HYDRAULIC MODELING AND OPTIMIZATION FOR REAL-TIME COMBINED SEWER OVERFLOW DECISION SUPPORT

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Older municipalities may experience combined sewer overflows (CSOs) during severe rainfall events. The Chicago tunnel and Reservoir Plan (TARP) was constructed to help mitigate CSOs by directing potential interceptor overflows via sluice gates to a deep tunnel. Sluice gate positions may be set at different intervals to partition flow between the CSO and the tunnel. Current gate operating rules restrict tunnel geysering by closing all gates when the downstream water surface elevation reaches 80 percent of the tunnel depth; this is a conservative strategy that may not utilize all system storage. This research seeks to better manage CSOs through a real-time decision support simulation that calls an efficient hydraulic model and a fast optimization routine. The benefits of real-time decision support are revealed for an interceptor and deep tunnel case study roughly based on the North Branch of the TARP system.

The hydraulic model developed for this real-time control case study uses a computationally implicit, stepwise steady computational scheme. Newton-Raphson iteration at each time step determines conduit water surface profiles and flow rates from the hydraulic performance graph (HPG) and volumetric performance graph (VPG). The HPG and VPG conserve momentum and mass, respectively, for each conduit and are offline curves constructed from conduit backwater profiles. The hydraulic model also includes tabulated equations based on the USGS FEQ model for flow through sluice gates to the deep tunnel. Lookup tables created offline allow for faster online computations, and the implemented model is shown to yield similar results to dynamic wave SWMM simulations.

Optimization takes place within a model predictive control (MPC) framework. At each 15 minute time step, a rainfall forecast is obtained and genetic algorithm (GA) iterations determine the combination of sluice gate positions and interceptor wastewater treatment plant pumping rate that best minimize CSOs for the next operational window (2 hours). Once a solution has been reached, the system state is updated to include the optimized gate positions and pumping rate, and the observed rainfall for the past 15 minutes. Three GA modifications are studied to reduce the total computational time. The first modification is a strategy in which GA memory is conserved between time steps by taking the best solution at the previous time window and shifting the decision variables to account for their implementation. The second approach is a reduction in decision variable values obtained by calculating the maximum water elevations under each sluice gate. The search alphabet is reduced by eliminating gate positions that do not affect the water surface. The third optimization approach is a micro-GA that enhances search diversity to quickly evaluate many solutions to the multi-dimensional problem.

Current operating practices require all sluice gates to be closed when the water elevation at the downstream end of the deep tunnel reaches 80 percent of the tunnel diameter. The test case

evaluated studies the North Branch tunnel which reaches a downstream junction with the Mainstream system; the water elevation at the junction is simulated with EPA SWMM. A new constraint is introduced that penalizes gate positions for allowing high North Branch inflow that causes water surfaces at the Mainstream junction to exceed 80 percent of the tunnel diameter. Results show the benefits of the altered constraint as well as the effectiveness of each GA approach.