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Optimal Monitoring Location Selection for Water Quality Issues

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Significant effort has been placed in developing optimal sensor placement for protecting public health against intentional contamination events. However, there are benefits for optimizing monitoring locations for objectives other than public health protection. Additional applications include locating monitoring stations for achieving adequate distribution system coverage for field-scale tracer tests, and regulatory sampling associated with the Total Coliform Rule and the Stage 2 Disinfection and Disinfection Byproducts Rule.

This study presents a modified integer programming formulation for sensor placement, initially utilized for public health protection, that will incorporate both "spatial" coverage and surrogate measures for water quality issues (specified as water age in this study), and is illustrated via three test applications.

The Sensor Placement Optimization Tool (SPOT) is capable of solving multiple objective sensor placement problems by minimizing a single objective function and incorporating additional objectives through side-constraint formulations. The current challenge for solving water quality related problems is in adequately specifying the appropriate "spatial" and water quality coverage metrics.

Given the discrete nature of distribution system network topology and the underlying transport characteristics, adequate "spatial" coverage cannot be measured simply by the cartesian distance between two locations. However, an existing objective within the SPOT maximizes the differences between the travel paths "observed" by a limited set of sensor locations. This metric provides the foundation of "spatial" coverage by attempting to "observe" as many different travel paths as possible. Unfortunately, this metric tends to select locations at the edges of the distribution system. This drawback is reduced through the use of an additional objective to provide adequate distribution system coverage with respect to water quality issues.

The additional objective added to the SPOT minimizes the absolute difference between a target water age distribution and the water age distribution from the sub-set of locations to be optimized. The target distribution represents the desired water age distribution for the specific problem formulation (e.g., for a tracer test, the target distribution represents the water age from all nodes within the study region). The inclusion of this water quality objective can force sensors to *not* be placed at the edges of the distribution system to ensure that the water age distribution is adequately represented. Thus, the overall sensor design results in "observing" a maximum number of travel paths while representing the targeted range of water age.

The capabilities of the modified SPOT will be illustrated through application to three problems: a) selection of 45 sensor locations from 2000 network model nodes for implementing a large field-scale tracer test; b) selection of 14 sensor locations from 4000 network nodes for a retroactive analysis from a previously performed field-scale tracer test; and c) selection of monitoring locations to assist compliance with the Stage 2 Disinfection and Disinfection Byproduct Rule. The necessary

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input files to the SPOT will be generated using the EPANET Programmer's Toolkit, and network simulations will be of sufficient duration to reduce the impacts of the initial model conditions and utilize the last 24-hours of simulated data to test the modified SPOT.