Bloomington Water Treatment Plant Operations Manual

Filter Surveillance and Operation

updated: July, 2006

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Filter Surveillance and Operation

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Introduction

This manual is intended to give an overview of filter operation and surveillance. It should be noted that, as part of a water treatment system, filtration is strongly related to previous steps in the treatment process and cannot be looked at completely independently. Ineffective pretreatment, including coagulation, softening and sedimentation or post-precipitation of calcium carbonate during recarbonation, can result in ineffective filtration.

Filtration is often considered the principal particle removal process in water treatment. However, only a small fraction of the particles entering or produced during water treatment are actually removed by the filters. By far, most of the particles originating in Bloomington's lake waters or created during softening in the ClariCones are removed in the clarifiers. The filters act largely as effluent 'polishers'. However, as of January 2002, new federal and state regulations have caused utilities to focus more attention on the performance of individual filters.

About the Filters

In total, there are 18 dual media (GAC/sand) filters installed at the Bloomington plant.

The twelve filters in the 'old plant' (Annex, 1929) were constructed in three groups of four that went into service in 1929, 1956 and 1966, respectively. Each filter box presently contains 19 inches of granular activated carbon (GAC) overlying a 12 inch layer of silica sand. Used primarily for taste-and-odor control, the GAC is replaced with new, virgin carbon on a three year schedule. Four filters are serviced each year.

At the time of carbon replacement, the height of the sand interface is measured in each bed. Since granular filters tend to lose 5 to 7% of their media each year, make-up sand is added to restore the original sand bed height of 12 inches.

Rated at 1.5 gpm/ft^2 (a downward flow velocity of 3.8 meters per hour), the 'old plant' filters are nominally operated around 0.6 gpm/ft^2 (1.5 m/h) This results in a substantial empty bed contact time (EBCT) of 19 minutes within the 19-inch layer of GAC.

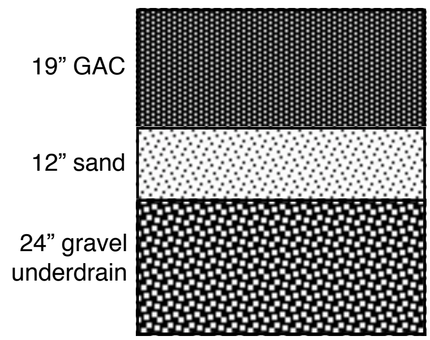
The six filters in the Main Building ('new plant') were constructed in 1994. Each filter consists of two separate filter boxes served by a single influent and wash water gullet. A 24 inch layer of GAC overlies a 12 inch layer of filter sand. Rated at 3 gpm/ft^2 (8 m/h), these filters are normally operated around 2 gpm/ft^2 (5 m/h). For 24 inches (0.61 m) of GAC, the EBCT is 7.3 minutes. GAC is replaced every 2-years.

New plant filter showing rotating arm surface wash

Vertical section of GAC undergoing replacement

The twelve filters in *Bloomington's Annex Building* each consist of a single 20' by 21.75' cell, providing an area of 435 square feet per filter.

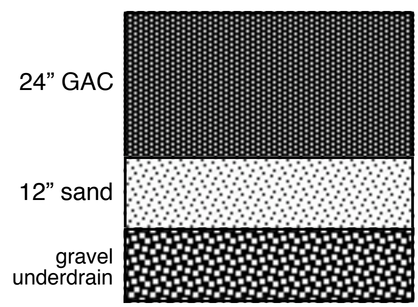
A flow in the range of 0.5 to 0.6 MGD through each of the 'old plant' filters is considered optimal. This corresponds to slightly less than one gallon per minute per square foot, a very conservative surface loading rate.



FILTER MEDIA- Old Plant

The six filters in *Bloomington's Main Building* consist of dual 10.75' by 21.5' cells. They provide a combined area of 462 square feet per filter.

A flow in the range of 1.0 to 1.3 MGD through one of the new plant filters is considered optimal. This corresponds to slightly less than two gallons per minute per square foot.

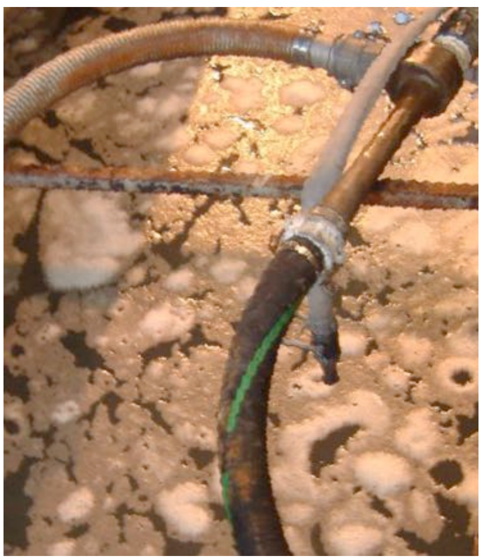


FILTER MEDIA- New Plant

Filter Operations

Filters are run for 48 hours before being backwashed. Backwash sequences are initiated manually in order to give the operator a chance to directly observe individual filters.   While observing a filter backwash , the operator should look for:

- air bubbles; a sign of air binding or entrainment of air in the backwater water line,
- calcium carbonate plates and chips; derived from spalling or pressure washing of filter walls and piping,
- foreign matter in the filter; such as mudballs, cemented media, algal filaments or mats, fibers, surface accumulations,
- uneven distribution of washwater; boils, horizontal flows, lifting of media, wall effects, shrinkage cracks, separation of GAC and sand, hydraulic surges,
- media blowoff; carryover of light media (GAC, fine sand) into the backwash launders,
- unusual quantities of solids (unusual color) in backwash water,
- foam; an indication of the presence of organic (surface-tension-lowering) compounds.



The release of air bubbles, which has been observed by operators at Bloomington, may be controlled by installing air release valves along the backwash water influent line or by constructing or refurbishing a separate elevated finished water storage tank to establish gravity flow.

Monitoring

Even with the SCADA systems, operators need to closely monitor treatment plant process performance, particularly in ways that computers can't. Automated equipment, alarms and computers have minimal powers of observation, lack judgment and are unable to respond to emergencies. They are susceptible to many types of failure, such as electrical power surges and outages plus system component failure. Corrosion and the build-up of solids in sampling lines also cause failure of monitoring systems and the recording of erroneous data due to blockage and solids sloughing.

Bloomington's filters are convenient to operate and maintain. They are all enclosed and protected from windblown debris and sunlight. Individual filter banks are further enclosed within partitions with windows for ready observation. Filter gallery areas are tiled for ease of cleaning and routine filter maintenance operations.

Each individual filter is equipped with a continuous flow turbidimeter. In addition to SCADA data acquisition systems for recording flow and head loss, turbidity is displayed visually for each individual filter.

Similarly, backwash can be automatically controlled and monitored. Surface wash is set for 4 minutes. After surface wash is completed, high flow backwash is initiated for 6 minutes, 40 seconds. Finally, two minutes of low-flow backwash complete the filter wash and restratification of the bed. Each step is detailed on the SCADA control panel.

On filter refilling to operating level, a preprogrammed, graduated return-to-service, or 'flow ramping', can be initiated to bring the filter back online gradually. Current filtration practice does not include flow ramping because no significant turbidity excursions are encountered at the low rates of hydraulic filter loading currently employed at Bloomington.

IEPA Turbidity Requirements

By law, filtered water turbidities on any given filter should:

- not exceed 1 ntu *
- not exceed 0.5 ntu * after the first four hours of filter operation following a backwash

  * for two consecutive fifteen minute sampling intervals

What to Do About High Turbidities

If it appears that a particular filter is about to exceed IEPA turbidity requirements, take the filter out of service until the automated results can be verified and the situation properly remedied. If time permits, a sample of filter effluent should be taken by hand for laboratory analysis to compare with the reading given by the continuous flow turbidimeter installed on the filter.

Continuous flow turbidimeters require frequent maintenance to avoid recording spurious turbidity readings. The small diameter finished water sampling line leading to each turbidimeter will progressively become coated and encrusted with attached particles, including calcium carbonate, making the line progressively cloudier. Subsequently, due to changes in flow, temperature or disturbance of the line, the attached particles may slough, causing an atypical reading that indicates the filter is passing particles.

Evaluation of Filters during GAC Replacement

Every year, under contract with Calgon Corporation, one-half of the the GAC caps on the Bloomington water treatment plant filters are replaced with virgin (not previously used) carbon. The two-year-old carbon at the new plant and three-year-old carbon at the old plant is removed from each of the beds hydraulically.

The carbon/finished water slurry is ejected from the bed through flexible hoses into an empty tractor-trailer capable of holding the GAC contents of a single filter bed. The trailer returns the used carbon to the manufacturer for thermal reactivation and reuse for less critical applications, such as decolorizing sugar or rum or for waste treatment processes.

The following comparative evaluations were conducted on the filter media while GAC was being removed and replaced in Filters #13, #15, #17 of the new plant and Filters #2, #3, and #4 of the old plant on April 23-24, 2002. Normally, the GAC in Filter #1 would also have been replaced during this cycle. However, Filter #1 was undergoing replacement of its underdrain system at the time.

Oxygen Persistence in Sand and GAC Media

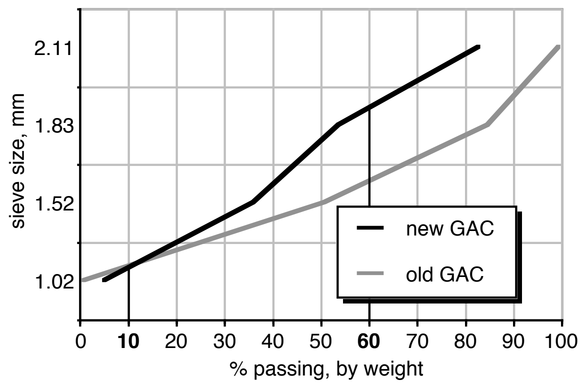
A container of filter sand removed from Filter #13 was rinsed with aerated tap water (DO 11 mg O/l; pH 9.0). Upon standing, dissolved oxygen was found to become totally depleted. The pH decreased to 8.5. The implication of these observations is that, as a result of continuing microbial respiration, oxygen depletion may occur in filters that remain idle for extended periods of time.

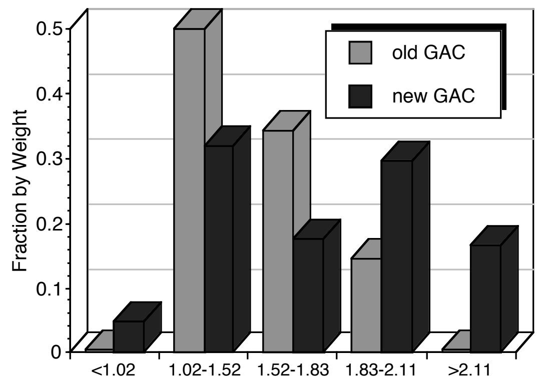
A similar test was conducted with both sand and GAC subsequently removed from Filter #4 (Annex). Whereas DO decreased to 3.5 mg O_2 /l in the GAC, it decreased to 7.5 mg O_2 /l in the filter sand. The pH had decreased to 8.0 and 8.5 in the GAC and sand, respectively. This would be consistent with microbially-mediated oxygen depletion (respiration) which results in the production of carbon dioxide.

The lowered pH during periods of stagnation may also result in the dissolution of calcium carbonate and magnesium hydroxide previously deposited on the filter media.
In June 2002, the Bloomington laboratory acquired a recently developed fiber optic dissolved oxygen probe that can be inserted into the media of a filter bed. This analytical device will provide the capability for observing dissolved oxygen at various depths within a filter both during filter operation and stagnation. For filters which support biological growth, the degree of dissolved oxygen depletion may be a most important measure of the necessary degree of filter backwashing.

GAC Size Distribution and Characteristics

From visual inspection, the GAC and sand media removed from Filters #13 (Main Building) and #4 (Annex) appeared very different from the fresh media that was being installed to replace the GAC and augment the sand. To confirm the observations, media size distributions were determined using Bloomington's laboratory sieve equipment.





From the sieving results obtained, it was clear that the size distribution of the GAC that had been in use for two years had narrowed considerably. This is attributable to the abrasion of the larger GAC granules so that their size is reduced. At the lower end of the size range, the finer GAC (<1 mm) granules may have been washed out of the filter during backwash. The result is a more uniform GAC size distribution. Despite the decrease in Uniformity Coefficient (U.C.), the effective size (E.S. or D_{10} particle size) appeared to have remained slightly above 1 mm. Overall, the narrowing size distribution with age makes the GAC, progressively, a more uniform and desirable filter medium.

In addition, there was a noticeable discoloration (graying) of the GAC that had been in service. Normally intensely black, the granules had begun to lighten in shade. Some of the particles among the GAC granules appeared to be solid white. These were thought to be calcium carbonate particles or chips recruited from the filter walls and piping. To determine the extent of this recruitment, a portion of GAC was dried, weighed and acidified to dissolve the calcium carbonate. This resulted in a 2% loss of weight.

In the future, it was decided that greater care should be taken to minimize the recruitment of these calcium carbonate particles. Many appear to begin as large platelets dislodged from the filter surfaces during pressure cleaning. With repeated backwash, they are broken into progressively smaller pieces. Raking of the filter surface after pressure washing should remove most of these particles.

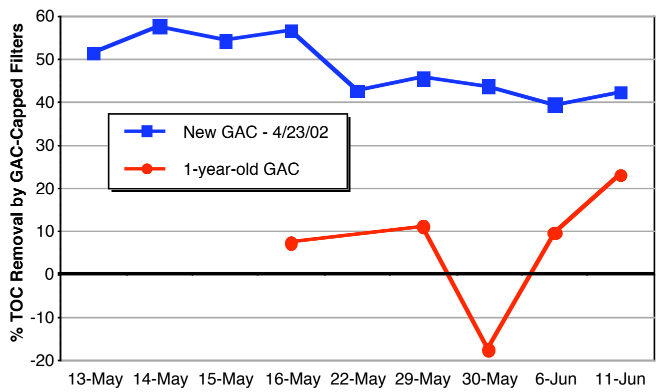
The carbon granules themselves showed varying degrees of white patches. When dislodged from the carbon by shaking in a test tube, the supernatant from these granules were found to consist of large numbers of microorganisms of diverse sizes and shapes. This is consistent with the characterization of GAC as a biological filter since the organic nutrient adsorbed by the carbon is converted to microbial cell mass. This cell mass is part of the turbidity removed by backwash after each filter cycle.

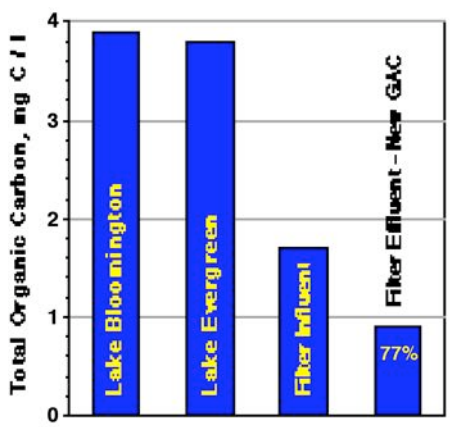
TOC Removal by GAC and through Plant

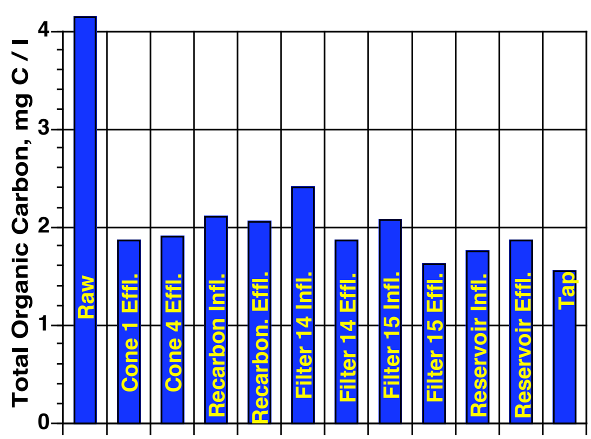
With the TOC equipment available in Bloomington's laboratory, it is possible to quantify the overall reduction in organic matter achieved by the GAC filter/adsorbers. This information should be important for assessing the useful life of the GAC cap as well as for determining the degree of solids removal from GAC which would maximize biological activity. Where biological processes are involved, a perfectly clean (organism-free) filter/adsorbent surface may not be optimal.

Initial data on TOC (primarily, dissolved organic carbon, DOC) removal in Filter #15 show that the GAC installed on April 23, 2002 initially adsorbed close to 60% of the TOC applied to the top of the filter bed. This exceptionally high percentage of TOC removal is expected to diminish as the adsorptive capacity of the virgin carbon is exhausted. The rate at which this will occur is not yet known.

Filter #14, which contains carbon which has been in service for one year, exhibits far less TOC removal. Long-term data on filters with older GAC is vital to determine the degree of TOC removal achieved by biological processes alone.







Overall TOC removals at the Bloomington plant (figure, left) were far higher than the 15% to 35% required under the USEPA surface water treatment regulations. In May, 2002, most of the TOC reduction in the plant, 56%, occurred during pretreatment (coagulation, lime softening, sedimentation). Subsequent filtration through freshly installed GAC increased overall TOC reduction to 77%.

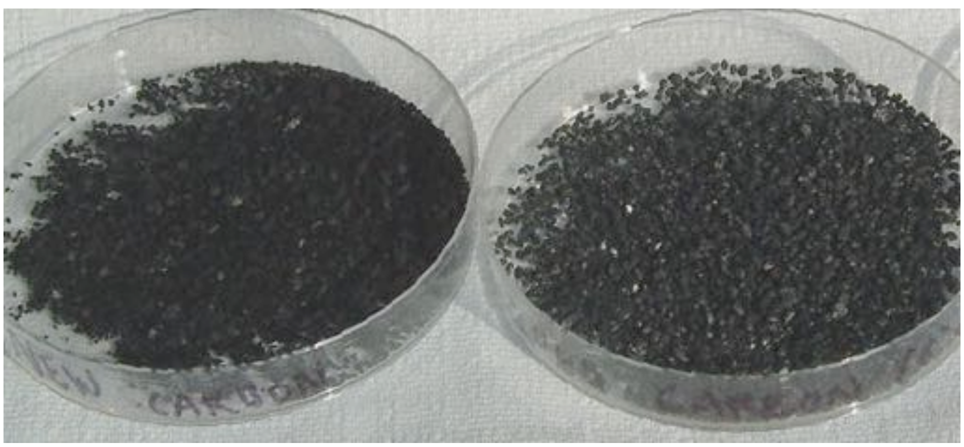
On June 11, 2002. a more comprehensive TOC profile through the plant (figure, right) confirmed that most of the TOC removal took place in the ClariCones as a result of coagulation and lime softening. Overall, TOC reduction was 63%.

Virgin GAC Replacement

After two years of service, the GAC cap is hydraulically removed from the top of the filter beds and replaced with virgin carbon. This GAC arrives in 1,000 pound ‘totes’ that hold 40 cubic feet of the adsorbent. Therefore, the bulk (dry) density of the GAC is 25 #/cu. ft. or 25% that of filter sand. This lighter material stratifies in filter beds during backwash to form a discrete layer of GAC atop the filter sand.

The GAC and sand media in Bloomington’s filters are not significantly intermixed. This discrete layering creates a sharp interface at which foreign materials and mudballs might settle and accumulate. Over time, this accumulation could partially blind the filter in a horizontal plane resulting in reduced filtration effectiveness, increased rate of head loss and decreased length of filter runs.

Freshly installed, the GAC will consume oxygen for some period of time since GAC is a strong reducing agent. GAC will also continuously consume chlorine and chloramine residuals reducing these compounds to chloride ion while the carbon itself is oxidized to carbon dioxide. This is why it is generally considered inappropriate to prechlorinate immediately prior to filtration through a GAC-capped filter. The consumption of disinfectant residuals also forms the basis for the claim of improved water taste when carbon adsorbers are used for household, point-of-use treatment.



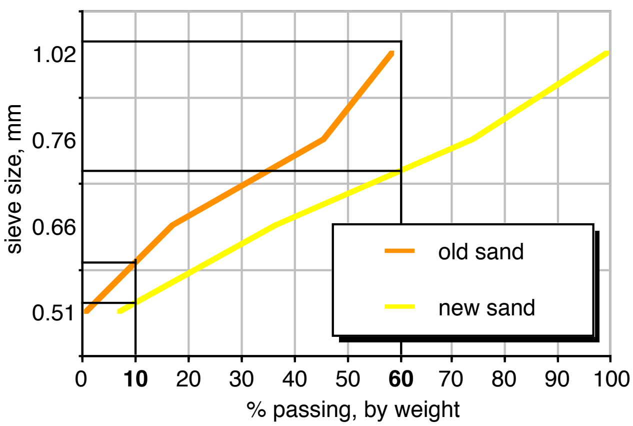
Virgin (dark black, left) and Used GAC (whitish patches on media, right)

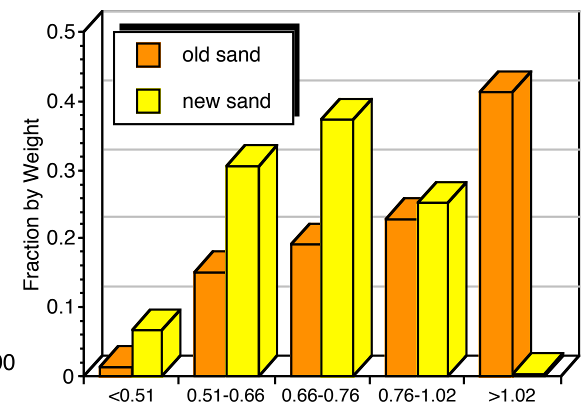
Trailer receiving and dewatering Used GAC removed from filters

Sand Size Distribution and Characteristics

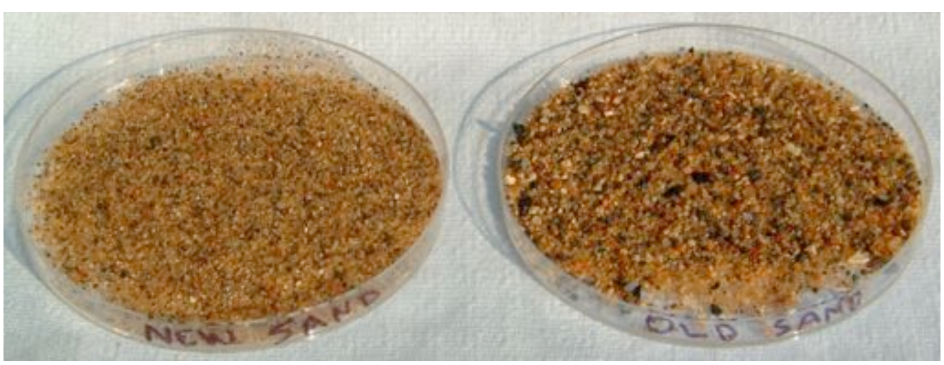
Because of its comparatively large particle size ($D_{10\%}$≈1 mm), GAC is not as effective a filter medium as filter sand ($D_{10\%}$≈0.5 mm). Whereas solids will accumulate within and on the surface of GAC, the finer particles in the filter influent would be expected to be retained in the sand layer. Accordingly, the sand layer could be critical in meeting stringent new regulatory standards on filtered water turbidity.

From the sampling of the underlying sand layer conducted during the changeover of the GAC, it is evident that the size distribution of the filter sand has changed since it was first installed. First, the $D_{10\%}$ size appears to have increased from approximately 0.52 to 0.58 mm. In addition, the $D_{60\%}$ size has increased substantially from about 0.72 to 1.05 mm.





The ratio $D_{60\%}/D_{10\%}$, encompassing 50% of the medium by weight, is used to calculate the *uniformity coefficient* (U.C.). The lower the U.C., i.e., the more uniform the grading, the more desirable the material is as a filtration medium. Due to intermixing, the U.C. of the filter sand has increased from 1.38 to 1.81.



Appearance of New and Old Filter Sand

These increases will combine to make it increasingly difficult to attain the degree of expansion of the sand layer which is believed to be optimal for scour and cleaning of the filter media. For washing sand filters without the assistance surface wash, air or auxiliary scour, a 20 to 50% bed expansion is commonly used. Since the surface wash at Bloomington does not reach into the expanded sand layer, sand bed expansion should be in this range. The absence of well-defined stratification in the sand layer may be an indication that this degree of expansion is not occurring.

Sand removed from the top...and bottom of Filter #2

Visual observation of the sand removed from the filters indicates that the increase in effective size (E.S.) and uniformity coefficient may have occurred for the following reasons:

- Torpedo sand, which forms the base for the filter sand, was thrust upward into the filter sand layer,
- some larger particles (white chips) of calcium carbonate, dislodged during filter box maintenance, had settled onto the top of the sand layer,
- a portion of the finest sand (< 0.5 mm) was absent, indicating that it may have migrated and escaped down into the underdrain system, and. finally,
- some GAC was collected in the sand sample. This was picked out as much as possible before the sand sieve analysis was conducted. However, these larger GAC particles would tend to increase the apparent effective size of the sand mixture.

Despite the observed changes, the sand medium remains in the range commonly utilized for filter sand, though at the upper range. The addition of make-up sand, practiced as part of routine GAC replacement, will lower the existing size distribution. Future additions of make-up sand may utilize still finer grained material (E.S. 0.4 mm) to continue to restore the sand to its initial size range.

Alternately, the addition of three to four inches of a still finer (E.S. 0.2 to 0.3 mm) and denser garnet sand (Specific Gravity 4.0 as opposed to 2.6 for silica sand) may serve to intermix with the existing media and further increase filtration efficiency.

Ultimately, however, the regulated test of filter media particle removal effectiveness is the measurement of turbidity. Continuous monitoring of filtered water turbidity profiles, as currently practiced by Bloomington Water, demonstrate that filtration efficiency routinely exceeds regulatory requirements by a significant margin

New Sand in Tote and Replacement of Filter Sand - May, 2002

Microbial Growth on Filtration Media

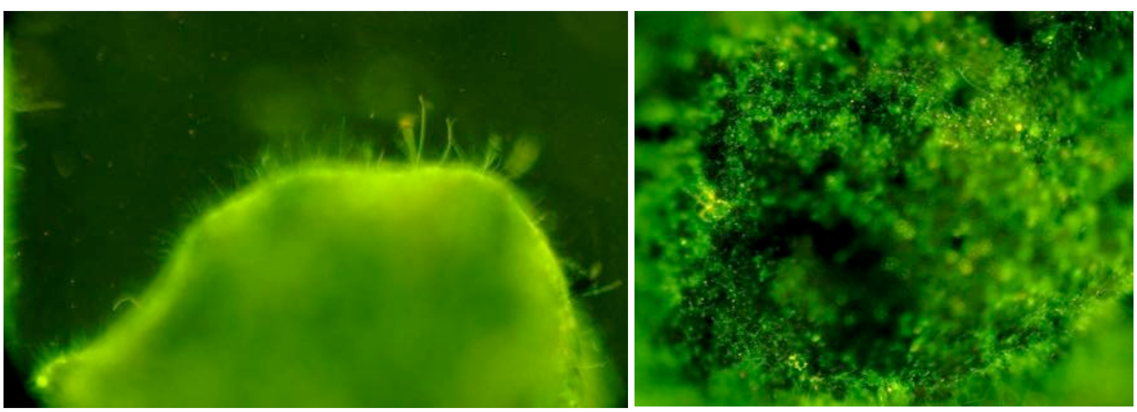
In the absence of the application of disinfectant prior to filtration, the significant surface area provided by the fine grained filtration media offers ample opportunity for microbial growth. Although this phenomena has been observed in water treatment plants from earliest times, the phenomena is currently being rediscovered as “biological treatment” or “biological filtration.”

A number of benefits can accrue to the development of a microbial community on the filter media. A portion of the organic content of the filter influent, the ‘labile’ or *biologically assimilable* portion, may be converted to cell mass and removed. While this may only be a small fraction of the dissolved organic carbon remaining after softening, these labile compounds reportedly include those contributing to tastes-and-odors.

Accordingly, the maintenance of an active, aerobic microbial community on the filter media may prove beneficial during episodes when Bloomington’s lake waters become enriched with nutrients, leading to the production of taste-and-odor compounds.

Alternately, *aerobic respiration* by the biological growth can lead to the loss of oxygen and anoxia within the filter bed. Periodic sloughing of attached accumulations of organism call mass can lead both to turbidity excursions and elevated numbers of organisms contributing to heterotrophic plate counts (HPC).

The unique micrographs below, taken with Bloomington’s epifluorescence microscope, illustrate the abundance of green-fluorescing microbial filaments and stalked bacteria colonizing a GAC granule removed from service at Bloomington. It has been speculated that the filaments (attached growth) may assist in the attachment of particles from the filter influent to the filter media.

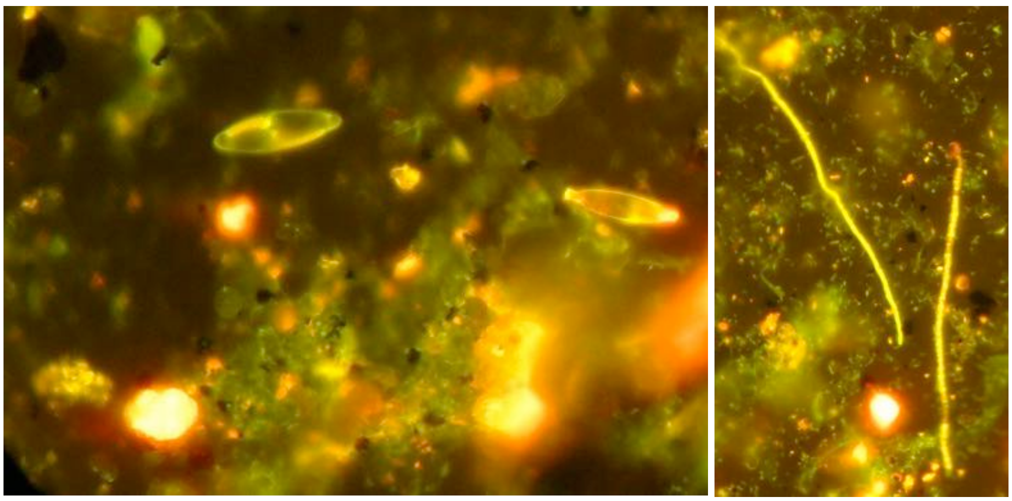


Bacterial filaments and colonies (green fluorescence) on GAC granule surface

Particles Washed from GAC

A portion of the accumulation of organisms on the biologically colonized GAC are stripped off the granules with each succeeding filter backwash. Their removal of the heterotrophic organisms reflects the removal of the assimilable portion of the dissolved organic carbon (DOC) achieved by the filter.

Examples of the particles and organisms removed during backwash are illustrated in the following micrographs. These micrographs show a large and diverse group of rod-shaped bacteria (green dots), generally embedded in clumps of detached slime (extracellular polymer) along with carbon fines (black). Long bacterial filaments and diatoms are also present.



Detached from GAC: diatoms; bacterial rods, clumps and filaments; carbon fines

The production, and subsequent removal, of this diverse group of organisms in the GAC-capped filter is credited with reducing microbial growths in the distribution system. These organisms have also been credited with oxidizing haloacetic acids (HAA) formed by prechlorination prior to filtration.

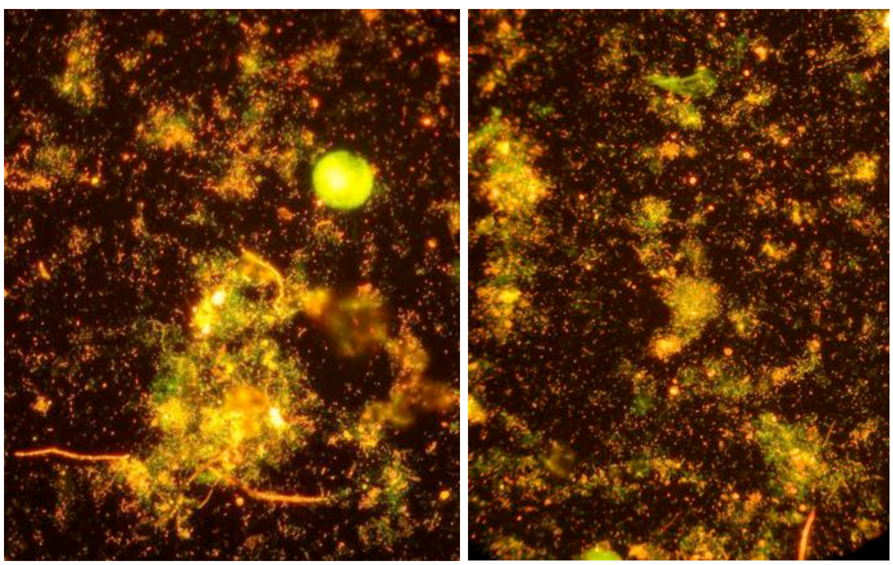
Alternately, the presence of a large microbial community has spurred studies of the degradation of water quality in filter beds when they are taken out of service for 6 to 24 hours. Oxygen is found to decrease within the filter pore water within hours. While DOC, ammonium and nitrite ion concentrations in the filter pore water increase, attached microbial cell mass declines under the anaerobic conditions. As a result, water quality degradation is reported upon start-up. To avoid this deterioration and restore the biodegradation performance of the filters, the idle filters were backwashed before being returned to service.

Particles Washed from Sand

While silica sand is inert and does not provide nutrient for microbial growth, the extensive surface provided by this fine-grained material does lend itself to the accumulation of attached microbial growth. In many treatment systems, the influent to sand filters have been prechlorinated to prevent the accumulation of microbial slime.

The micrographs below show organisms recovered in the rinse water from sand taken from Filter #4. The microbial community is abundant and appears diverse. Many of the bacterial cells (orange-red rods and filaments) are aggregated or embedded in clumps of detached slime.

It is important to note that any organisms of 'potential health concern' that were present in the lake water source have largely been physically removed by coagulation and sedimentation or inactivated at the high pH maintained during the lime softening process. Alternately, the organisms (shown in the micrographs) that were recovered from Bloomington's filter media are primarily new growth that has occurred as the result of surface colonization and the utilization of the dissolved organic matter in the filter influent. These organisms are not known to represent a human health hazard. Similar results are observed wherever individual consumers use household treatment devices containing granular activated carbon.



Planktonic bacteria (tiny orange dots) and aggregations of organisms in clumps.

Filter Washing Protocol

While there is no optimum filter backwash procedure, a recommended protocol for filter washing at Bloomington, based on conventional U.S. practice, is, as follows:

- Following the lowering of the water surface level in the bed, the surface wash should be activated and operated alone for four minutes or until any surface caking or accumulations are broken up.

- A low-rate wash which will cause a 10% expansion of the sand layer and expand the upper bed of GAC into the rotating arms of the surface wash should then be conducted for 5 minutes. (It may be desirable to minimize this wash since extended surface wash may contribute to the break-up of the friable GAC granules, thereby creating micrometer-sized carbon 'fines'. These carbon fines may penetrate the filter following restart.)

- High rate wash at a nominal rate of 20 gpm/ft^2 for up to five minutes should then be used to expand the sand layer into the 20 to 50% expansion range. (At this point, there is the greatest danger of washing out the lightest fraction of the GAC so that, based on operators' observation, the maximum backwash rate may be limited to that which precludes loss of GAC.) The duration of the high-rate wash should be determined by the operator for the seasonal (temperature) and pretreatment conditions. For example, following the addition of polymeric coagulant aids, the backwash may be extended to assist in removing the more tightly attached polymer.

- Finally, a low-rate wash may be employed at the end of the backwash procedure to assist in restratifying the media.

New plant filter with rotating arm surface wash

Since some of the filter sand has increased in size and some has been lost in operation, it may be advantageous to conduct some laboratory column studies using filter media removed from several typical filters to observe the backwash rates that are, in fact, effective in achieving the desired degree of expansion and cleaning). These filters can subsequently be used to observe the effect of polymer addition of filter performance, head loss and removal of attached solids.

Filter Backwash Procedures

The graph (blue line, below) depicts the filter backwash water turbidities observed as backwash proceeds. These results are the averages observed in July, 2005 for the left side of new plant Filter 14.

Filter backwash begins with pressing *Start* to initiate the backwash sequence. This closes the *influent valve* to the filter being washed. With the closing of the influent valve, both the right and left sides of the filter are drained. The time to drain the filter to below the media surface can be observed visually.

After draining, the *effluent valve* is closed and the *drain valve* opened. The backwash pump is then started against the (closed) *low* valve. Subsequently, the low backwash valve opens after the pump has started. This is time "0" on the graph.

Two minutes after low backwash has started and the media has been hydraulically lifted over the surface wash rotating arms, the *surface wash* is activated. As the plot indicates, a slight increase in backwash water turbidity is observed at this time. The surface wash will continue for just 3 minutes after which high rate backwash is initiated.

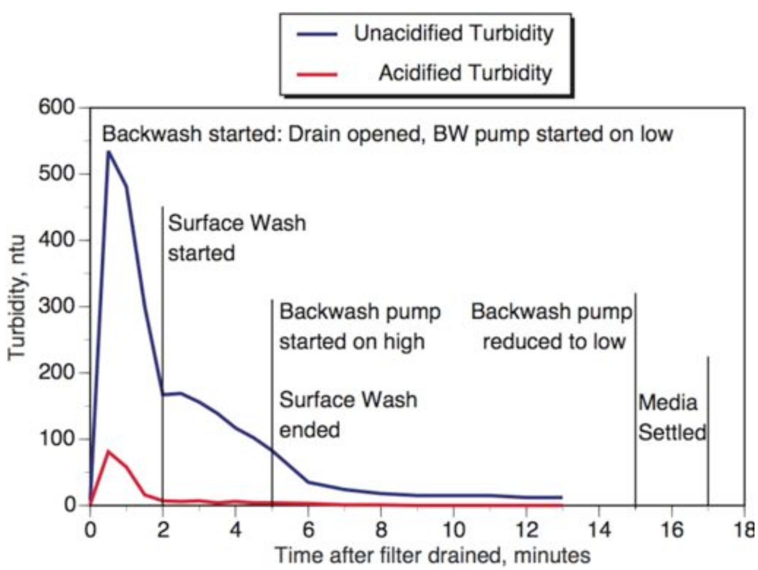
At five minutes, the backwash pump is started against the *high* valve and the media is further expanded with the opening of that valve. This high-rate wash, is programmed into the switch activation times in the SCADA system, to last for ten minutes.

Two minutes prior to completion of high-rate backwash, the pump is returned to low-rate wash. This allows gradual settling of the dual sand/GAC media to help preserve stratification.

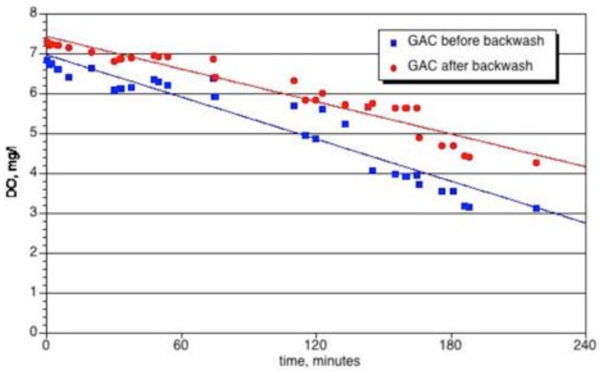
With completion of backwash on the left side, the wash cycle is repeated on the right side before returning the filter to service.

The graph for acidified turbidity (red line, below) illustrates the predominance of calcium carbonate in the solids removed from the filters during backwash. After acidification, only an average of 7% of the unacidified turbidity remained.

At Bloomington, filters are backwashed every 48 hours unless filter effluent turbidity has exceeded 0.5 ntu or head loss is greater than 7 feet, both rare events which trigger separate alarms. Each filter at the new plant produces about 1.25 mgd at constant flow.



Effectiveness of Backwash in Removing Bacterial Accumulations



Luminescent probes were used to observe DO depletion rates in BOD bottles containing GAC rinse water suspensions

Measurements of dissolved oxygen depletion in suspensions derived from GAC extractions (before and after old plant Filter #6 backwash) illustrate the effects of bacterial removal. As indicated by the slopes of the lines, the DO depletion rate declined from 1.02 mg/l/h prior to backwash to 0.83 mg/l/h following backwash.

These results, although preliminary, indicate that this innovative analytical procedure can provide an index of the degree of removal of bacterial accumulations on filter media. If greater bacterial removals from more vigorous or extended backwash are found to result in higher removals of taste-and-odor-producing compounds, backwash procedures would be modified.

Procedure for Evaluating Biological Activity on Filter Media

- Collect surface samples of filter medium immediately before and after backwash.
- Gently compact 50 ml of wet medium into measuring container.
- Transfer medium into BOD bottle along with 100-200 ml of rinse water (membrane-filtered filter effluent).
- Cap and shake BOD bottle vigorously for 2 minutes to strip attached solids from medium.
- Add rinse water to fill BOD bottle and mix to blend in with rinse water.
- Add magnetic stirring bar to BOD bottle.
- Place bottle on magnetic stirrer set on lowest mixing rate to maintain solids in suspension.
- With cap off, insert probe into bottle and take initial measurement of DO and temperature.
- Take measurement every 5 to 15 minutes depending upon rate of DO depletion.
- After 50% of oxygen is consumed, plot line of DO vs. time.
- From linear slope of plot, estimate *mg/l DO depleted/hour.*

Filter Surveillance (Old Plant Filters)

Beginning in July, 2006, systematic efforts were undertaken to assess the performance of the old plant (Annex) filters. Several filter flow rates were directly measured to determine the accuracy of the filter flow meters. In addition, backwash rates were observed as, first, one pump, then, a second pump, was started. Finally, the degree of media of expansion was measured using a pan-flute device fabricated in the Bloomington plant shop by Greg Montague.

Old plant filter with fixed nozzle surface wash during backwash: beginning and near end of wash

Measurement of Filter Bed Expansion during Backwash

A pan flute device was fabricated in the Bloomington plant shop to determine bed expansions during backwash. Removable pipe sections would allow this one device to be used in both the old plant where bed expansions are low and in the new plant where bed expansions are high.

For Filter #6 in the old plant, expansion of the 19-inch GAC layer was anticipated to be 30% or 5.7 inches at the warmest water temperature of 30°C. and an upflow rate of about 20 gpm/ft^2. A concurrent 10% expansion of the 12-inch filter sand layer would add another 1.2 inches to the bed expansion for a total of approximately 7 inches.

Pan flute with 1.5" to 5" tall pipe sections was placed in old plant Filter #6 prior to backwash; 3.5" GAC depth recovered

Instead, as measured using the pan flute device, total bed expansion during Filter #6 backwash was found to be only 3.5 inches. This degree of expansion would constitute a low rate wash resulting in only relatively weak cleansing of the filter media. This result was qualitatively confirmed by the subsequent rinsing of the GAC samples collected from the surface of a freshly washed filter (See photo of sediment in BOD bottles, above). The old filters are limited to this low expansion because the backwash water pumps lack capacity to provide adequate flow to further suspend the media.

Recommended Testing of Auxiliary Air Scour

Auxiliary air scour at 2 to 5 $ft^3/min/ft^2$, along with low rate water wash, has been found to provide more effective cleaning action than water wash alone. While auxiliary air scour can reduce backwash water requirements, the increased turbulence it creates can also result in disruption of supporting layers of gravel.

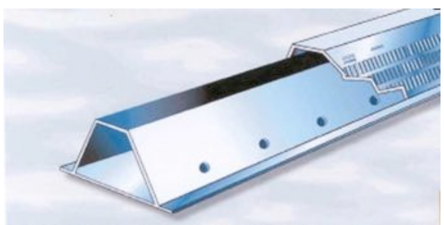
Accordingly, Bloomington is considering testing a replacement for the cast iron filter underdrain system in one filter at the old plant. A porous stainless steel filter bottom would replace the current pipe lateral underdrain and allow for placement of the filter sand directly atop the new underdrain. This system would accommodate air scour and reduce the overall depth of the current filter bed by approximately 20 inches. This would also allow for an increase in the depth of the GAC filter cap to about 30 inches, providing greater contact time for removal of taste-and-odor producing compounds while allowing more head space for bed expansion during backwash. However, fine pores in the underdrain system have shown the tendency to clog and require maintenance, particularly, when filtering lime-softened water.

It has been estimated that a test filter refurbishment could be installed by the plant personnel at a cost of $54,000 using virgin GAC that is already stored on the Bloomington plant site. Comparative data from the operation of this test filter with the other old plant filters could quantify the benefits to be expected if all the old plant filters were subsequently rehabilitated. An increase in filtration capacity might be one such benefit since pipe laterals introduce relatively high head loss.

To provide stratification of the dual media bed, a high rate water wash (15 to 23 $gpm//ft^2$) would have to follow the cessation of air scour. Air scour can also be expected to virtually eliminate the mudball formation which has been observed at the media interface in some of the old plant filters.

The replacement underdrain system under consideration is the *AWI Phoenix Underdrain System*. It promises:

- Guaranteed uniform distribution
- Rapid, low-cost installation
- Integral air scour chamber
- Durable stainless steel construction
- Lowest profile available



Underdrain lateral - stainless steel

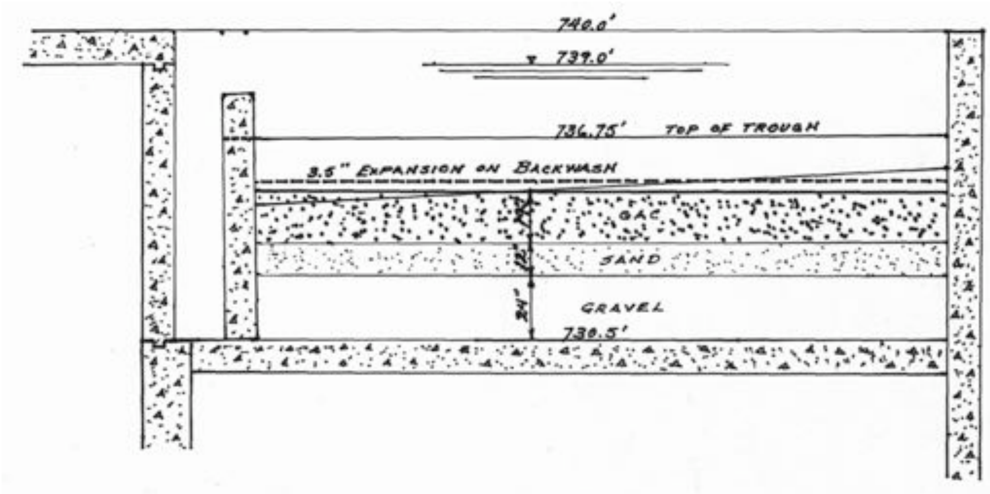
AWI Phoenix underdrain system

effluent launders with air scour headers

Comparison of Existing with Proposed Rehabilitated Test Filter

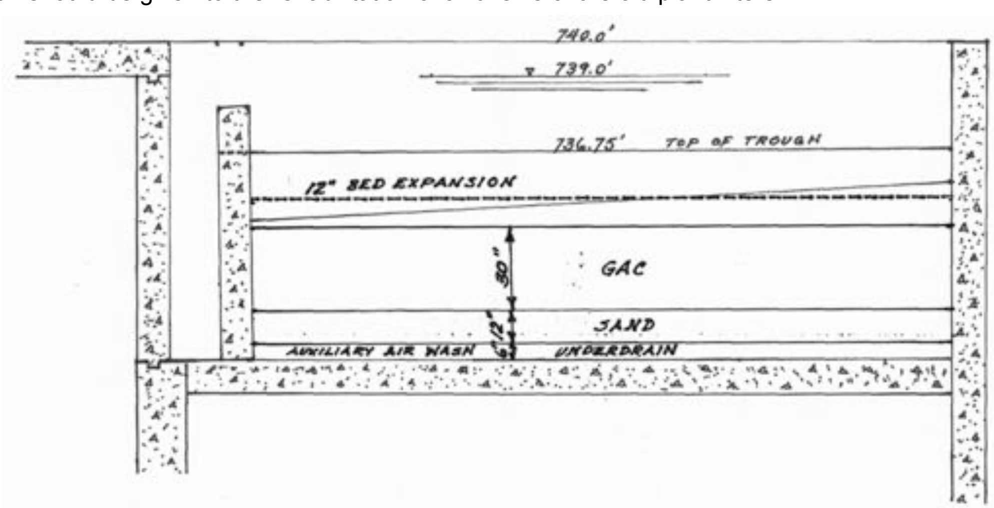
Based on the information available from design drawings, the following figure illustrates the approximate cross-section of the existing old plant filters. The old plant filter underdrains appear corroded and the orifices may be partially plugged, thereby interfering with the uniform distribution of backwash water. The appearance of white patches on the filter surface during backwash indicate that wash is not uniform.

With only 3.5 inches of total bed expansion with both backwash pumps in operation, it also appears that the sand layer is not expanded. Failure to wash the sand layer would be expected to contribute to plugging of areas within the filter and mudball formation at the sand/GAC interface.



Installation of a low profile underdrain system, without gravel, would allow for the addition of air scour along with backwash. More importantly, auxiliary air wash promises to require significantly less backwash water flow. This is important at the because, currently, old plant backwash pumping capacity is limited.

With the elimination of the gravel support layers, the depth of the GAC cap could be increased from 19” to 30”, increasing EBCT by 58%. The renovated filter should allow for more than 30% expansion of the GAC layer and, at least, 10% expansion of the sand layer. If the operation of the test filter (Filter #1) is found to be satisfactory, consideration should be given to the rehabilitation of all twelve of the old plant filters.



Cross-Section of Rehabilitated Old Plant Test Filter with Low-Profile Underdrain System