Software for Drinking Water & Wastewater System Reliability: Evaluation, Optimization, and Effluent Quality Risk

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Current Problems with Water Treatment

RELIABILITY Problems

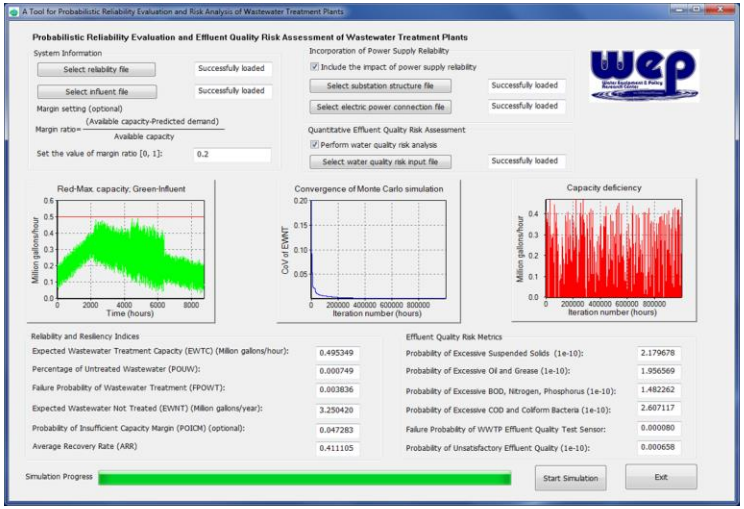
- Drinking water and wastewater treatment plants (WWTPs) are inadequate when it comes to quantitatively assessing reliability of the facility infrastructure
- There is a need to develop a comprehensive method to asses variables and uncertainties such as:
  - ➢ Random failures of mechanical components
  - ➢ The amount of influent
  - ➢ Power supply reliability
  - ➢ Biological risk analysis
  - ➢ Cyber attacks
- Many facilities are aging and are in need of expensive repairs

Our Solution

- Easy to use software and proprietary algorithms which aim to provide comprehensive decision support tools for evaluating the reliability of municipal water/wastewater systems
- Ability to guide cost-effective preventative measures before system failures
- Aid in making informed decisions on infrastructure repair, maintenance, and staffing when budgets are limited

<u>Areas assessed</u>:

- Reliability evaluation
- Impact of power supply reliability
- Effluent quality risk analysis



Intellectual Property and Market

- Copyrighted Code and proprietary algorithms
- Available for evaluation, testing, and licensing

Market

- The total opportunity based on the annual repair cost of broken water mains is approximately $3 billion
- The U.S. EPA recently found that municipalities expected to spend some $77.2 billion over the next 20 years to satisfy drinking water infrastructure needs
- The Clean Water Needs Survey found that over the next 20 years cities need to spend $10B on upgrading existing wastewater collection systems, nearly $22B for new sewer construction, $45B for controlling combined sewer overflows, and $7B to control municipal storm water

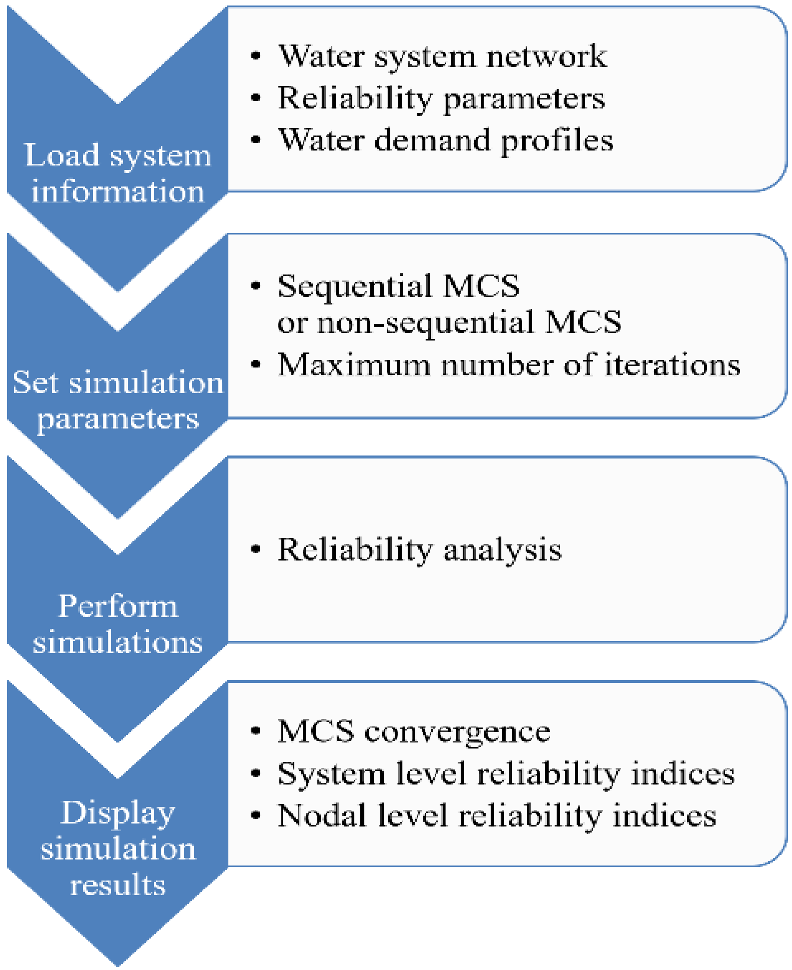
Reliability Evaluation Indices

- In this study, several reliability indices indicating both system-wide and nodal reliability performance are defined.
- The indices include the percentage of unsatisfied water demand (PUWD), the probability of loss of water service (PLWS) and the expected water not supplied (EWNS).
- All these indices indicate the system or node level reliability characteristics of the water distribution network from different perspectives.

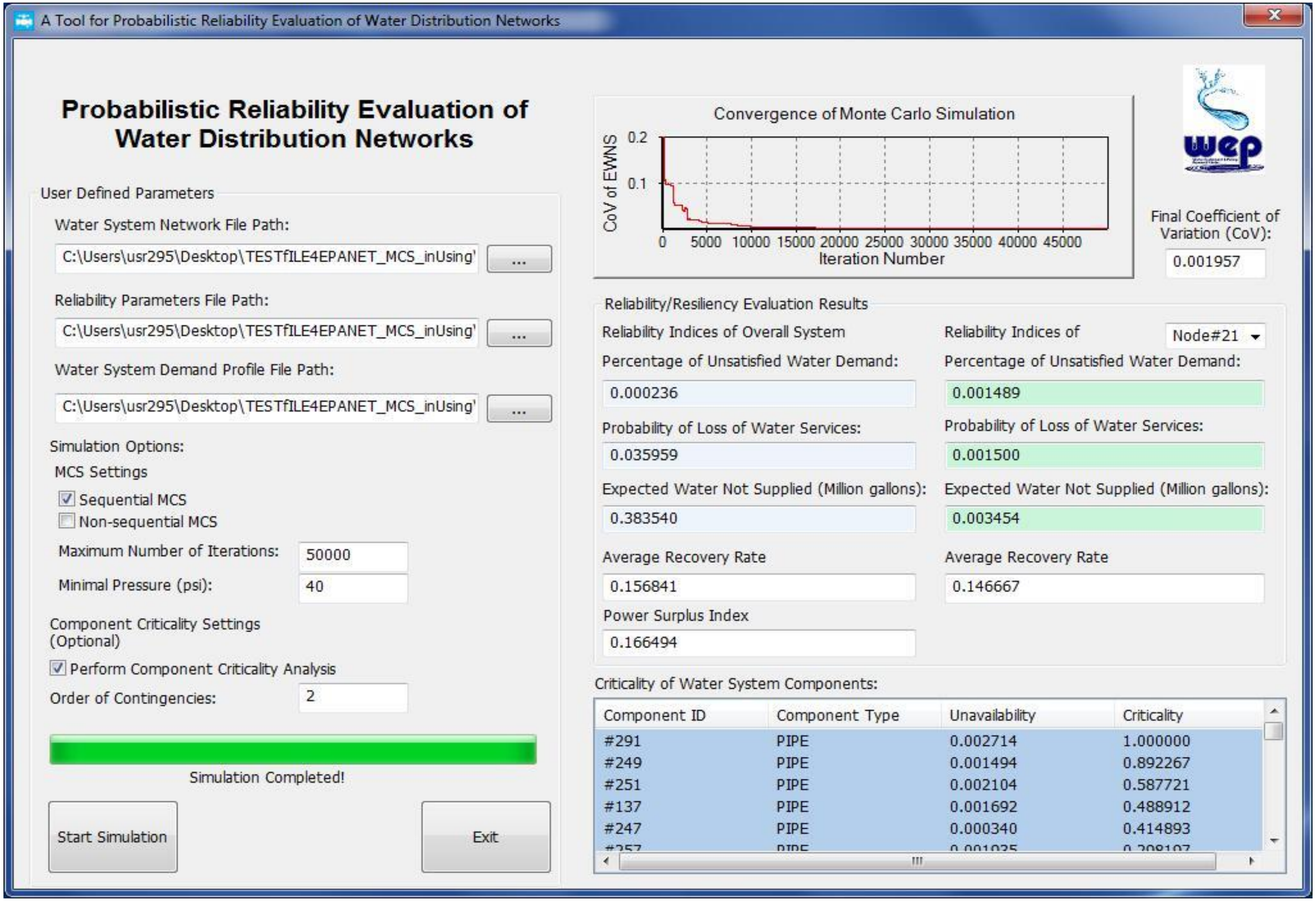
Criticality Analysis

- Due to aging or disturbances arising within the system, a system component in the water distribution system may fail
- A component may stay in the failure state for a certain period of time until it is repaired or replaced
- Quantitative reliability assessment of the water distribution system will enable quick and informed decisions
- Aids both planning and maintenance activities for maintaining or improving the reliability of the overall system

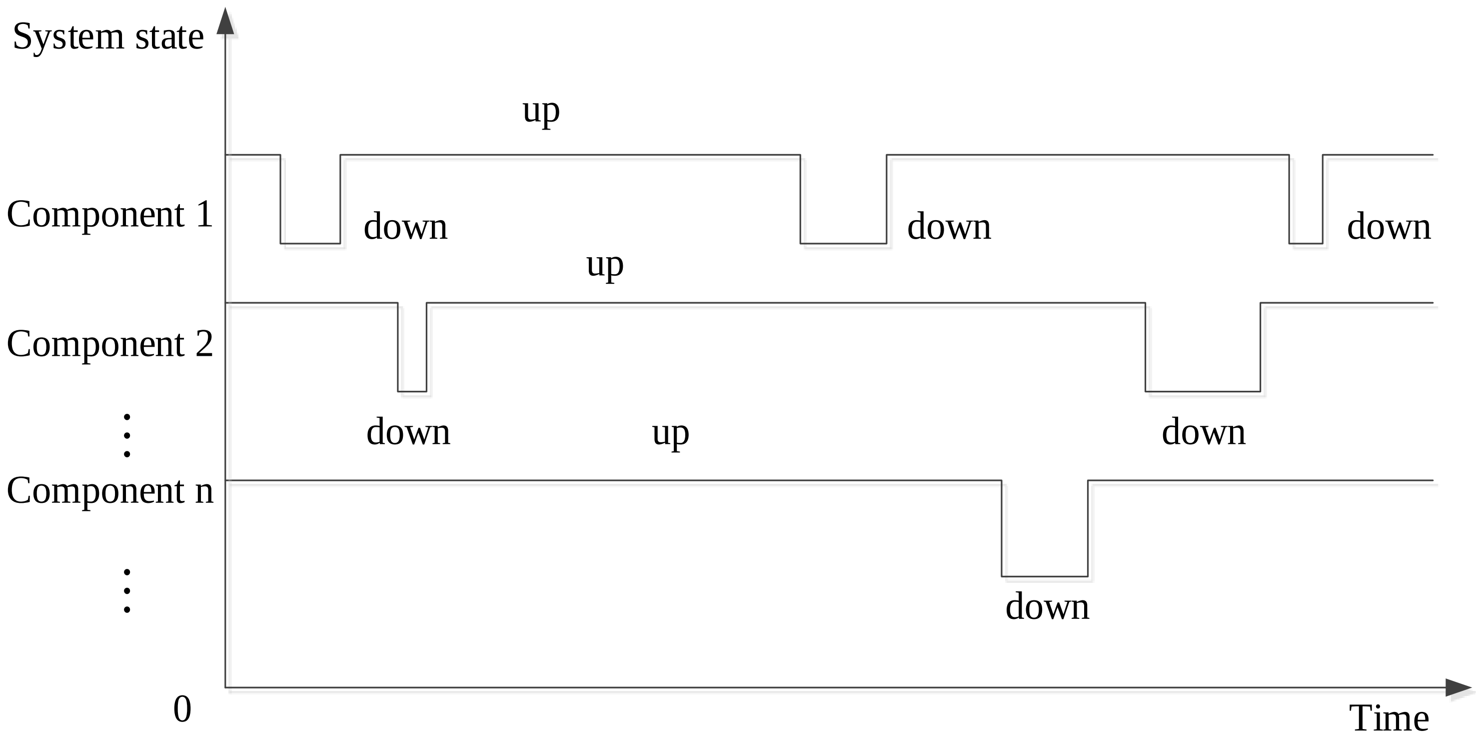
Software Simulation Drinking Water



GUI of the Drinking Water Software Tool



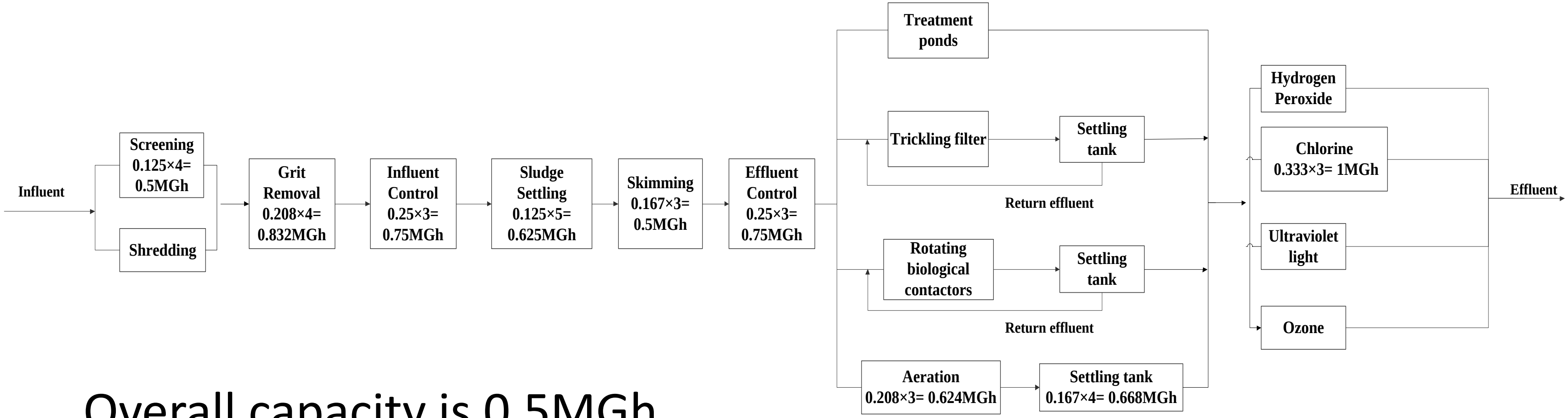
Component Status



- ➢ "UP" status indicates the normal condition of the component;
- ➢ "DOWN" status represents the faulty condition of the component.

Reliability Evaluation of WWTPs

- After all statuses of components are determined, the status (UP/DOWN) of a treatment process can be determined using the fault tree model.
- Then after all statuses of processes are determined, the available wastewater treatment capacity of the WWTP in each time interval can be calculated.



Overall capacity is 0.5MGh

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Effluent Quality Risk Assessment

- In this study, several pollutants are defined for treated discharges quality assessment, including *BOD, COD, Nitrogen, Phosphorus, Oil and grease, Suspended solids, Coliform bacteria*.
- Based on the function of each treatment process, the pollutants are linked to one or several treatment processes for removal or inactivation.
- For the fault tree analysis, the quality risk assessment of each pollutant is analyzed separately, and the overall effluent quality risk assessment of the WWTP is determined based on the results of each part.

3 Major Events for Risk

- For the quality risk assessment of each pollutant, there are three major events:
  - The treatment process failure (including mechanical failure and other possible failure modes, e.g., human errors, inadequate contact or reaction time, etc.).
  - Facility monitoring system failure.
  - Effluent quality test sensor failure.
- Three events should happen simultaneously to cause an effluent quality incident.

Software Simulation WWTP

Load system information

- Wastewater treatment plant configuration
- Reliability parameters of major components
- WWTP influent profile

Set simulation parameters

- The capacity margin for wastewater treatment
- (Optional) Power netowrk structure and connection with WWTP
- (Optional) Reliability parameters related to water quality

Perform simulations

- Mechanical reliability analysis
- Resiliency analysis
- (Optional) Power supply reliability analysis
- (Optional) Biological risk analysis

Display simulation results

- Simulation convergence
- System-level reliability indices
- Biological risk indices

Input Data for the Software Tools

- The collection and preparation of high-quality data are of critical importance for deriving meaningful decision information.

- The input data should be obtained from historical statistics, while expert opinions and estimation may also be needed in some cases if the historical data are not available.

- For data source selection, the selected drinking water network and WWTPs should have adequate historical data and they should be willing to cooperate in the data collection effort.

Potential Input Files

- For probabilistic reliability evaluation:
  - The WWTP influent input file (the amount of wastewater needing to be treated in the WWTP)
  - The WWTP reliability data input file (the reliability data of each WWTP component)
- For incorporating the power supply reliability evaluation:
  - The power supply system structure input file (the topological structure of the power supply system)
  - The electric power connection input file (the connection between the power supply system and the WWTP facilities)
- For quantitative effluent quality risk assessment:
  - The effluent quality risk input file (the failure probability of each basic event)

Summary

- Comprehensive, quantitative reliability/adequacy assessment of WWTP facilities accounting for uncertain factors
- At the component level, knowledge of the equipment failure rates can provide insight into deciding spare parts inventories
- At the system level, the tool can help refine overall future maintenance schedule/budget and staffing projections.

Future Steps

- Cyber contingencies/failures/intrusions
  - Analyze how the WWTP cyber network (SCADA) may fail or malfunction.
  - Integrate its impact into the fault tree analysis
- System Resiliency during extreme events
  - Extreme weather
  - Insider attacks
  - Physical attacks
  - Operator errors, etc.
- Improved usability/software compatibility

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