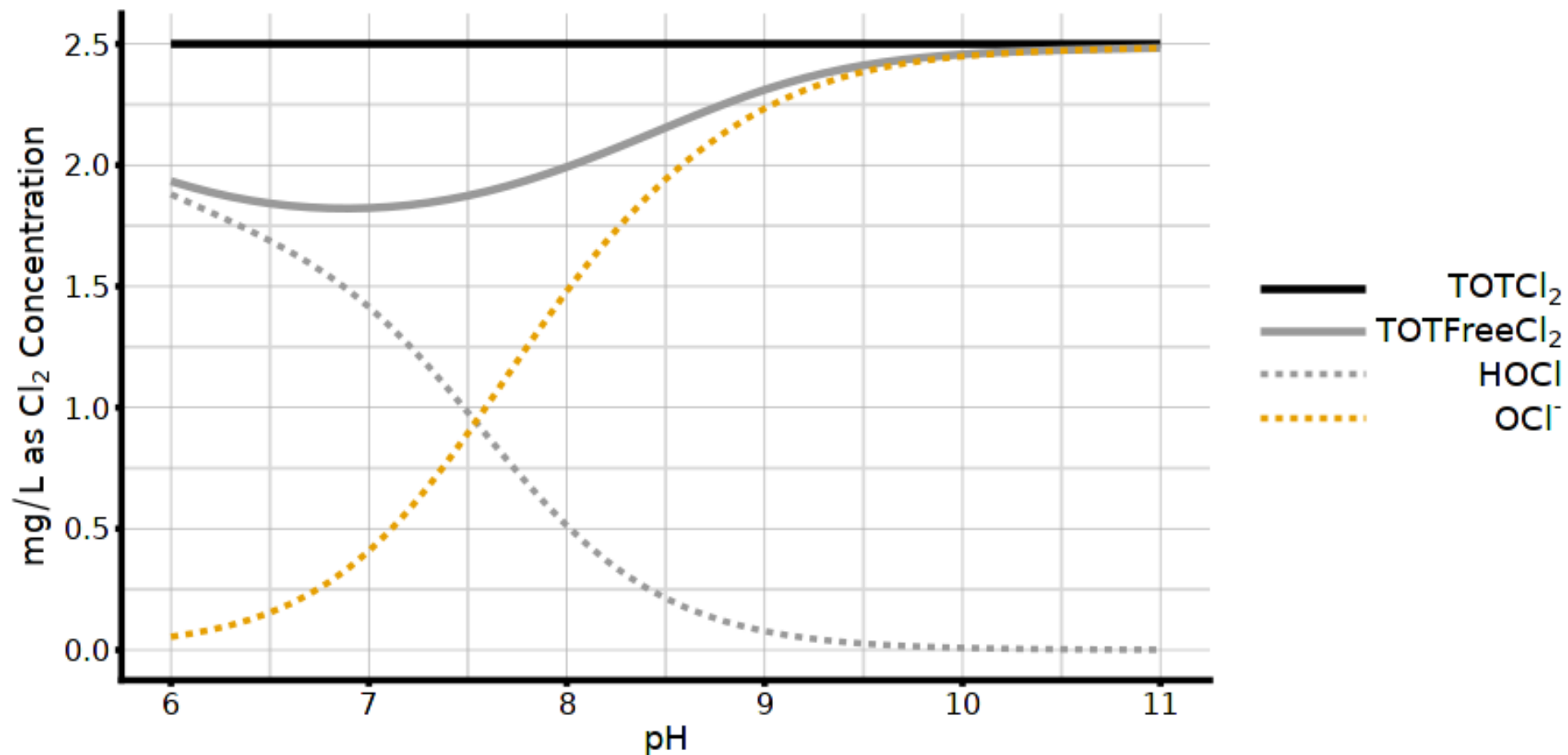
pH 7



pH 9

# Treatment Models: Free Chlorine and Cyanuric Acid

FCCAS predicts how much free chlorine is present when using Dichlor or Trichlor as the free chlorine source

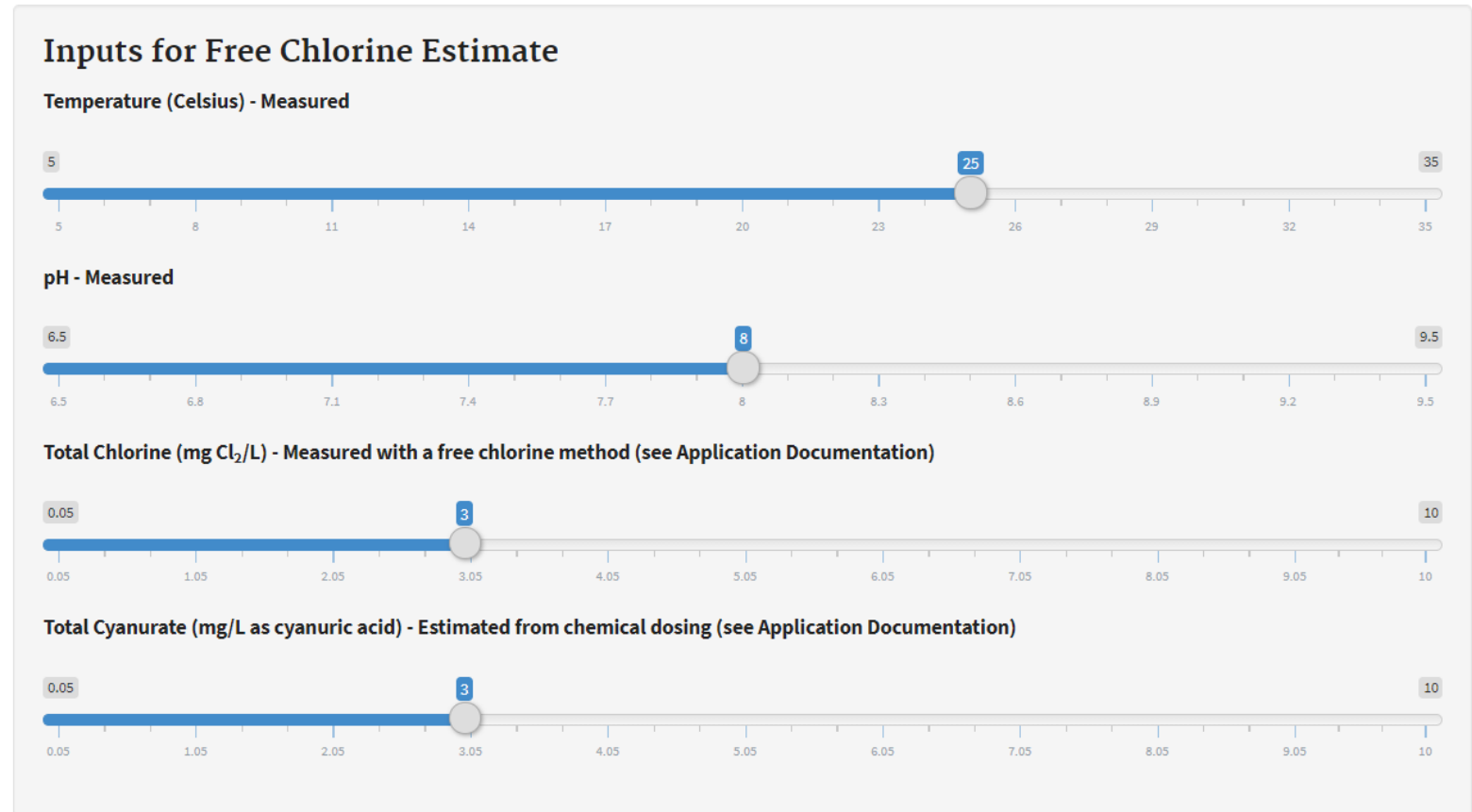


<https://shiny.epa.gov/fccas/>

# Treatment Models: Free Chlorine Estimator for Dichlor and Trichlor Systems

- 💧 Calculates free chlorine concentration.
- 💧 Dichlor or trichlor are used as disinfectant.
- 💧 Cannot accurately measure free chlorine in the field.

<https://shiny.epa.gov/fcedts>



Estimated free chlorine concentration = 1.44 mg/L as chlorine

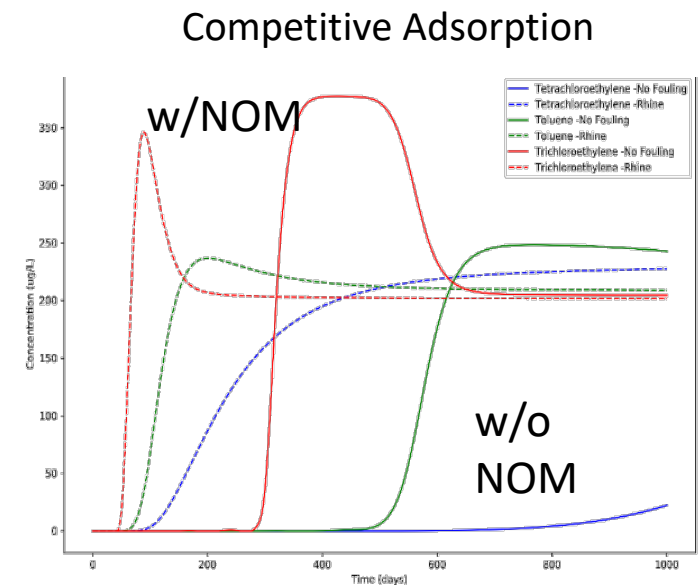
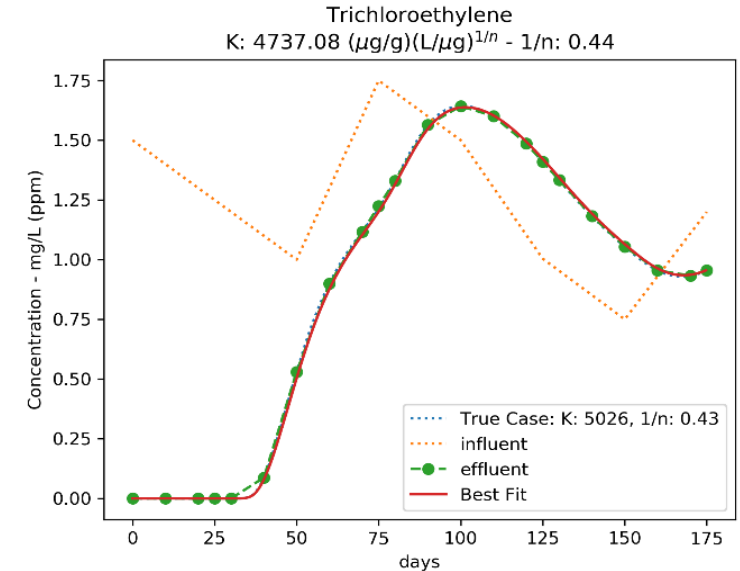
# Treatment Models: WTM

## 💧 Granular Activated Carbon Model

- Pore and Surface Diffusion Model (PSDM)
- Fouling related to natural organic matter (NOM)
- Estimates model parameters based on pilot data
- Supports multiple component adsorption
- Estimating real-world operational bed replacement

## 💧 Ion Exchange Media

- Supports gel-type ion exchange resins
- Planned support for macroporous resins (early 2021)
- Applicable to low natural organic matter (NOM) waters
- Model competition from divalent ions, such as sulfate



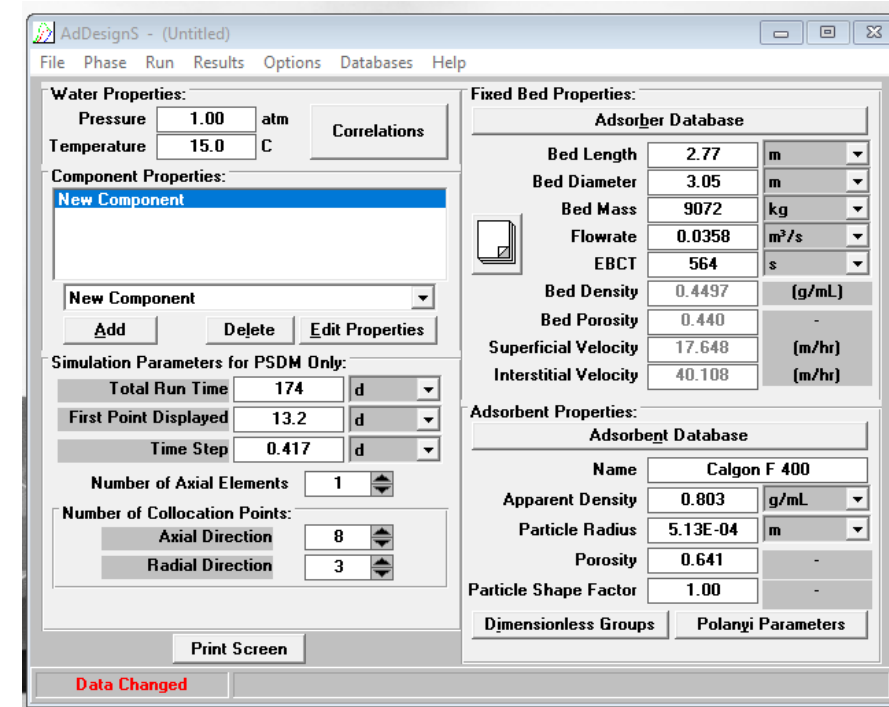
# Treatment Models: ETDOT

## Environmental Technologies Design Option Tool (ETDOT)

- 💧 Suite of software for modeling a variety of treatment technologies
- 💧 Originally developed by Michigan Technological University (MTU)
- 💧 Now available on EPA's website

- Adsorption Design Software for Windows (AdDesignS) - *Version 1.0*
- Advanced Oxidation Process Software (AdOx) - *Version 1.0.2*
- Aeration System Analysis Program (ASAP) - *Version 1.0*
- Biofilter Design Software - *Version 1.0.27*
- Continuous Flow Pore Surface Diffusion Model for Modeling Powdered Activated Carbon Adsorption - *Version 1.0*
- Dye Study Program (DyeStudy) - *Version 1.0.0*
- Predictive Software for the Fate of Volatile Organics in Municipal Wastewater Treatment Plants (FaVOr) - *Version 1.0.11*
- Ion Exchange Design Software (IonExDesign) - *Version 1.0.0*
- Software to Estimate Physical Properties (StEPP) - *Version 1.0*

### Example: AdDesignS



AdDesignS - (Untitled)

File Phase Run Results Options Databases Help

**Water Properties:**

Pressure: 1.00 atm  
Temperature: 15.0 C

**Component Properties:**

New Component

New Component

Add Delete Edit Properties

**Simulation Parameters for PSDM Only:**

Total Run Time: 174 d  
First Point Displayed: 13.2 d  
Time Step: 0.417 d

Number of Axial Elements: 1  
Number of Collocation Points: 8  
Axial Direction: 8  
Radial Direction: 3

**Fixed Bed Properties:**

Adsorbent Database

Bed Length: 2.77 m  
Bed Diameter: 3.05 m  
Bed Mass: 9072 kg  
Flowrate: 0.0358 m³/s  
EBCT: 564 s  
Bed Density: 0.4497 (g/mL)  
Bed Porosity: 0.440  
Superficial Velocity: 17.648 (m/hr)  
Interstitial Velocity: 40.108 (m/hr)

**Adsorbent Properties:**

Adsorbent Database

Name: Calgon F 400  
Apparent Density: 0.803 g/mL  
Particle Radius: 5.13E-04 m  
Porosity: 0.641  
Particle Shape Factor: 1.00

Dimensionless Groups Polanyi Parameters

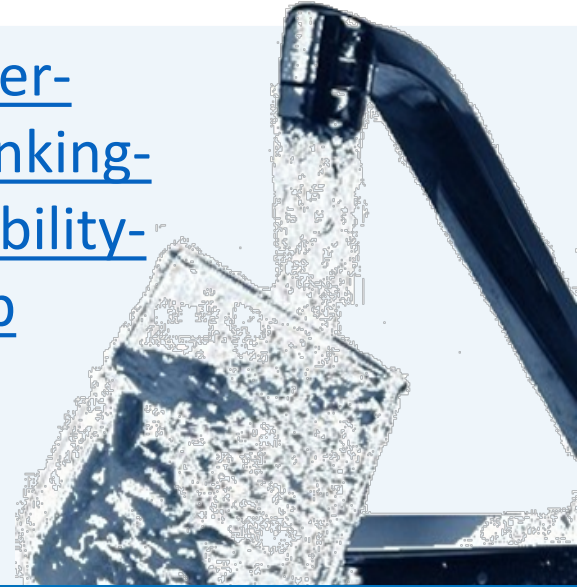
Print Screen

Data Changed

# Treatment Tools: Treatability Database

- 💧 Interactive searchable database.
- 💧 123 regulated and unregulated contaminants.
- 💧 35 treatment processes commonly employed or known to be effective.
- 💧 Referenced information gathered from thousands of literature sources.

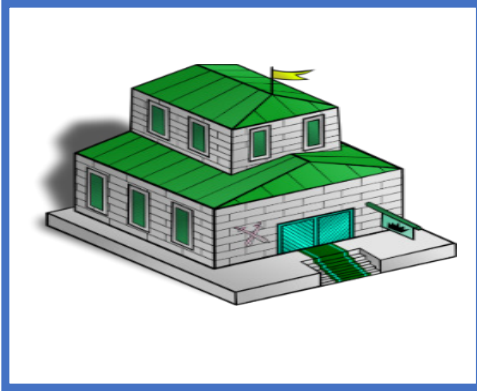
[epa.gov/water-research/drinking-water-treatability-database-tdb](https://epa.gov/water-research/drinking-water-treatability-database-tdb)



[Home](#) [About the TDB](#) [Contact Us](#) [Find Contaminant](#) [Find Treatment Process](#) [Help ▾](#) [Quick Links ▾](#)

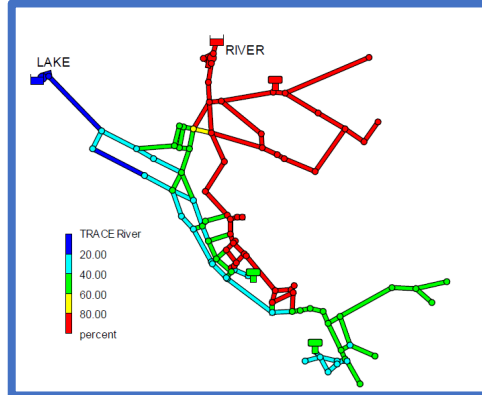
## Welcome to the Drinking Water Treatability Database

# Drinking Water Models and Tools



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## Drinking Water Distribution System Models & Tools

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- CANARY
- WNTR

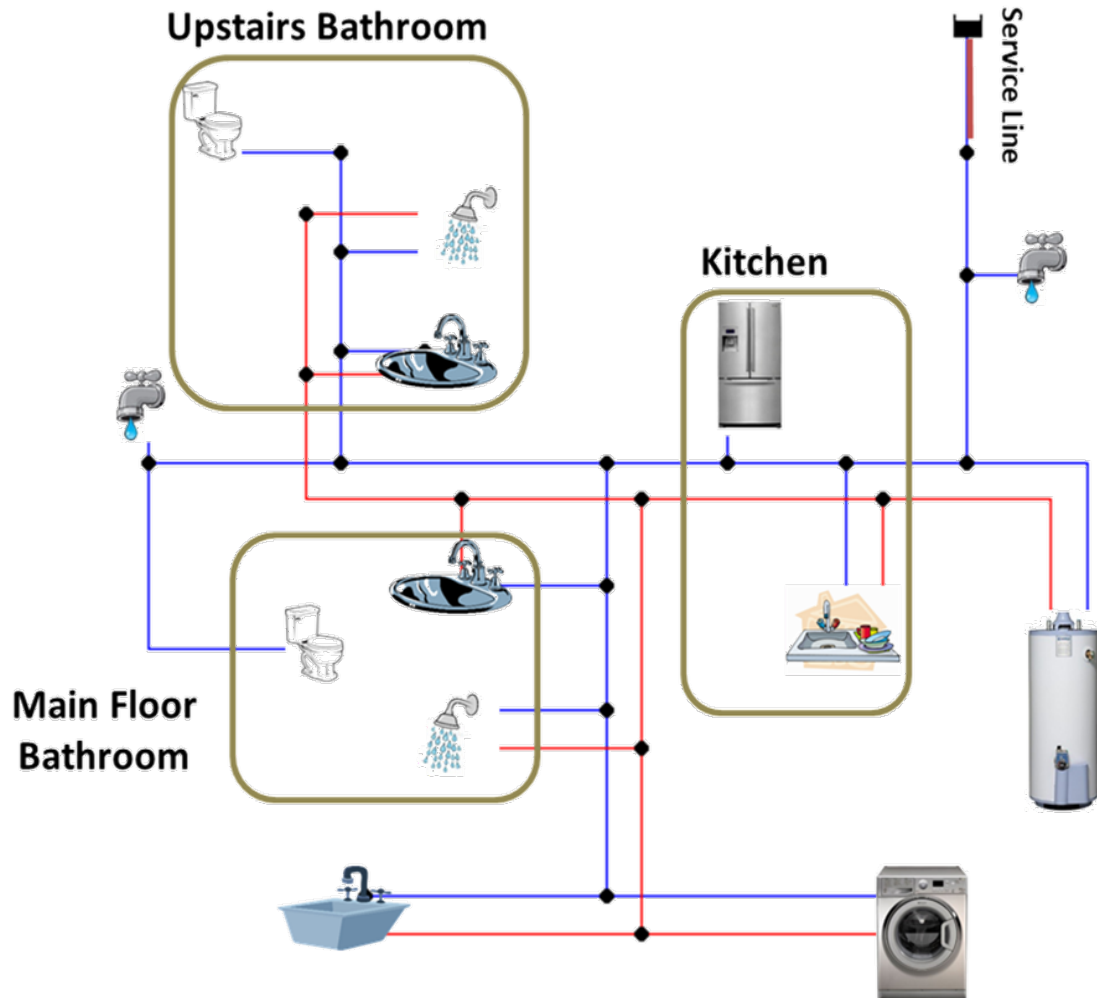


## Drinking Water Premise Plumbing Models & Tools

- PPM Tools

Access these models and tools through EPA's [Science Models and Research Tools \(SMaRT\) Search](#)

# Premise Plumbing Tool: PPM Tools



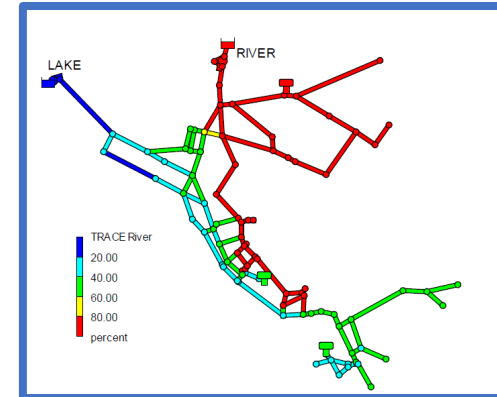
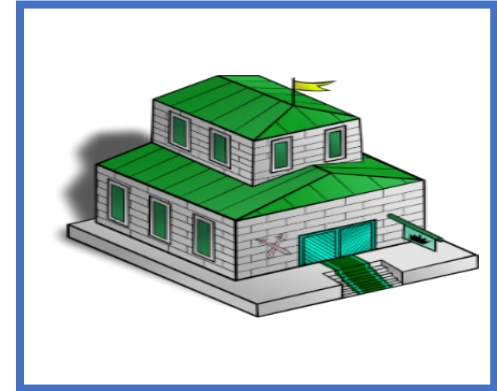
## Premise Plumbing Modeling Tools (PPM Tools)

- 💧 Leverages EPANET and WNTR
- 💧 Models real-world fixtures
- 💧 Estimator realistic usage patterns
- 💧 Generates and runs many scenarios
- 💧 Predicts water quality information over time (e.g., water age, contaminant concentration)
- 💧 Simulates flushing to remove contaminants
- 💧 Estimates exposure to contaminants

<https://github.com/USEPA/PPMtools>

# Summary

- 💧 Models and other tools can be used to help solve drinking water problems:
  - Water distribution systems design, vulnerability and resilience assessment, operational improvements.
  - Water treatment design, evaluation, assessment.
  - Premise plumbing design, contaminant exposure assessment, flushing.
- 💧 Tools and supporting documentation are available for free on the web and easily searchable from EPA's [Science Models and Research Tools \(SMaRT\) Search](#).



# Contacts

## **Regan Murray, Ph.D.**

Director, Water Infrastructure Division

Center for Environmental Solutions and Emergency Response

US EPA Office of Research and Development

[murray.regan@epa.gov](mailto:murray.regan@epa.gov)

513-569-7031



## **Specific Models and Tools:**

- 💧 **EPANET and EPANET-MSX:** Feng Shang ([shang.feng@epa.gov](mailto:shang.feng@epa.gov))
- 💧 **EPANET-RTX, RTX:LINK and TEVA-SPOT:** Robert Janke ([janke.robert@epa.gov](mailto:janke.robert@epa.gov))
- 💧 **WNTR:** Terra Haxton ([haxton.terra@epa.gov](mailto:haxton.terra@epa.gov))
- 💧 **CANARY, ETDOT, WTM and PPM Tools:** Jonathan Burkhardt ([burkhardt.jonathan@epa.gov](mailto:burkhardt.jonathan@epa.gov))
- 💧 **CFD, CBCS, FCCAS, FCEDTS:** David Wahman ([wahman.david@epa.gov](mailto:wahman.david@epa.gov))
- 💧 **TDB:** Page Jordan ([jordan.page@epa.gov](mailto:jordan.page@epa.gov))