Direct Filtration for Wet-Weather Conditions

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Deep-bed sand filters have been found to be capable of processing wet-weather, peak-flow, sanitary sewer overflow (SSO) events at high filtration rates. As a result, a $300 million peak-flow treatment facility is being constructed at the Village Creek Wastewater Treatment Plant near Birmingham, Alabama.

Flow to the existing Village Creek biological treatment plant can increase from the normal 30 million gallons per day (MGD) to 360 MGD or higher because of infiltration during significant rain events. In the past, any excess flow over about 80 MGD had to be bypassed to the Village Creek waterway.

Village Creek feeds Bayview Lake. Both the creek and lake are considered impaired and have been the focus of continuing improvement efforts by community groups and governments for nearly two decades. The new peak-flow wastewater-treatment facilities will contribute significantly to these goals.

The new treatment system includes a diversion interceptor structure and tunnel to partially bypass the existing biological treatment plant during rainstorms and to supply a base flow of wastewater to the new plant between rain events. Other parts of the new construction are a large pump station, surge basins with 90 million gallons of storage volume (four hours' capacity at peak flow), a second, new biological treatment plant, deep-bed sand filters, and ultraviolet (UV) disinfection.

Operation of the filters will be innovative, based on piloting done at the Village Creek plant site in the summer of 2000. The filtration study was commissioned by the Environmental Services Department of Jefferson County, Alabama, and by consulting engineers Gary L. Owen & Associates. A large filter pilot plant was supplied and operated by Severn Trent Services with help from Jefferson County personnel for operation and sample testing. Over the course of the summer during a variety of tests, over 1 million gallons of wastewater was treated by this pilot plant.

Pilot Testing

The filter pilot plant was set up near the front end of the Village Creek Treatment Plant next to a source of raw plant influent wastewater treated only by coarse screening and grit chambers. The raw wastewater was piped to a mixing tank. Plant reuse water was added to the tank to adjust the total suspended solids (TSS) content to the projected wet-weather conditions of 100 mg/L TSS. A submersible pump was placed in the tank to supply wastewater to the pilot filter plant. The pumped flow passed through an in-line mixer (for possible chemical addition) and a flow meter on the way to the top of the filter.

The filter pilot plant contained two 10-square-foot filters, each housing a six-foot depth of large, rounded sand filter media. The filter effluent passed through a clear well with the same overflow elevation as the top of the filter media. The water level rose above the media as head loss increased. When needed, the filters were backwashed from the clear-well supply with a vigorous combined air/water backwash. Very short backwashes using water alone were also employed to control head loss. Automatic samplers collected filter influent/effluent composites for each filter run.

The pilot program lasted over two months while a variety of flow and solids loadings and operating techniques were investigated. The focus for future design purposes became loading the pilot filters with about 100 mg/L TSS wastewater at 10 gallons per minute per square foot of filtration area (100 gallons per minute per 10-square-foot filter cell). This represented applied loading rates two to four times higher than previous experience and required the development of new ways to maintain filter flow. Results from weeks of repetitive testing were very good:

Influent TSS – 37 to 197 mg/L, average 94 mg/L
Effluent TSS – 7 to 18 mg/L, average 12 mg/L

Influent CBOD – 28 to 92 mg/L, avg. 49 mg/L
Effluent CBOD – 10 to 26 mg/L, avg. 17 mg/L

The best effluent and longest filter runs were achieved with no chemical addition. Monthly average effluent requirements were 30 mg/L TSS and 25 mg/L CBOD. The filter pilot plant met these limits with room to spare.

With high influent flow and solids loadings like these, filters that were operated conventionally would quickly plug. New methods of operating and backwashing were developed during this pilot study to keep the water moving. These methods are now patented or patent-pending.

One proprietary operating method, SpeedBump™, involved stopping effluent flow, reversing flow using the backwash pumps for a short period, then proceeding immediately to the next filter while flow was restored to the first filter, and so on. Closing influent valves during this process was optional, depending on the initial filter water level. This continuous process can roll through a group of filters very quickly and provides a surprisingly effective reduction in backed-up wastewater and improved flow through the filter from 20 minutes up to two hours. This technique was a key to achieving reasonable filter run times when handling high flow rates of wastewater and heavy solids loadings.

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Further testing was done to simulate the "first flush" of the collection system in the first few hours of a major rain event. This testing led to the development of new backwashing methods to allow for the continuous application of 200 to 500 mg/L TSS undiluted raw wastewater to the filters at about 5 gpm/ft^2. With this very high loading, filter run time was cut to about one hour, even with 20-minute interval speed bumping. A short air/water backwash of only a few minutes in length was found to be sufficient to get wastewater flow going again by expelling most of the solids causing the backup.

This method will be automated in the large filter plant to proceed continuously, seamlessly, and quickly from one filter to the next, completing the circuit in sufficient time to operate at elevated solids loading conditions. This proprietary, rapidly indexing backwash is called SpeedWash™.

The results of these first-flush treatment tests still produced effluent quality of about 40 mg/L TSS, below the projected weekly permit average of 45 mg/L. This gives operators more options.

Results & Discussion

Successful piloting results allowed the full-scale filtration plant to be designed and bid in late 2000. A contract was awarded in early 2001 with completion set for September 2003. The final plant design included 22 filters, each at 1,167 square feet.

The filters will be laid out in two trains

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with room for future expansion. The new control methods and innovative piping designs (a technology package referred to as StormMaster™) will allow continuous, rolling execution of as many as two simultaneous air/water backwashes and four water-only backwashes to proceed at the same time, divided among the two filter trains to control head loss through the filters and expel excess solids during wet-weather events. These events will peak at up to 360 MGD for four hours, with elevated flows persisting for as long as 24 hours. Dirty backwash water will be sent to thickeners in the biological wastewater treatment plant.

The full-scale filter design is a heavy-duty one that has been proven in large new high-flow rate plants in Atlanta and also in heavy industrial and steel-mill service all over the world. The filters serve a valuable role of effluent polishing for many municipalities, especially in Florida. The filters will perform this polishing function at Village Creek in between the several significant rainstorms per year.

One key feature of the filters is the six-feet-deep bed of large, rounded sand that allows high flow rates, large storage capacity for heavy solids loadings, and long run times. Self-flocculating mechanisms for solids lodged within the filter media reduce the need for chemical addition.

A second key feature is the T-block™ filter underdrain, a series of rows of special arched concrete blocks that rest on the filter floor with large passages for water flow underneath and between rows. This design is very resistant to biological fouling and so is ideally suited for wastewater applications. The blocks also protect the backwash air distribution system.

A third key feature is the system of stainless-steel backwash air laterals underneath alternate rows of T-blocks. This system meters air precisely underneath the entire bottom of the filter, allowing for even, effective backwashing. With reliable backwashing, the filter can recover from very heavy loadings. The design can stand up to heavy-duty conditions for years. Many filter plants using this design are now over 20 years old with no major maintenance or media loss.

Simultaneous air/water backwashing provides far superior cleaning capability and much lower water consumption than separate air scour and high-rate water wash, which will be extra important in a filter plant of this size, loaded this heavily. Backwash water consumption is calculated during rare peak-flow operation to be about 10 percent of forward flow, but only 1 to 2 percent for normal operation. Other filter types in a field survey were averaging 11 percent of forward flow for backwash, even for normal operations. The Village Creek plant will benefit from reduced recycle flows and treatment costs.

Adjacent to the filter plant will be 24 surge basins so that the first flush of undiluted wastewater with the highest concentration of pollutants can be held for processing later. This water may be applied directly to the filters at the operator's discretion.

The new biological treatment plant will also take some of the surge flow directly. To keep the new biological plant active between storm events, which occur five to 15 times per year, a permanent portion of the water now treated by the old plant will be diverted to the new plant for treatment. All wastewater treated by the new biological plant will also end up going through the new filters.

Final effluent after filtration is treated by UV disinfection before discharge to Village Creek. UV disinfection is greatly enhanced when supplied with filtered water for kill effectiveness, reduced power draw, and greatly lowered tube maintenance.

The new facilities being built at Village Creek will provide a great advance in wet-weather, peak-flow treatment practices and knowledge. This knowledge will have application to SSO, combined sewer overflow, and other stormwater treatment as well.