PROJECT PROFILE

Dynamic Model Pinpoints Bottlenecks at Naval Hospital

As engineers working at the National Naval Medical Center (NNMC) in Bethesda, MD, demonstrated recently, storm events influence calculations even when a sanitary sewer system gets an upgrade. A rehabilitation plan to handle 10 years of future growth at NNMC incorporated not only population projections and predicted sanitary flows but also data for a 10-year design storm. The goal was to determine the current, total, and remaining capacity of the existing collection system and the impact of planned construction.

A dynamic modeling program helped limit costs and minimize construction disruptions at NNMC by pinpointing bottleneck areas where pipe diameter needed to be increased. By graphically illustrating variations in flow through the system as a storm passes through at different times in relation to peak sanitary flows, the model made it possible to identify choke points that required replacement with larger-diameter pipes to solve the most critical problems.

Almost a small city in itself, NNMC and its tenant activities employ more

than 6,500 people on a 243-ac. campus in Bethesda, in the Washington, DC, metropolitan area. The infrastructure consists of more than 5 million $ft.^2$ of patient care, research laboratory, educational, and supporting space. The hospital serves as a contingency platform in the event of a national disaster. Outpatient clinics see 2,500-plus patients per day. NNMC also contains housing for more than 1,000 personnel, recreational facilities, stores, restaurants, fire and police services, and a steam/chilled water plant.

Scope of the System

NNMC's sanitary sewer system consists of 19,000 lin. ft. of gravity sewer ranging from 4 to 15 in. in diameter, a pumping station, exterior detention structures, and other components. Michael Baker Jr. Inc. of Alexandria, VA, performed an evaluation study of the system. Baker engineers modeled the entire system using Hydra software from Pizer Inc. of Seattle, WA, to identify the current, total, and remaining capacity of each modeled pipe reach, detention structure, and pump station under existing and future condition loadings. For the capacity analysis, the sanitary collection system within the study area was divided into 12 drainage basins, which were used for flow monitoring to allow accurate calibration of the model. Subdividing the collection system in this fashion and creating a separate model for each basin means that any revisions to the model resulting from future development will require recomputing only the hydrographs for pipe reaches within the area of development.

Generating Hydrographs

Baker engineers analyzed flow monitoring data, rain-gauge data, and closed-circuit television data to determine both the wastewater flows within the system and defect flows that enter the system. The software allowed separate allocation of the wastewater flow and the defect flows within each pipe reach. Defect flows consist of rainfall-dependent infiltration and inflow (RDI/I) and groundwater infiltration (GWI). The RDI/I is input into the model as an effective area in square feet, within which rainfall is captured and eventually migrates into the defect or defects in the system. This method of specifying effective contributing areas allows for analysis using both actual storms and design or theoretical storms.

To develop the model, John Ricks, P.E., the engineering manager for Baker, and Derek Thorsland, an environmental engineer, represented the conveyance system and system flows by entering the physical characteristics of each pipe and flow information into the model to form hydrographs. These hydrographs were then routed through the modeled system.

NNMC provided current population data to compile existing and projected average sanitary flows by building. US Census Bureau population predictions for surrounding areas through 2009, as well as planned construction, were taken into account.

Determining Dry- and Wet-Weather Flows

Dry-weather average base flow (ABF)—the typical flow in sewer systems during nonrainfall periods—is the combination of average sanitary flow and GWI from sources other than rainwater. For this analysis, ABFs were developed from flow data collected during nonrainfall days not impacted by prior storm events. Each monitoring day was noted as dry, wet, or "influenced." Average weekday base-flow hydrographs were developed for each drainage basin by averaging the flows from the dry weekdays during the base-flow period. GWI rates were estimated through an evaluation of nighttime flows occurring in the average (dry-weather) base flow.

Determining wet-weather flows in the sanitary sewer system involved evaluating the impact of rainfall events, groundwater levels, and wet-weather flow monitoring data. Wet-weather flow consists of dry-weather ABF plus RDI/I. Average dry-weather base-flow curves were compared to weekday wet-weather flow curves and rain events to determine the response of the wastewater system flows so RDI/I could be estimated. Flows resulting from the selected design storm helped determine not only the impact of RDI/I on flows conveyed by the system, but also projected reduction in peak flows resulting from several targeted infiltration/inflow reduction strategies.

A six-hour-duration storm with a recurrence interval of 10 years was selected as the design storm, based on review of rainfall records for the Northeast, comparison with approaches taken by other public agencies, the size of NNMC, and an understanding of the sewer system and surface waters at NNMC. This storm has a total rainfall of 3.48 in. and was designed based on intensity-duration-frequency curves for Beltsville, MD. All drainage basins were evaluated using this 10-year design storm.

Calibrating the Model

The Hydra model of the NNMC sanitary

sewer system was calibrated using the flow monitoring data for April and May 1999. Flow input at various modeled system entities was allocated so that the model would more accurately represent the actual system flow patterns for both dry- and wet-weather conditions.

The model was run eight different times with different loads for each drainage basin. The first run, based on existing system dry-weather conditions, was used to calibrate the model for dry-weather conditions. Similarly, the second run, based on existing system wet-weather conditions, was used to calibrate the model for wet-weather conditions. The third and fourth runs used existing system conditions with the 10-year-frequency design storm and modeled the system with and without recommended repairs. The fifth and sixth runs used future system dry-weather conditions, which included population growth estimates and future construction where applicable, and modeled the system with and without the repairs. The seventh and eighth runs used future system conditions with the 10-year-frequency design storm and modeled the system with and without the repairs.

Recommendations

Although the capacity analysis indicated that the majority of the system is sized adequately to handle both existing and potential future flow conditions, several pipe reaches in two drainage basins appear to decrease the performance and capacity of the system under design-storm conditions. Under all other modeled conditions, including those that considered only projected population growth and future construction at NNMC, no other pipe reaches were identified as exhibiting capacity problems. As a result, Baker and the Engineering Field Activity Chesapeake recommended that NNMC replace only the pipe reaches that are hydraulically overloaded and perform selective and far less expensive rehabilitation on the rest of the sewer system. Selective rehabilitation will reduce infiltration and inflow—and therefore total flow—to help protect against any future decrease in performance and capacity and will help reduce treatment costs and reduce the burden on the receiving wastewater treatment plant.

The cost of developing a rehabilitation plan using these modeling techniques was approximately $100,000, significantly less than upgrading the entire system without the insights of the dynamic model.

Figure 1: The procedure for determining the wet-weather flows in the sanitary sewer system at NNMC involved an evaluation of the impact of rainfall events, groundwater levels, and wet-weather flow monitoring data. Wet-weather flow is composed of dry-weather ABF plus RDI/I. Dry-weather ABF curves were compared to weekday wet-weather flow curves and rain events to determine a storm event that induces a response in the wastewater system flows so that RDI/I could be estimated.

Figures 2 and 3: Calibration of the model with actual meter data produced very good results. Good calibration results provide confidence in the model setup, simulation, and results when projecting to design or other wet-weather conditions.

Figure 1. Flow-Data Summary
Wet-Weather Day Compared to Average Dry-Weather Flow With GWI and Rainfall Shown

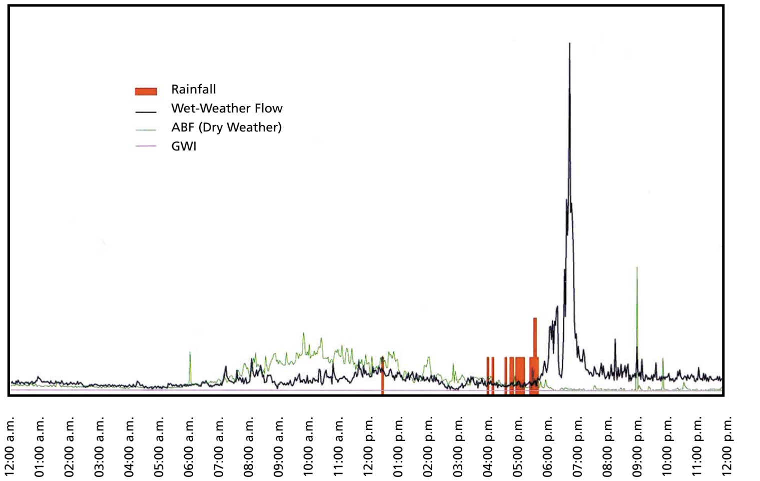

Figure 2. Meter Data vs. Model Results (Dry Weather)

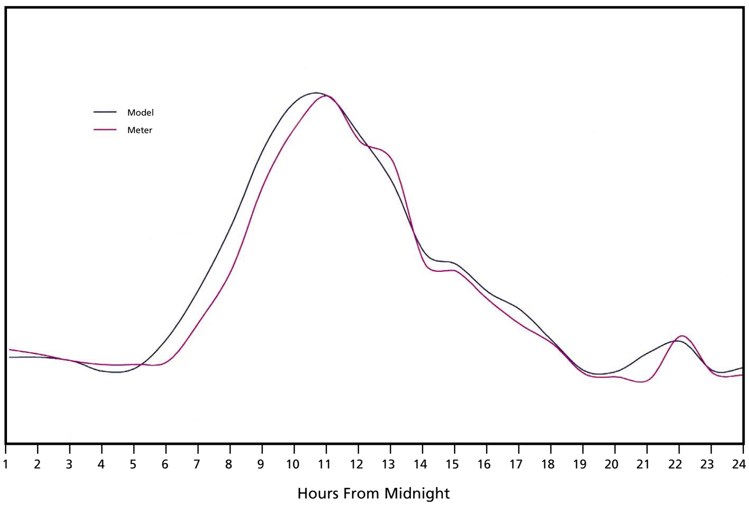

Figure 3. Meter Data vs. Model Results (Wet Weather)