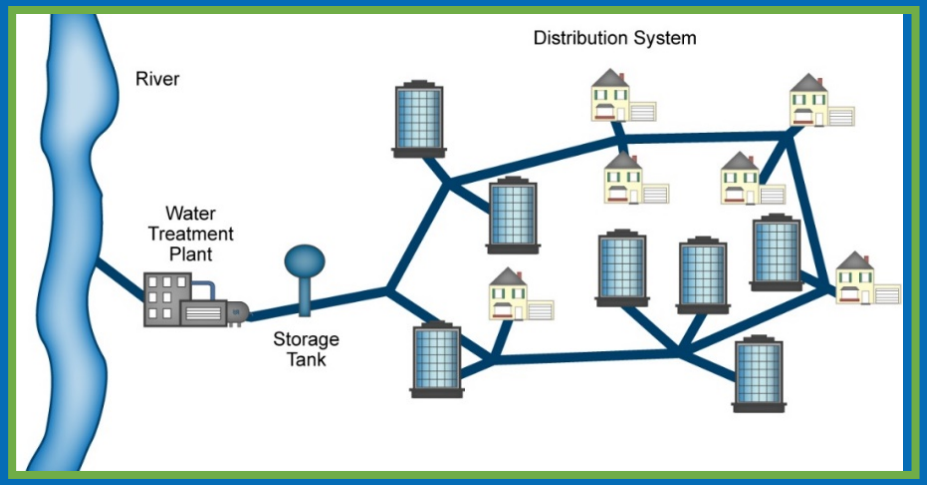
United States Environmental Protection Agency

EPA Tools & Resources Webinar: Drinking Water Models and Tools

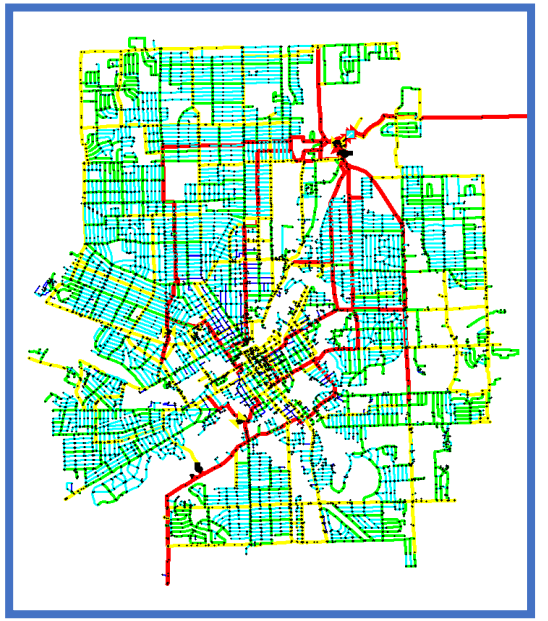
Regan Murray, PhD
US EPA Office of Research and Development

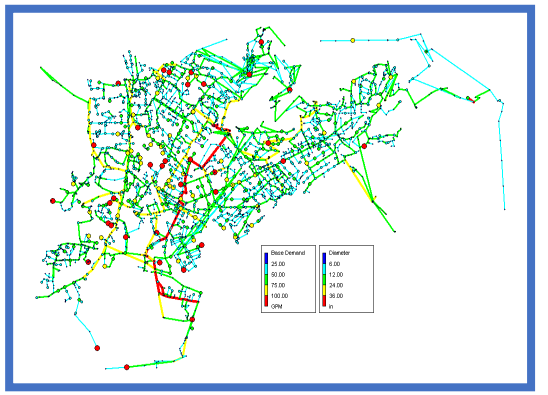
November 18, 2020



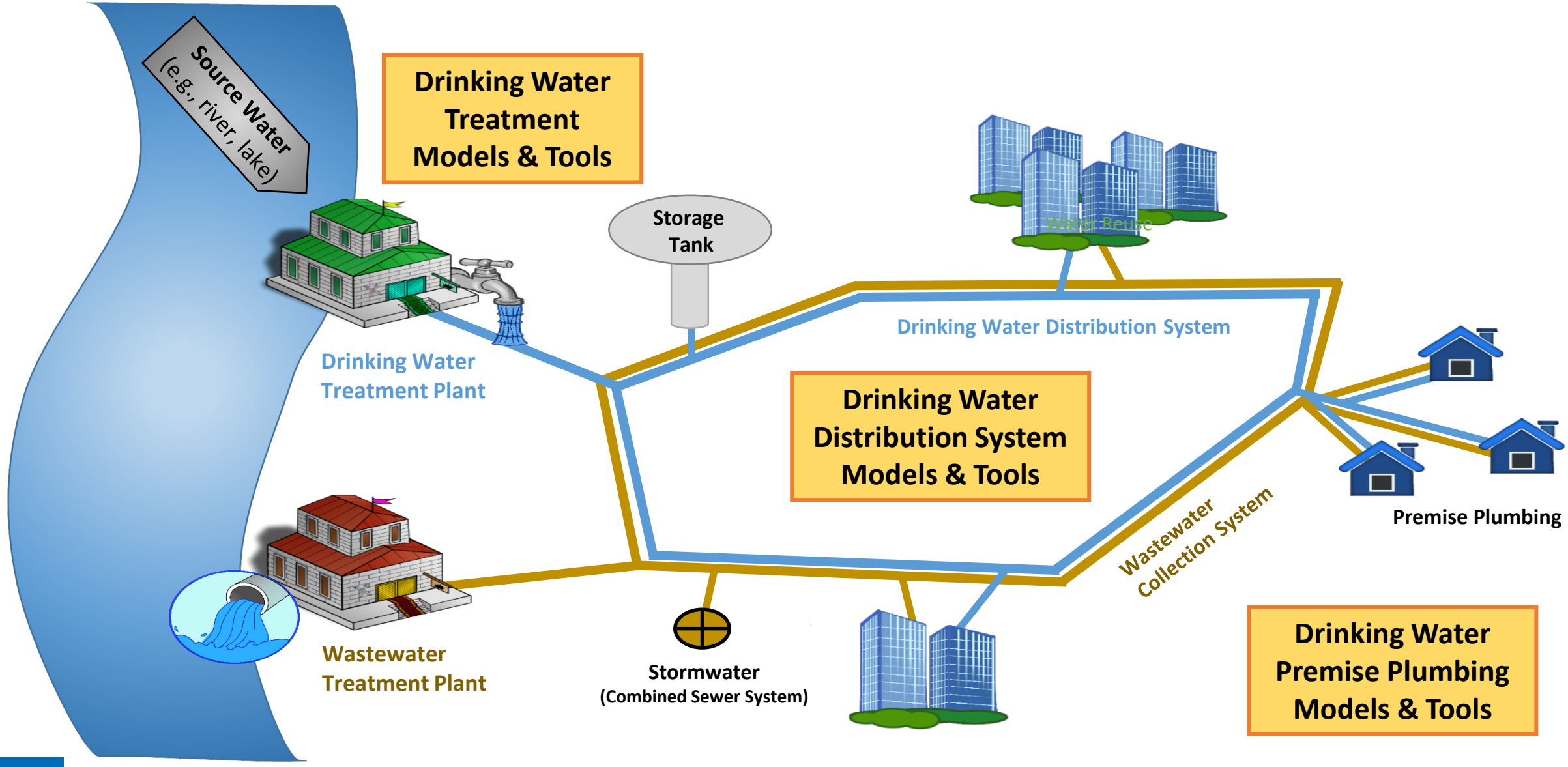
Background and Motivation

- 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.

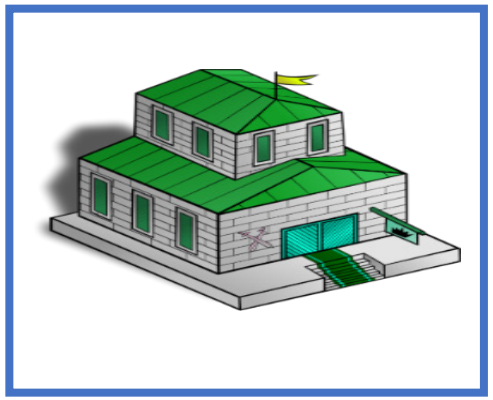




Water Infrastructure

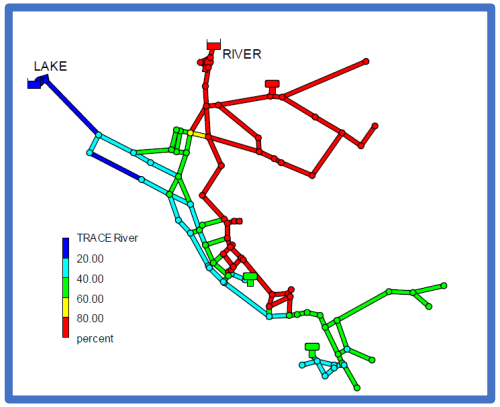


Drinking Water Models and Tools



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

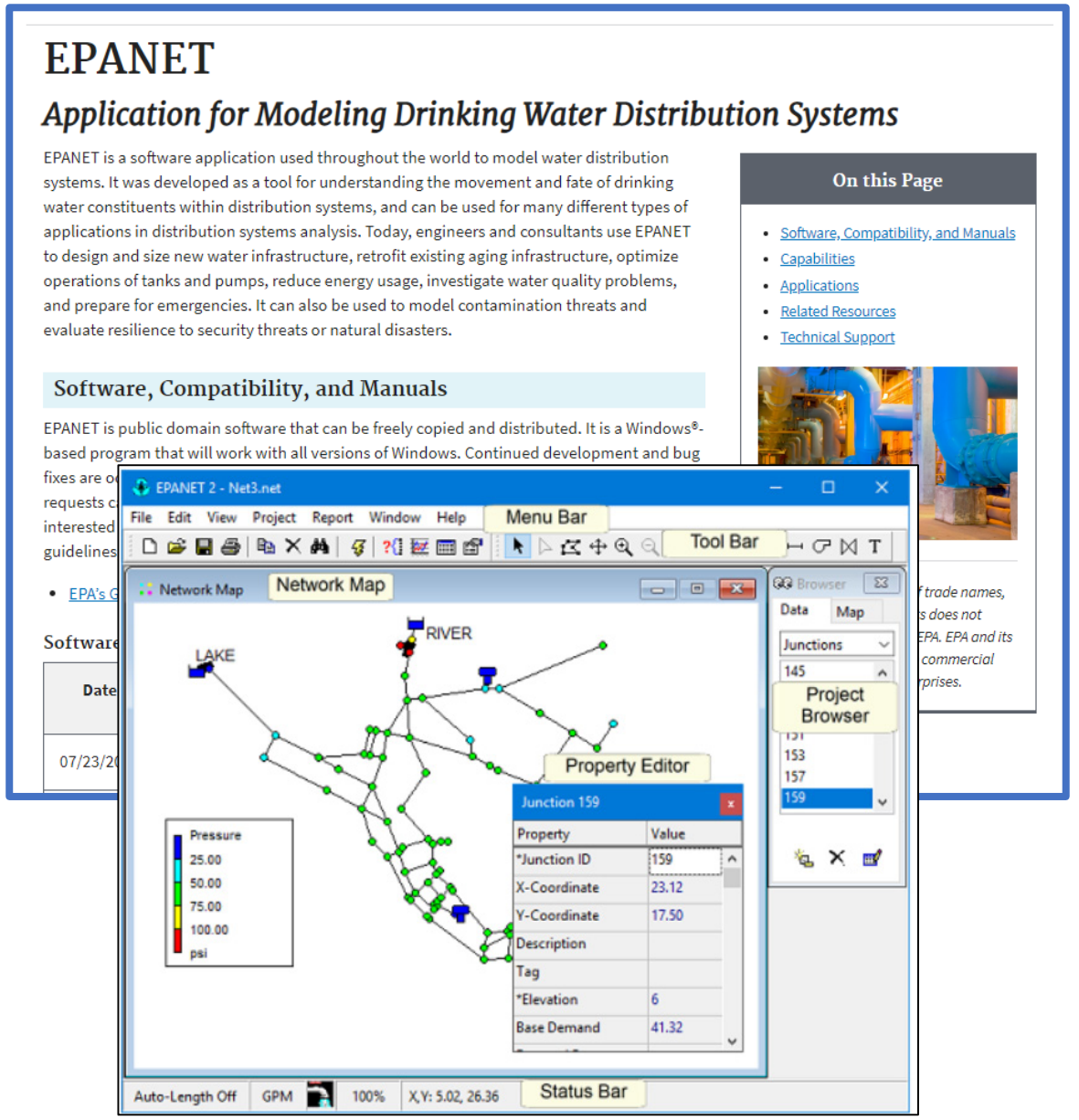
- PPM Tools

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

Distribution System Model: EPANET

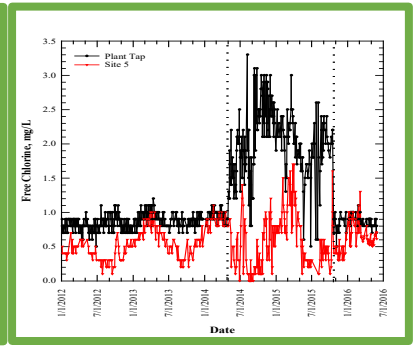
- Simulates hydraulics within a water distribution network.
- Models decay/growth of a single substance.
- More than 50,000 downloads per year.
- Components utilized for multiple commercial software packages.
- Latest official release: version 2.2 in July 2020.

epa.gov/water-research/epanet



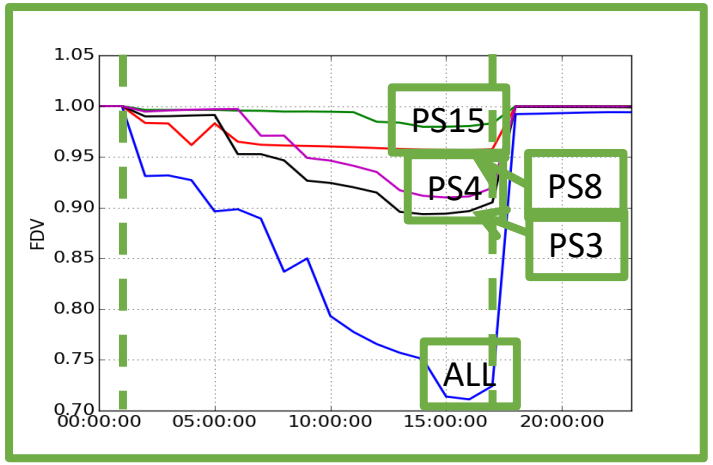
EPANET Typical Uses and Applications

Solving Regulatory Problems

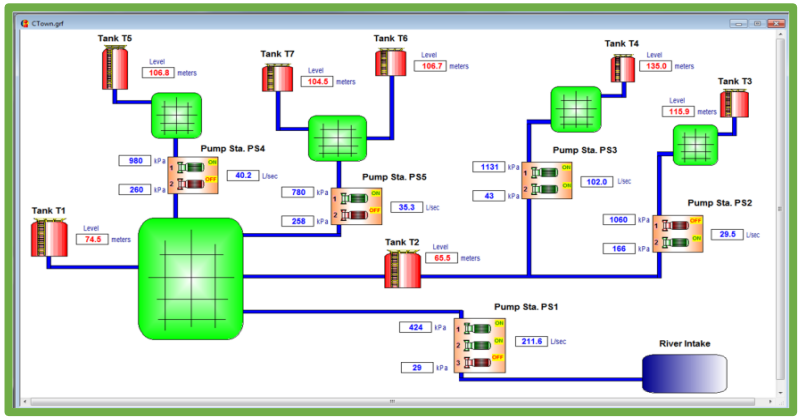


Designing and Replacing Aging Infrastructure

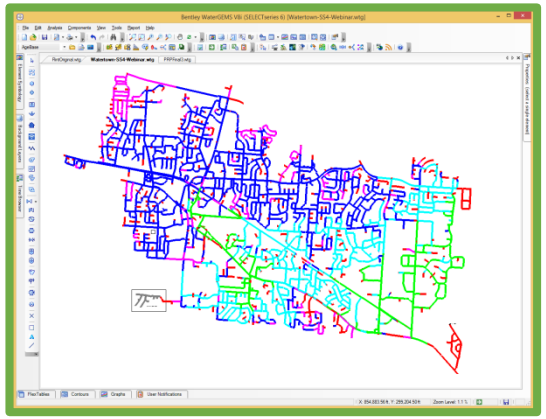
Preparing for Emergencies



Optimizing Operations to Improve Water Quality

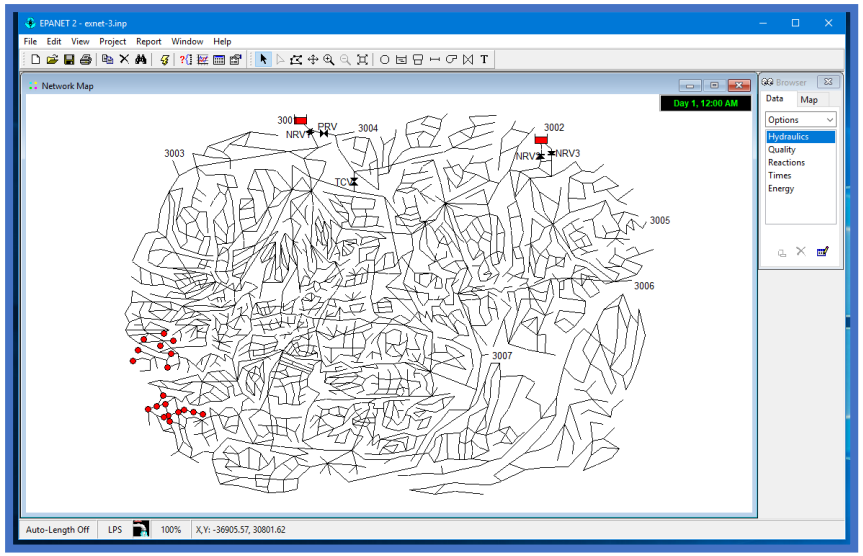


Real-time Operations and Decision Making



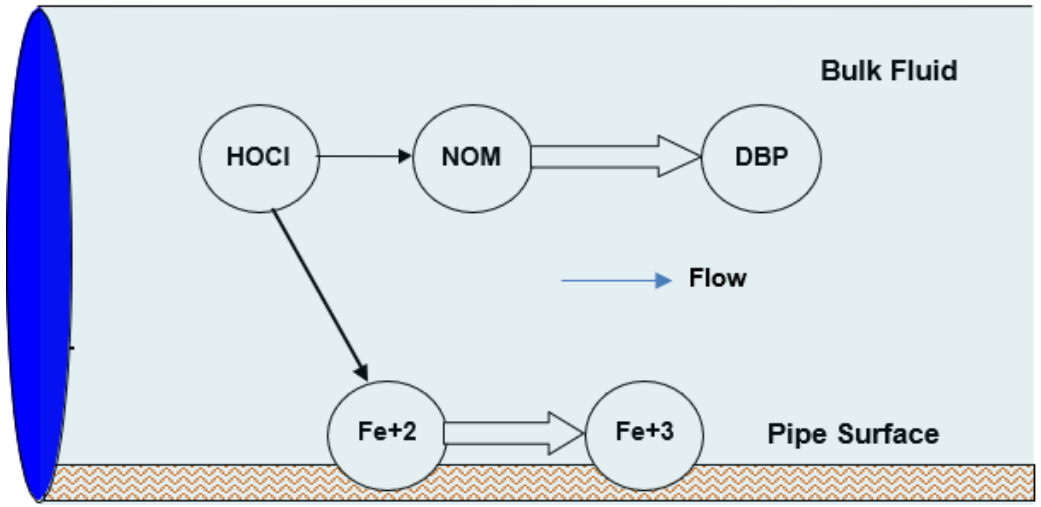
EPANET Recent Updates *(version 2.2)*

- 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



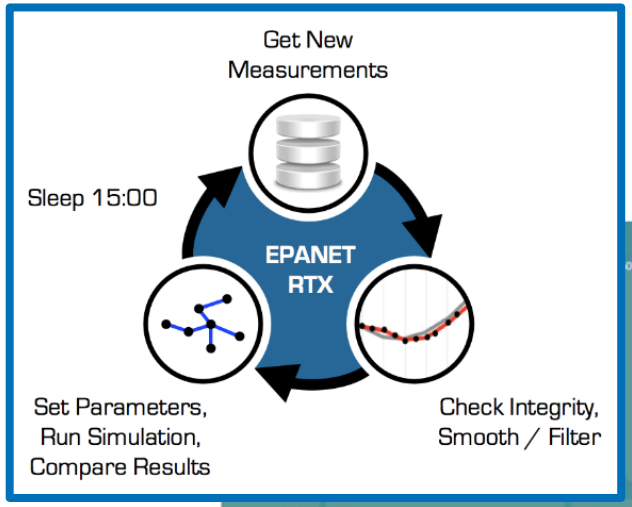
Distribution System Model: EPANET-MSX

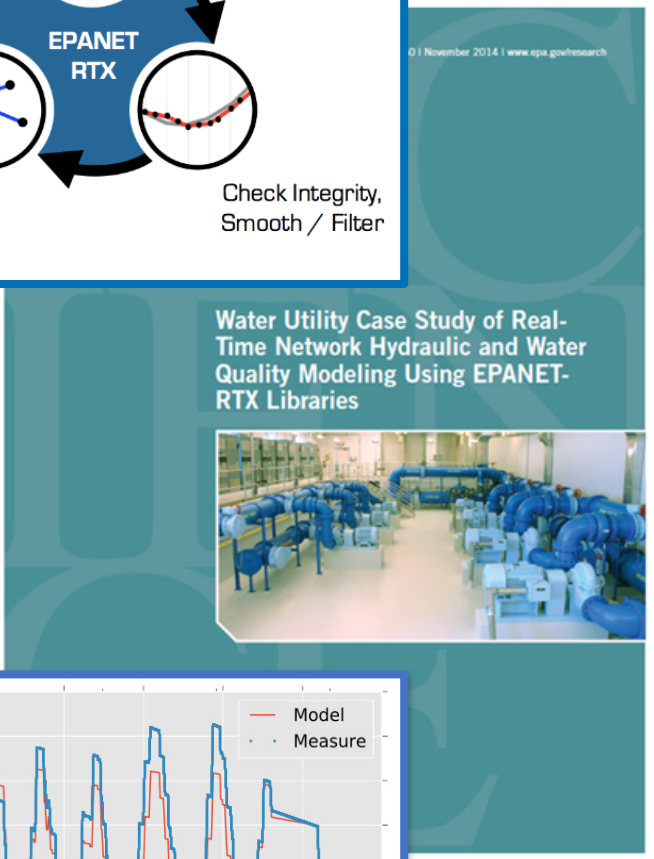
- EPANET-MSX can model the following:
  - Adsorption/desorption on pipe walls
  - Attachment to biofilms
  - Chemical reactions
  - Biological growth and decay
- Planned features:
  - Graphical user interface
  - Dispersion modeling
  - Parcel tracking
  - Built in contaminant fate and transport models

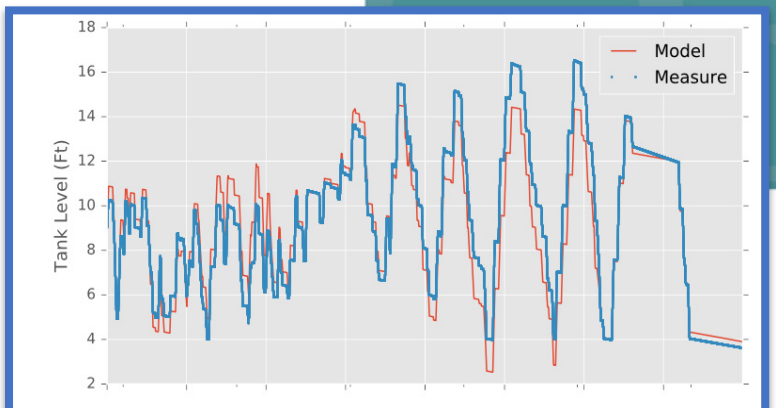


Distribution System Model: EPANET-RTX

- 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.



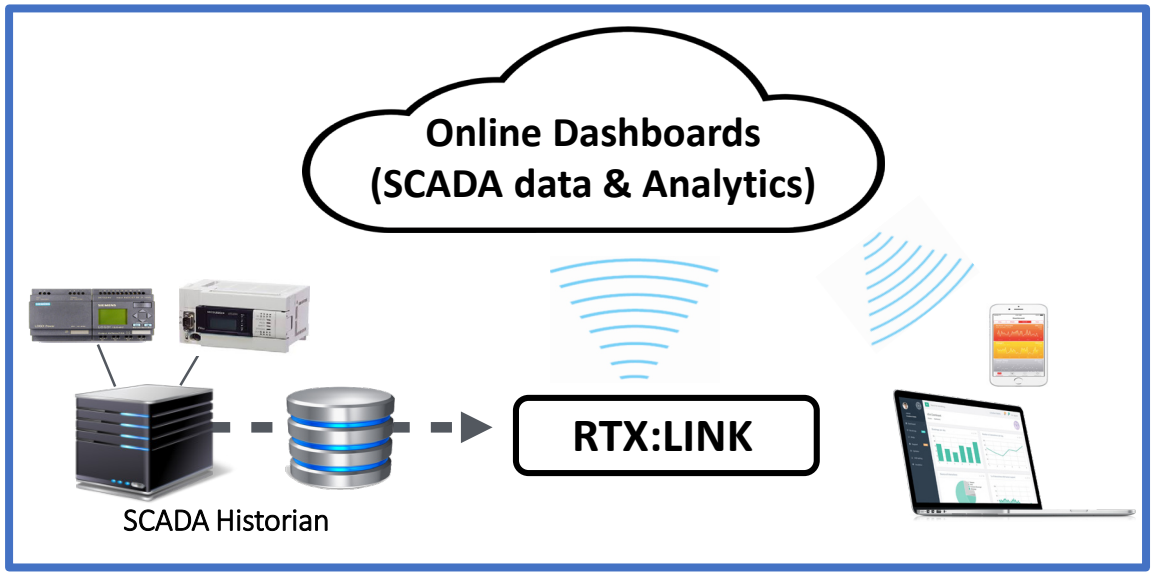


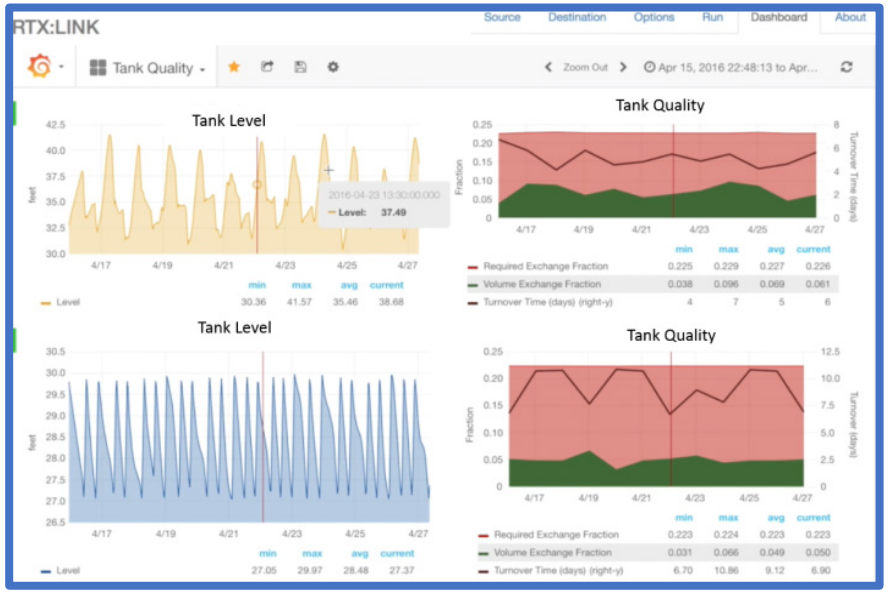


Distribution System Tool: RTX:LINK

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

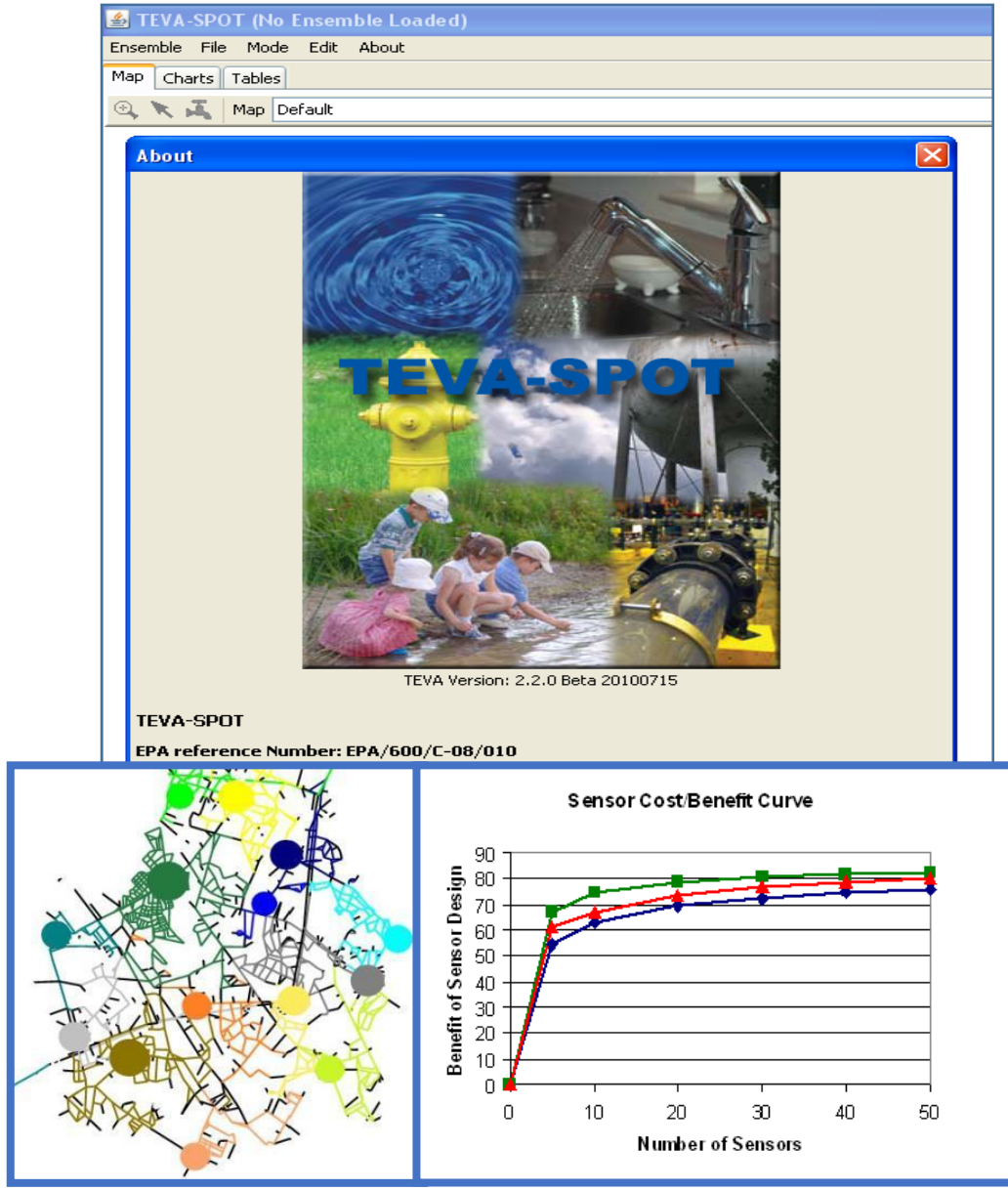
- Available for free on EPA's website.
- Shows real-time statistics and trends, water age, tank turnover time, tank degree of mixing, energy usage and system demand.
- Can alert based on min/max (set point) levels or other methods.
- Helps support rapid and accurate decision making at water utilities.





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.

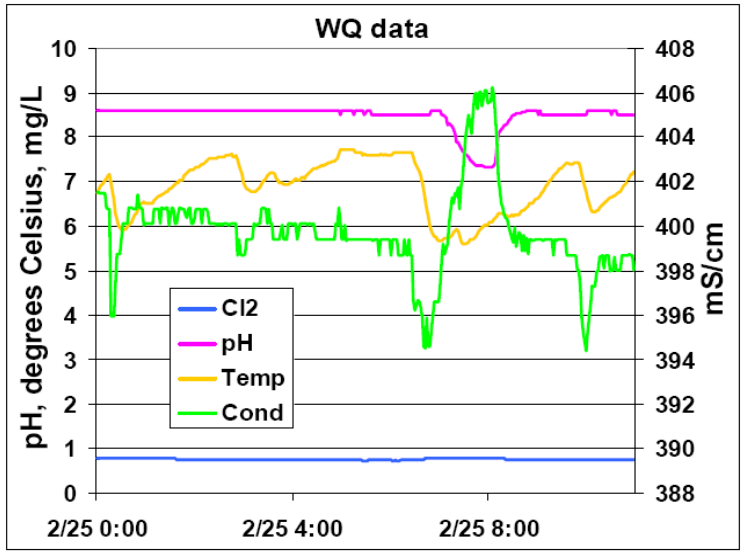


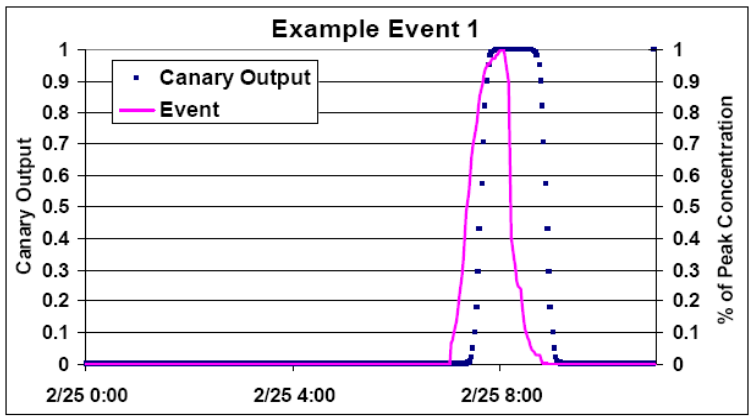
Distribution System Tool: CANARY

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



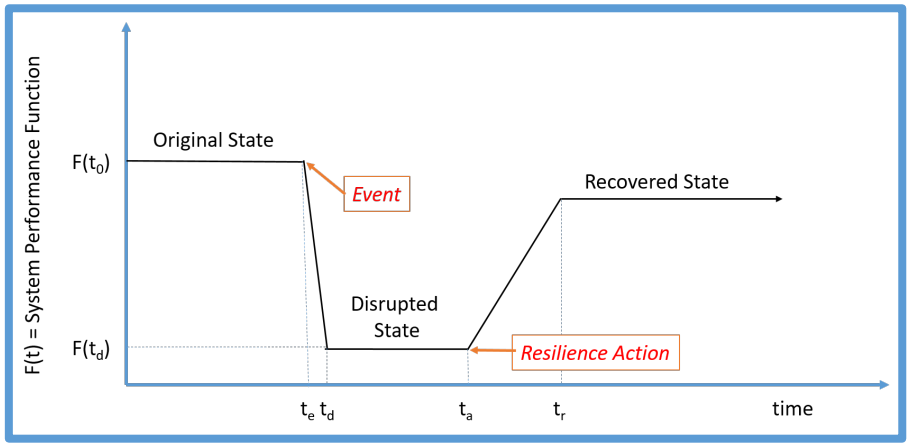


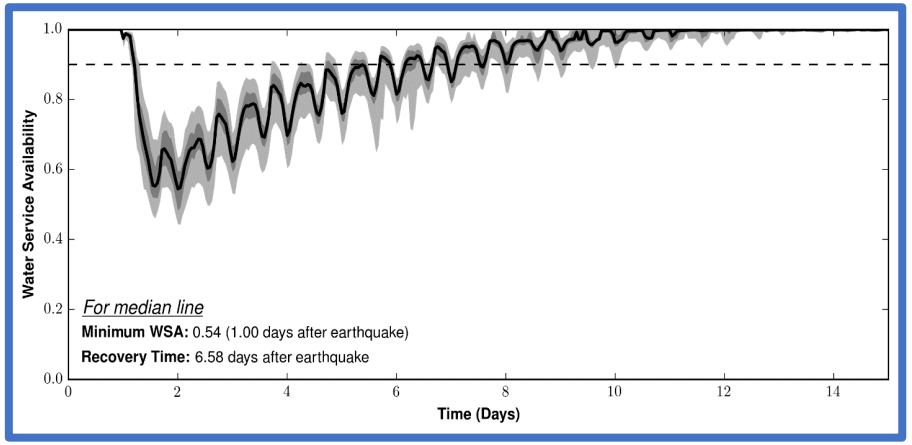
Distribution System Tool: WNTR

- 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

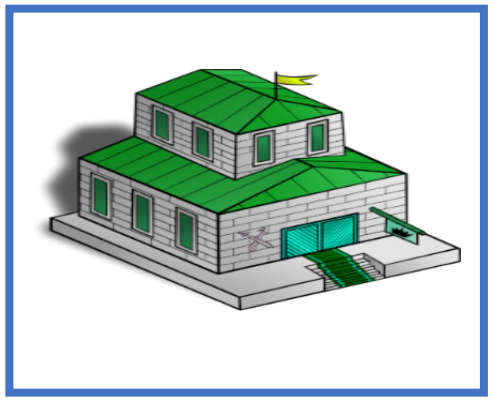
WNTR
Water Network Tool for Resilience

https://github.com/USEPA/WNTR





Drinking Water Models and Tools



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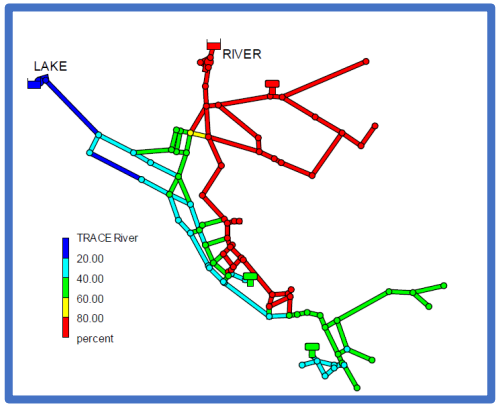

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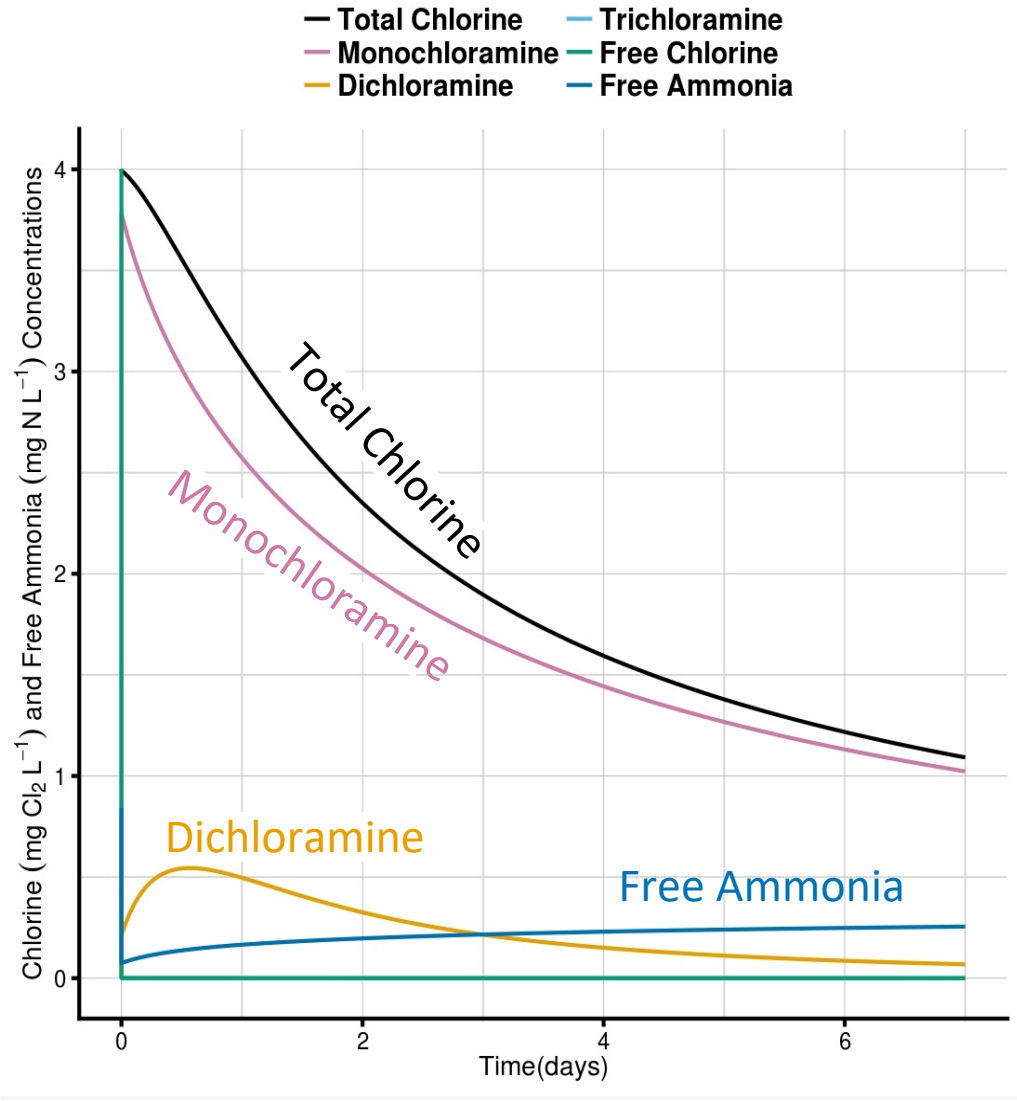
Access these models and tools through EPA's Science Models and Research Tools (SMaRT) Search

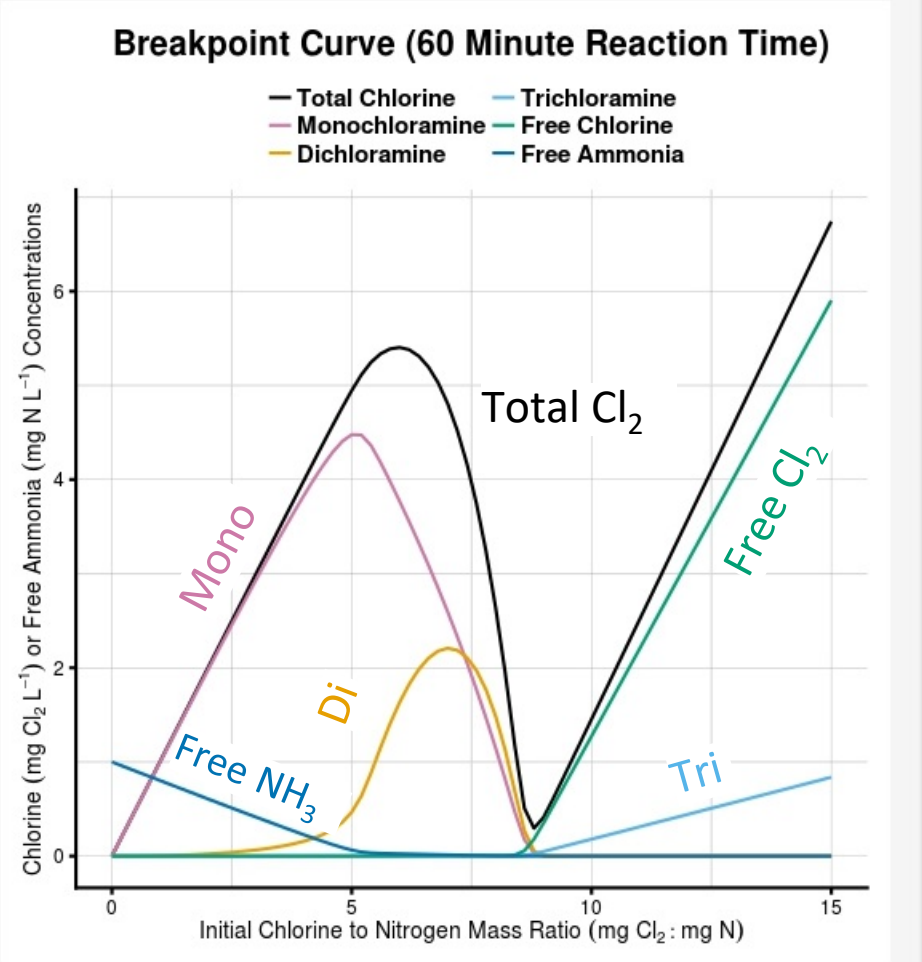
Treatment Models: Chloramine Formation/Decay

- 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

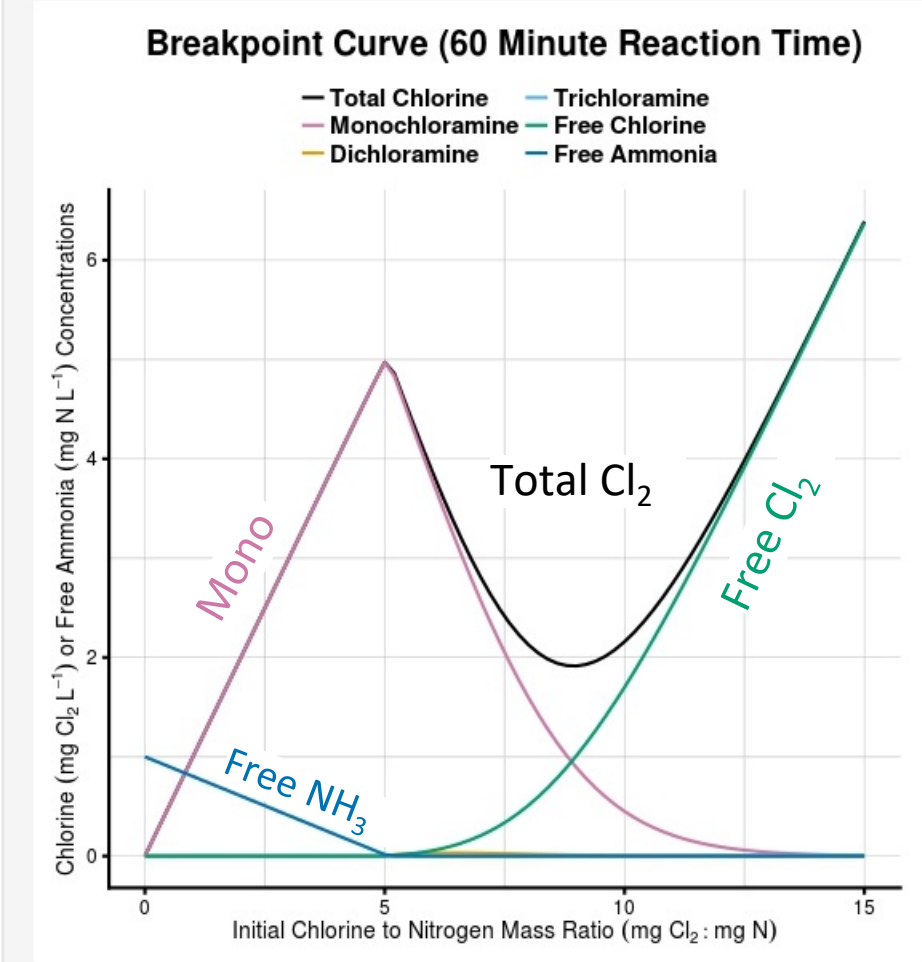
https://shiny.epa.gov/cfd/



Treatment Models: Chlorine Breakpoint Curve



pH 7

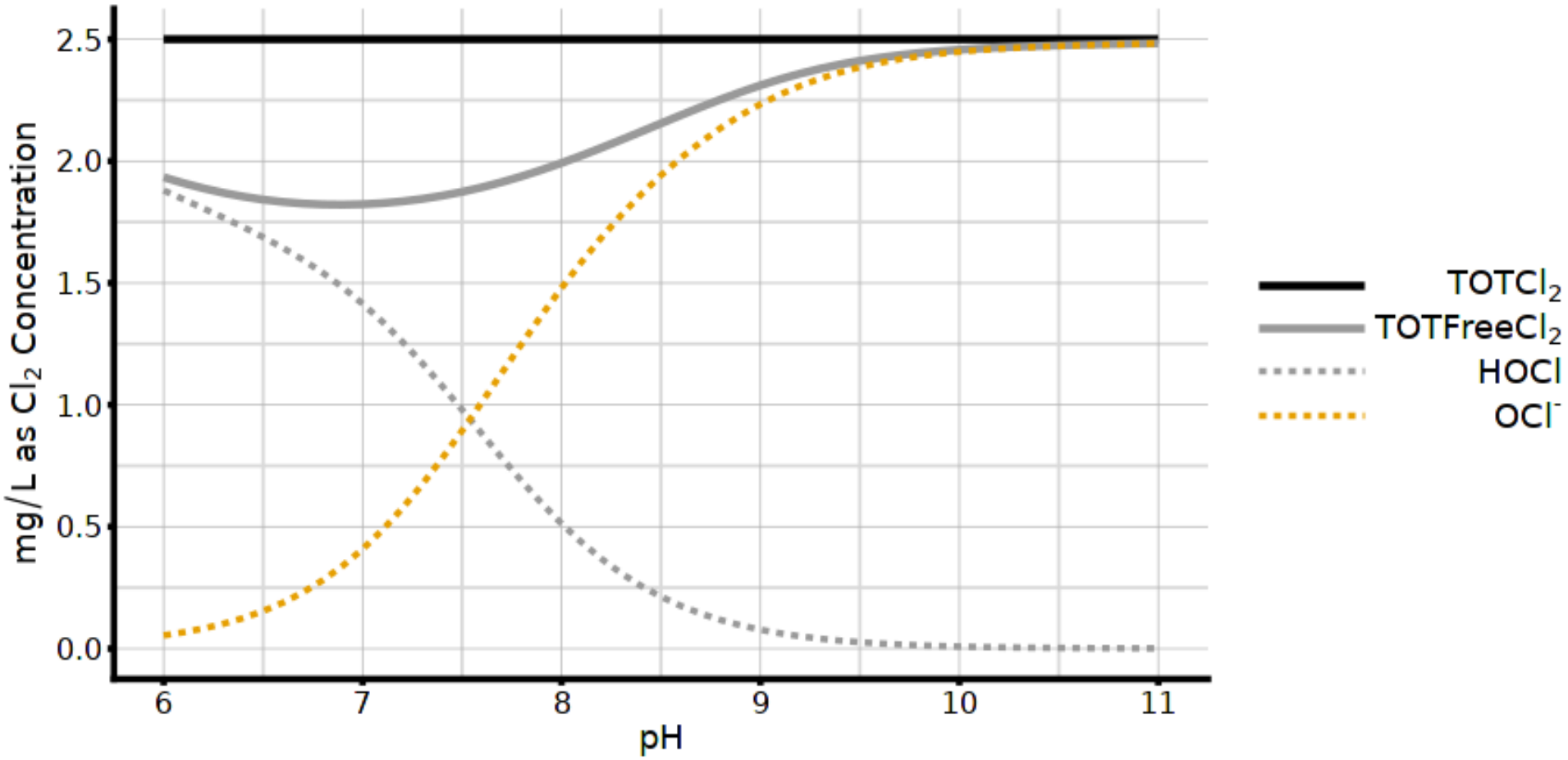


pH 9

https://shiny.epa.gov/cbcs/

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

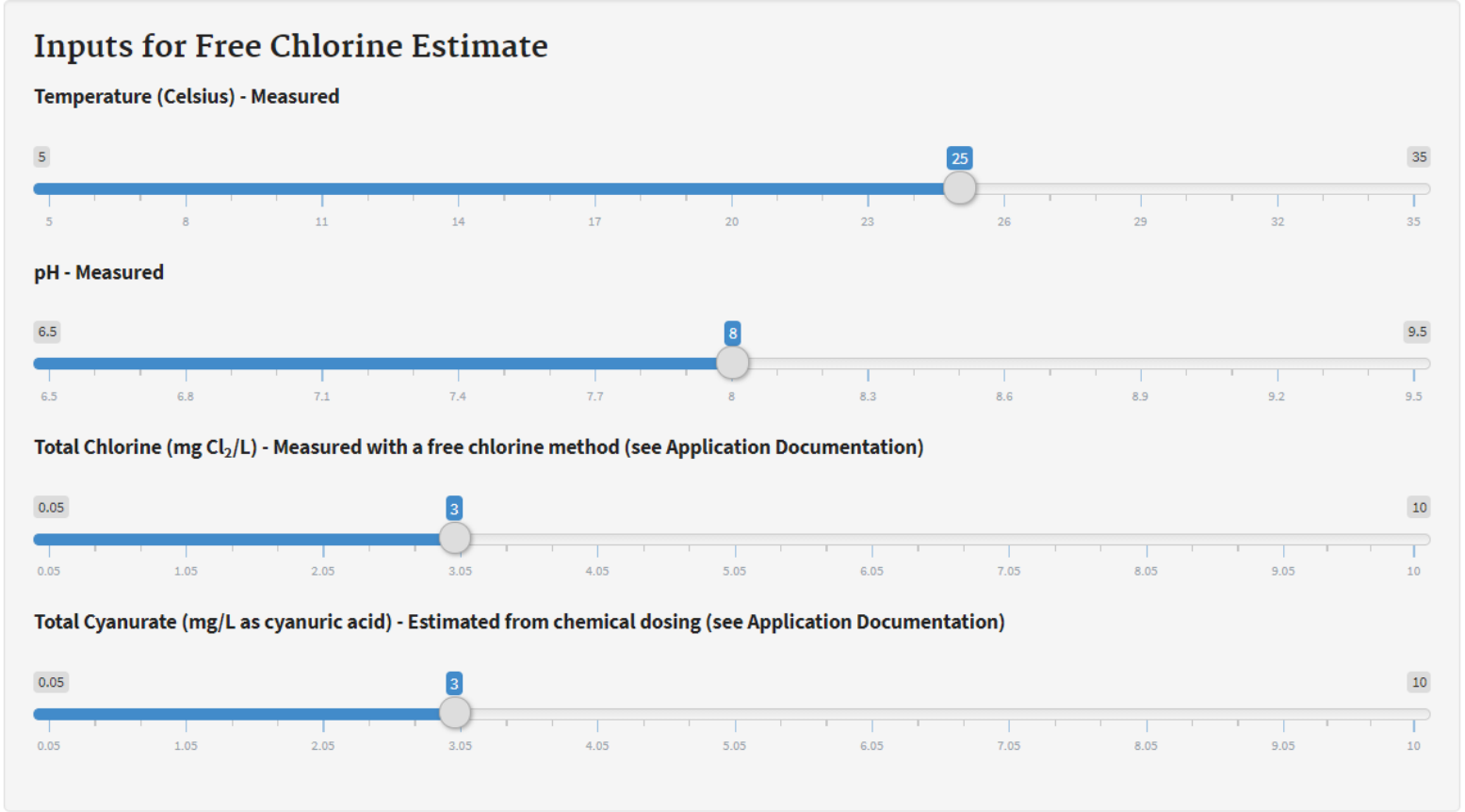


https://shiny.epa.gov/fccas/

Treatment Models: Free Chlorine Estimator for Dichlor and Trichlor Systems

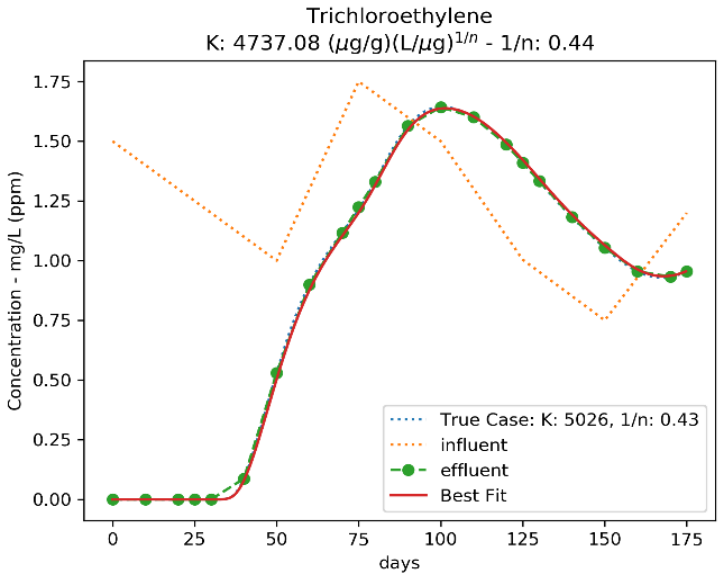
- Calculates free chlorine concentration.
- Dichlor or trichlor are used as disinfectant.
- Cannot accurately measure free chlorine in the field.

https://shiny.epa.gov/fcedts



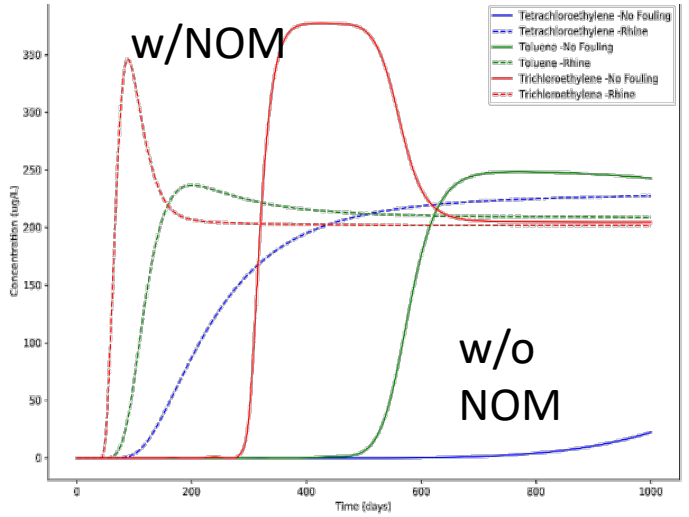
Treatment Models: WTM

- **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

Competitive Adsorption



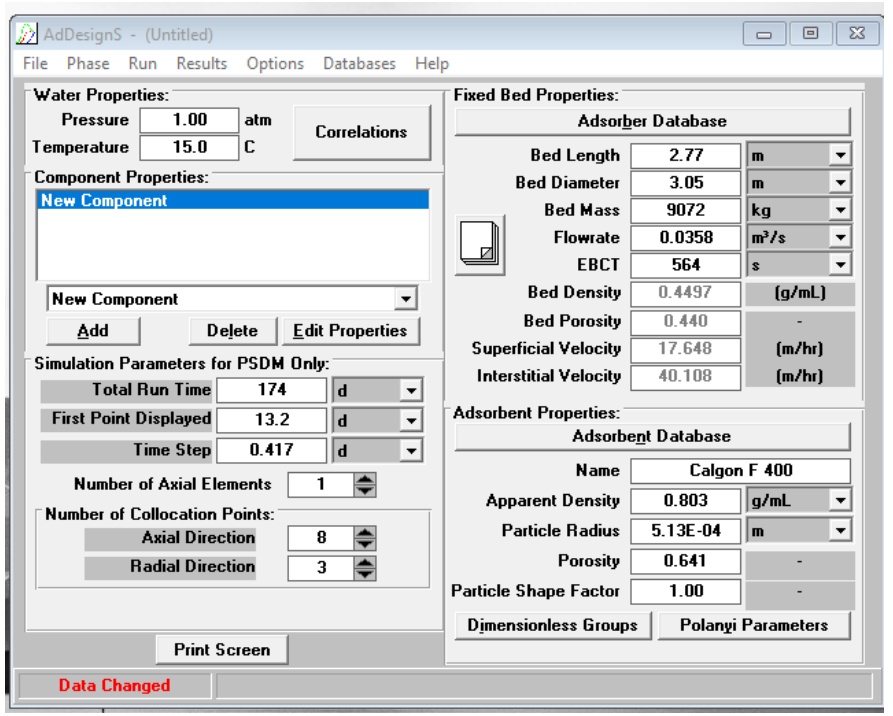
https://github.com/USEPA/Water_Treatment_Models

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

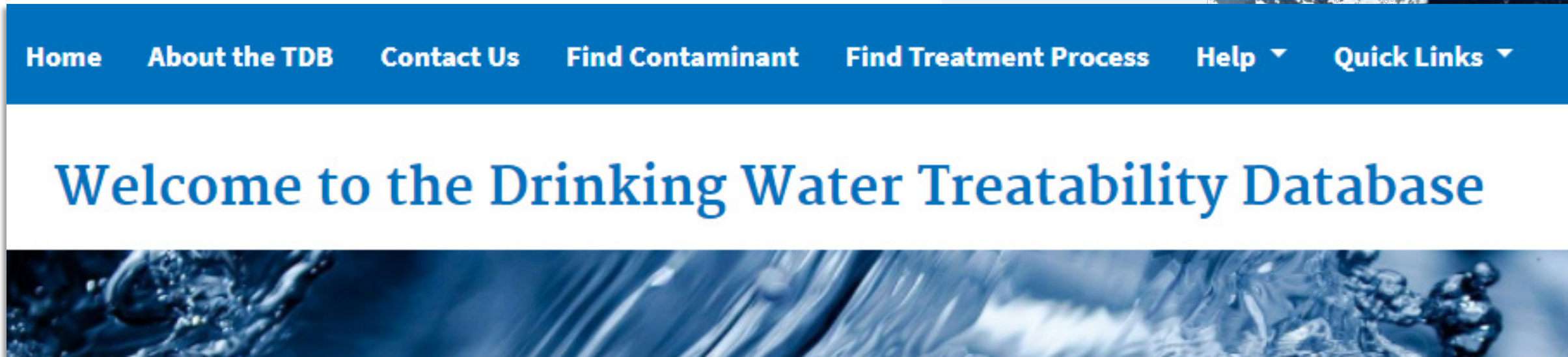


epa.gov/water-research/environmental-technologies-design-option-tool-etdot

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



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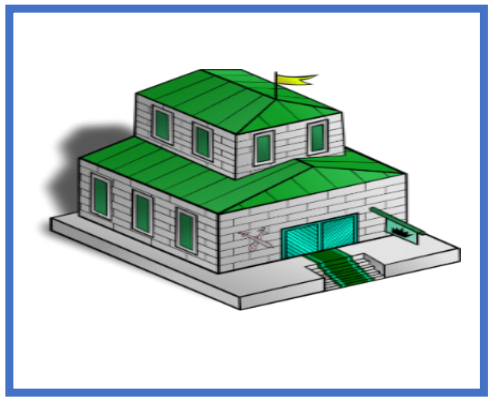

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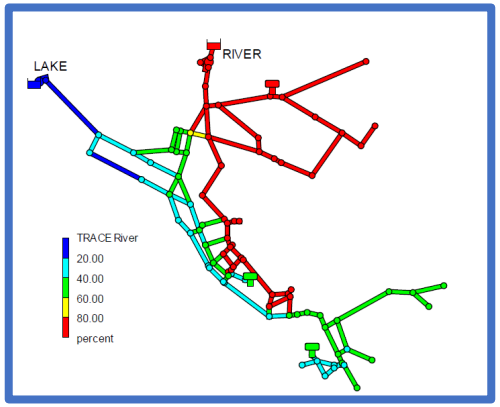

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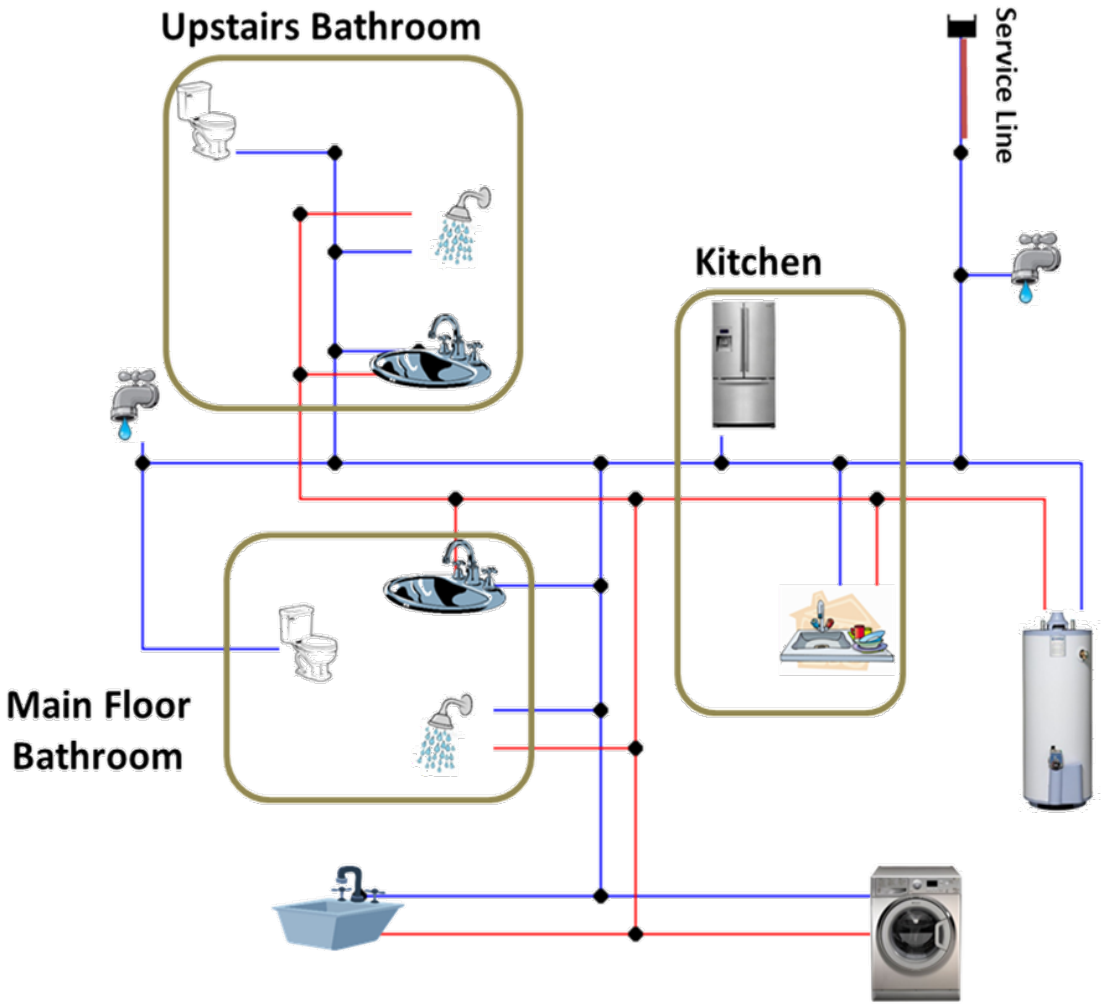
Drinking Water Premise Plumbing Models & Tools

- PPM Tools

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

Premise Plumbing Tool: PPM Tools



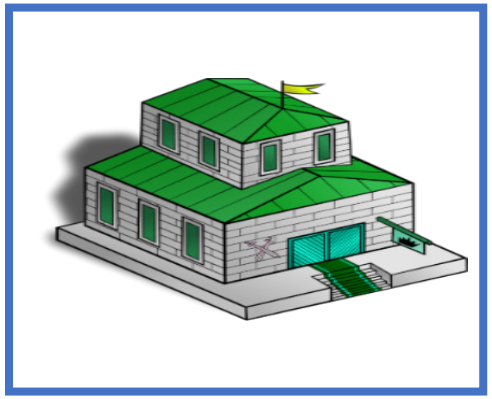
Premise Plumbing Modeling Tools (PPM Tools)

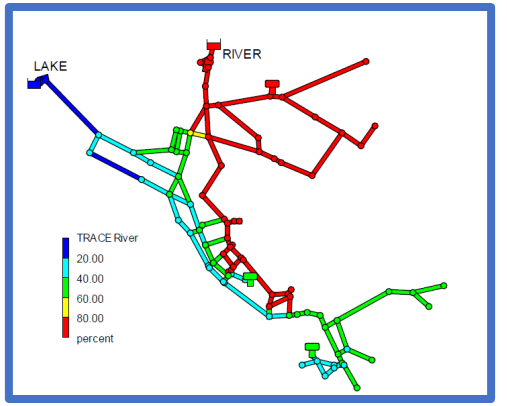
- Leverages EPANET and WNTR
- Models real-world fixtures
- Estimator realistic usage patterns
- Generates and runs many scenarios
- Predicts water quality information over time (e.g., water age, contaminant concentration)
- Simulates flushing to remove contaminants
- Estimates exposure to contaminants

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

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US EPA Office of Research and Development
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Specific Models and Tools:

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