5. INDIVIDUAL FILTER SELF ASSESSMENT

5.1 Introduction

Based on individual filter monitoring requirements in the IESWTR, some systems may be required to conduct an individual filter self assessment. Specifically, a system must conduct an individual filter self-assessment for any individual filter that has a measured turbidity level greater than 1.0 NTU in two consecutive measurements taken 15 minutes apart in each of three consecutive months. The system must report the filter number, the turbidity measurement, and the dates on which the exceedances occurred.

Filters represent the key unit process for the removal of particles in surface water treatment. Although filters represent only one of the "barriers" in a treatment process their role is the most critical as the final physical "barrier" to prevent passage of chlorine resistant pathogenic microorganisms into distribution systems. Properly designed filters used in conjunction with coagulation, flocculation and sedimentation processes (if in use), when in proper physical and operational condition, are capable of treating raw water sources.

For any situation regarding a single poor performing filter, or a bank of poor performing filters:

- Performance limitations observed at the start of a filter run are most often attributed to improper chemical conditioning of the filter;
- Limitations observed during the filter run are most often attributed to changes in hydraulic loading conditions; and
- Limitations observed at the end of the filter run are most often related to excessive filter runs.

Filter performance issues may only be apparent during excessive hydraulic loading and care should be taken to not attribute all turbidity spikes to hydraulic bumping or overloading. In some circumstances performance "symptoms" for other causes may only be evident during these hydraulic episodes. Oftentimes disrupted filter media may cause filter performance problems. The following chapter describes the process of an individual filter self assessment and is intended to provide clarity regarding which of these areas are limiting the performance of a filter.

The following chapter will include each of the following components of an individual filter assessment:

- **A general description of the filter** including size, configuration, placement of washwater troughs and surface wash type (if applicable) and filter media design (e.g., type, depth and placement) and if filter-to-waste is present and/or used and if any special conditions exist regarding placing a filter back into service (i.e., is the filter rested, polymer or coagulant added prior to placement into service, etc.). Table 5-1 provides a worksheet to assist the evaluator in collecting this information.

- **The development of a filter run profile** of continuous turbidity measurements or total particle counts versus time for an entire filter run from start up to backwash, including assessment of filter performance while another filter is being washed. The run length during this assessment should be representative of typical plant filter runs. The profile should include explanations of the cause of performance spikes during the run.

- **An assessment of the hydraulic loading conditions of the filter** which includes: the determination of the peak instantaneous operating flow for the individual filter, an assessment of the filter hydraulic loading rate at this peak instantaneous operating flow, and an assessment whether plant flow is distributed evenly among all the filters.

- **An assessment of the actual condition and placement of the media** with a comparison to the original design specifications. The filter bed should be investigated for surface cracking, proper media depth, mudballs and segregation of media in dual media filters. The media should be examined (using coring and/or gross excavation techniques as appropriate) at several locations to determine the depth of the different media layers in dual and multi-media filters.

- **A description of backwash practices** including length, duration, presence of and type of surface wash or air scour, and method for introducing wash water (i.e., via pump, head tank, distribution system pressure, etc.) and criteria for initiating the wash (i.e., degraded turbidity or particle counts, head loss, run time, etc.), the backwash rate, and bed expansion during the wash.

- **An assessment of the condition of the support media/underdrains** including a filter grid detailing placement of support media, as well as a summary of inspection of the clearwell for the presence of filter media and any observances of boils or vortexing during backwash.

- **An assessment of the filter rate-of-flow controllers and filter valving infrastructure adequacy**. The rate-of-flow controllers and ancillary valving related to the filter can also have an impact on filter performance and should be visually inspected to assure proper operation.

Table 5-1. Individual Filter Self Assessment Worksheet

Topic	Description	Information
General Filter Information	Type (mono, dual, mixed)	
	Number of filters	
	Filter control (constant, declining)	
	Surface wash type (rotary, fixed, none)/Air Wash	
	Configuration (rectangular, circular, square)	
	Dimensions (length, width, diameter)	
	Filter-to-waste (capability/specify if used)	
	Surface area per filter (ft^2)	
Hydraulic Loading Conditions	Average operating flow (mgd)	
	Peak instantaneous operating flow (mgd)	
	Average hydraulic surface loading rate (gpm/ft^2)	
	Peak hydraulic surface loading rate (gpm/ft^2)	
Media Design Conditions	Depth, type	
	Media 1 – Sand	
	Media 2 (if applicable) – Anthracite	
	Media 3 (if applicable) – Garnet	
Actual Media Conditions	Depth	
	Media 1 – Sand	
	Media 2 (if applicable) – Anthracite	
	Media 3 (if applicable) – Garnet	
	Presence of mudballs, debris, excess chemical, cracking, worn media	
Support Media/Underdrain Conditions	Is the support media evenly placed (deviation <2 inches) in the filter bed?	
	Evidence of media in the clearwell or plenum	
	Evidence of boils/vortexing during backwash	

Table 5-1. Individual Filter Self Assessment Worksheet (continued)

Topic	Description	Information
Backwash Conditions	Backwash initiation (headloss, turbidity/particle counts, time)	
	Sequence (surface wash, air scour, flow ramping, filter-to-waste)	
	Duration (minutes)	
	Introduction of wash water (via pump, head tank, distribution system pressure)	
	Backwash rate (gpm/ft^2)	
	Bed expansion (percent)	
	Coagulant or polymer added to wash water	
	Filter rested prior to return to service	
Other Considerations		

5.2 Developing A Filter Run Profile

The profile for the filter being evaluated shall include a graphical summary of filter performance for an entire filter run from start-up to backwash inclusively. Performance is typically represented by turbidity although total particle counts may be used in addition to, or in lieu of, turbidity measurements. Use of particle counting in conjunction with turbidity monitoring of filter effluents may offer additional insights to filter performance, however, care should be taken in the interpretation of particle count results. The interpretation should focus on the change in count levels as opposed to the discreet particle count numbers. Plotting the performance data versus time on a continuous basis is the desirable approach for development of the filter profile. However, time increments less than a continuous basis may be used with the understanding that the intent is to identify and minimize “real” deviations in performance. The filter run should be representative of a typical run and should encompass the time period when another filter is being washed. The profile shall include an explanation of the cause of performance spikes during the run.

Example

A utility has plotted total turbidity data versus time for a filter that cannot meet requirements for individual filters. The filter run is typically 24 to 28 hours with a resting period after backwash that varies from 8 to 10 hours. The generated filter profile is shown below in Figure 5-1. The review of turbidity data showed an inordinate number of spikes occurring during the filter run. This data corroborated with turbidity data that triggered the filter assessment. These spikes corresponded to changes in hydraulic loading rates made by the staff and may be indicative of greater problems within the filter itself. The significant increases in turbidity passing the filters occurred when the plant staff initiated recycle of treated backwash water to the head of the plant and when plant loading rates were modified during the evening to take advantage of off-peak electrical costs (represented by item B&D). Table 5-2 provides explanations for turbidity spikes.

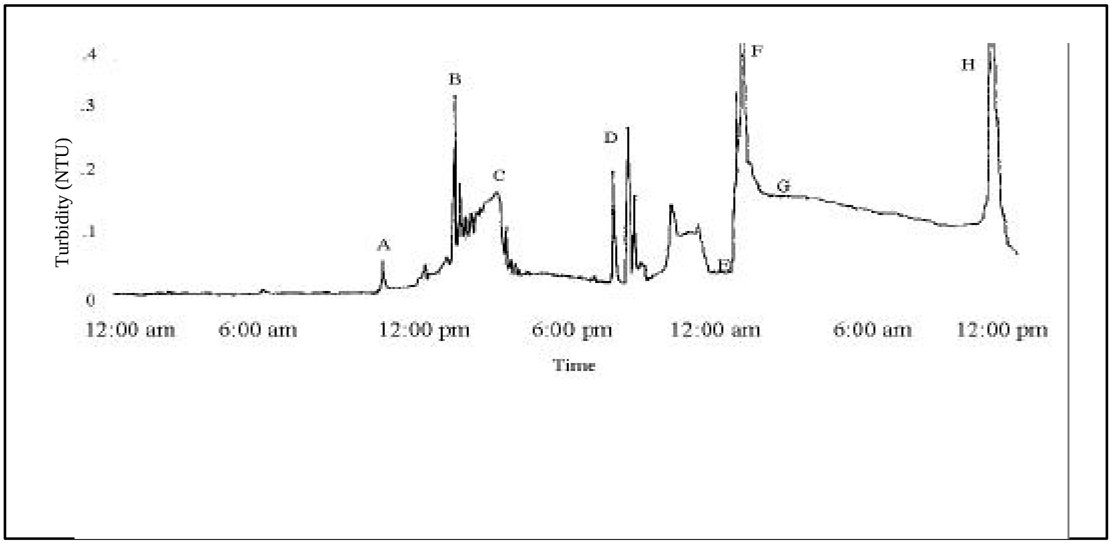

Figure 5-1. Filter Run Profile – Turbidity (NTU) vs. Time

Table 5-2. WTP Performance Deviation Trigger Events

Event	Performance Deviation Trigger Explanation
A	Pump change
B	Backwash water decant recycle to head of plant initiated
C	Backwash water decant recycle completed
D	Pumping rate increased to take advantage of off-peak electrical costs
E	Immediately following backwash of adjoining filter
F	Filter backwash
G	Filter taken out of service
H	Filter placed back in service

5.3 Assessing Hydraulic Loading Conditions Of Filter

Filters with properly chemically pretreated influents are most vulnerable to pass particles (including pathogenic microorganisms) at peak loading rates in excess of filter design or during sudden changes in hydraulic loading rates. Table 5-3 presents a summary of acceptable filter loading rates for various filters. **However, filters may exhibit capable performance at loading rates in excess of those presented in Table 5-3; these values are rule-of-thumb and provide a basis for evaluating excessive filter hydraulic loading.** State requirements may differ from acceptable industry loading rates and should be considered during the assessment.

Since the filters are most vulnerable during excessive loading rates, it is critical to determine the peak flow on an instantaneous basis that filters are performing under and to minimize incidences when filters are expected to perform at these higher loading rates. Peak instantaneous operating flow rate is identified through review of operating records and observations of operational practices and flow control capability.

A review of plant flow records can be misleading in determining the peak instantaneous operating flow. For example, peak daily water production can only be used when those values are generated during a 24-hour operational day during specific conditions. If values are used that were generated for a day when the plant only was in operation for 12 hours, the peak instantaneous operating flow would be of the true value. Additionally, if pumps are used in multiple combinations throughout the operational day, care should be taken to determine the actual peak loading on the filters during the day. The peak instantaneous operating flow should be determined based on the flow distributed to the filters on a maximum daily minute. The peak instantaneous operating flow that each filter sees is dependent on the minimum number of filters used per day at the plant's peak instantaneous operating flow.

Table 5-3. General Guide to Acceptable Filter Hydraulic Loading Rates

Filtration Type	Air Binding	Loading Rate
Sand Media	None	~2.0 gpm/ft^2
	Exists	~1.0 - 1.5 gpm/ft^2
Dual/Mixed Media	None	~4.0 gpm/ft^2
	Exists	~2.0 - 3.0 gpm/ft^2
Deep bed	None	~6.0 gpm/ft^2
(anthracite > 60 in.)	Exists	~3.0 - 4.5 gpm/ft^2

Example 1

A plant which operates 24 hours per day uses three 5-mgd pumps in various combinations throughout the year to meet system demand. The pumps are capable of being throttled to reduce individual flow to 80 percent of capacity. The average daily production is 8 mgd while the peak production day over a previous 2-year period has been 12 mgd. The plant in the previous two years has never run all three pumps simultaneously for an entire day. However, for a 2-hour period each evening, all three pumps are used to fill on-site storage. Two pumps are used for the first hour with the third pump only used with the other two pumps for the last 30 minutes of the 2-hour period. During that 30 minute period plant flow increases to 14 mgd. The peak instantaneous operating flow that go onto the filters is 14 mgd. The plant's six dual media filters (each 425 ft^2) would have a loading rate of 3.8 gpm/ft^2 at this 14 mgd peak flow.

Example 2

A plant with 8 dual media filters and a constant high service pumping rate of 8 mgd operates 24 hours per day and is unable to consistently meet the filter requirements. Each filter has 175 ft^2 of surface area and typically has a flow rate of 1 mgd. However, two filters are backwashed per day at the same time with no reduction in plant flow. During backwash the two filters are out of service for 40 minutes. During that 40 minute period the entire plant flow of 8 mgd is handled by just six filters. The peak instantaneous operating flow for each filter becomes 1.33 mgd. The hydraulic loading rate in gpm/ft^2 for each 175 ft^2 filter at this peak flow becomes 5.3 gpm/ft^2 (1.33 mgd converted to gpm divided by the filter surface area) which is at the upper end of the acceptable loading rates for a dual media filter and may be contributing to the unacceptable performance.

5.4 Assessing Condition & Placement Of Filter Media

Assessment of the condition and placement of the filter media is an integral step in identification of factors limiting performance of the filtration process. The presence of mudballs, surface cracking, or displaced media may often be attributed to excessive use of coagulant chemicals, inadequate backwashing or a more serious problem related to the underdrain system. The assessment of the condition and placement of the filter media should include a physical inspection of the filter bed and a comparison of the actual media findings to the original specifications. The filter bed should be investigated for surface cracking, proper media depth, presence of mudballs and segregation of media.

Figure 5-2. Box Used for Excavation

Figure 5-3. Box Excavation Demonstration

The filter inspection should begin by draining the filter. The filter should be drained enough to allow for excavation of the media to assess the depths of each media type, as well as, each media interface (e.g., just below the anthracite/sand interface in a dual media filter). Deeper excavation of the filter may be necessary if evidence suggests disrupted support gravels or an inadequate underdrain system (see Section 5.6). Care should be taken not to disrupt the support gravel/media.

Filter media assessments may be conducted using a gross excavation of media technique or application of a variety of coring devices (typically a 1 to 2 inch pipe). Coring methods offer the advantage of being able to apply the Floc Retention Analysis procedure, if conditions warrant (see to Section 5.5). Evaluators should place small pieces of plywood on the media prior to getting on the filters to avoid sinking into the media. The excavation technique may be conducted using a gross excavation of the media or a plexiglass box shown in Figures 5-2 and 5-3. The box excavation consists of sinking a plexiglass box into the media and excavating inside the box down to the support media. The box excavation technique allows for visual observation of the media depths and interfaces after the excavation is completed.

Whatever media excavation technique is used, the evaluators should note the depth of each media type, (comparing this to the original specifications), the general condition of the media interface, the presence of any mudballs or excess chemical. After the excavation is completed, the excavation team should make certain that the media is placed back in the excavations in the same sequence that it was removed. The filter should be backwashed after completion of the excavation prior to return to service.

5.5 Assessing Backwash Practices

Proper maintenance of filters is essential to preserve the integrity of the filter as constructed. Limitations of poor performing filters relating to filter media degradation or disruption of support gravel placement can often be attributed to inadequate backwashing or excessive backwashing rates. The duration of the backwash, if excessive, may also be detrimental. Different facilities have had different experiences in how clean the filters should be after backwashing. Consideration should be given to site-specific circumstances in the application of any recommendations regarding filter backwash procedures with the focus always being on filter effluent water quality. Table 5-4 summarizes guidelines for acceptable backwashing practices.

Table 5-4. Guidelines Regarding Acceptable Backwashing Practices

Area of Emphasis	Guideline
Basis for initiating backwash	focus on filter performance (turbidity, particle counts) degradation versus headloss or time
Backwash flow	slowly ramped to peak rate
Backwash flow rate	15 - 20 gpm/ft^2
Bed expansion during backwash	20 - 25 percent

The assessment of the filter backwash procedure should include the following:

- A collection of general information related to the backwash;
- Verification of the adequacy of the backwash SOP;
- A visual inspection of a backwash; and
- Determination of the backwash rate and expansion of the filter media during the wash.

The individual filter assessment worksheet (Table 5-1) can be used to collect general information regarding the backwash.

An adequate backwash SOP should describe specific steps regarding when to initiate backwash, how flows are ramped during the wash, when to start and stop surface wash or air scour, and duration of the wash.

Backwash rates are designed to provide adequate cleaning of the filter media without washing media into the collection troughs or causing disruption of the support gravels. Table 5-4 identifies generally acceptable backwash rates. These values are to be used as a guide when assessing adequacy of the backwash procedures. Backwash rates in gpm/ft^2 may be determined by simple calculation if backwash pump rates or backwash flows are available and known to be accurate. If these values are unavailable or suspect, backwash rates can be determined by performing a rise rate test of the filter. Periodic rise rate tests can also be used to verify the backwash flow measurement instruments. The rise rate test entails determining the amount of time it takes backwash water to rise a known distance in the filter bed. Typically, a metal rod marked at 1-inch intervals is fixed in the filter to enable measurement of the distance that water rises during the wash. The rise rate test should be conducted such that measurements are taken without the interferences of the wash water troughs in the rise volume calculation. Extreme care and great attention to safety should be followed while conducting the rise rate test. Rise rate is used to calculate backwash rate by dividing the rise volume for a known time period by the filter area as follows:

$$rise \cdot volume(gal) = filter \cdot surface \cdot area(ft^2) \times rise \cdot distance(ft) \times 7.48(gal / ft^3)$$

$$backwash \cdot rate(gpm/ft^2) = \frac{rise \cdot volume(gal) / rise \cdot time(\mathrm{min})}{filter \cdot surface \cdot area(ft^2)}$$

Example backwash rate calculation: A filter having a 150 ft^2 surface area has wash water rise 10.7 inches in 20 seconds during the rise rate test. The backwash rate would be 20 gpm/ft^2.

$$rise \cdot volume = 150 ft^2 \times 10.7 in \times ft / 12 in \times 7.48 gal / ft^3 = 1000 gal$$

$$backwash \cdot rate(gpm / ft^2) = \frac{1000 gal / (20 \sec \times (\mathrm{min} / 60 \sec))}{150 ft^2}$$

$$backwash \cdot rate = 20 gpm / ft^2$$

In addition to backwash rate, it is also extremely important to expand the filter media during the wash to maximize the removal of particles held in the filter or by the media. Bed expansion is determined by measuring the distance from the top of the unexpanded media to a reference point (e.g., top of the filter wall) and from the top of the expanded media to the same reference point. The difference between these two measurements is bed expansion. A proper backwash rate should expand the filter 20 to 25 percent (AWWA and ASCE, 1990). Attention should be given to the influence of seasonal temperature changes on bed expansion during application of this procedure. Percent bed expansion is given by dividing the bed expansion by the total depth of expandable media (i.e., media depth less support gravels) and multiplied by 100 as follows:

$$expanded \cdot measurement = depth \cdot to \cdot top \cdot of \cdot media \cdot during \cdot backwash(inches)$$

$$unexpanded \cdot measurment = depth \cdot to \cdot top \cdot of \cdot media \cdot before \cdot backwash(inches)$$

$$bed \cdot expansion = unexpanded \cdot measurement(inches) - expanded \cdot measurement(inches)$$

$$bed \cdot expansion(percent) = \frac{bed \cdot expansion \cdot measurement(inches)}{total \cdot depth \cdot of \cdot expandable \cdot media(inches)} \times 100$$

Figure 5-4. Pipe Bed Expansion

A variety of apparatus can be used to measure bed expansion. The apparatus can vary from a metal shaft with a white disk attached on one end and a steel measuring tape fitted along the shaft to a metal pole with an attached collection of pipe segments of varying lengths each plugged at the bottom. The pipes are arranged like a set of church organ pipes with each pipe 1-inch longer than the next (see Figure 5-4). The unit is solidly affixed, resting on the top of the media. During backwashing the expanded media fills each successive piece of pipe until the rise stops. Care should be taken to affix the pipe organ apparatus such that it can easily be determined where bed expansion ended because during certain situations, all of the pipe segments will be filled with expanded media making it impossible to accurately determine media expansion. During this situation, the apparatus should be emptied, affixed higher in the filter above the media and the bed expansion test repeated. The disk unit is used by placing the disk on the unexpanded media prior to backwash and recording the length of the metal rod to the reference point. The disk unit is then removed and backwashing is initiated. After the backwash is allowed to reach its peak rate the disk is lowered slowly into the backwashing filter until media is observed on the disk. The measurement of the expanded media is then recorded and percent bed expansion may then be determined. Figure 5-5 depicts the disk bed expansion apparatus. The key attribute of any method is that determination of the top of the expanded media be accurately characterized.

Figure 5-5. Bed Expansion Device

Example bed expansion calculation:

The backwashing practices for a filter with 30 inches of anthracite and sand is being evaluated. While at rest, the distance from the top of the media to the concrete floor surrounding the top of the filter is measured to be 41 inches. After the backwash has been started and the maximum backwash rate is achieved, a probe containing a white disk is slowly lowered into the filter bed until anthracite is observed on the disk. The distance from the expanded media to the concrete floor is measured to be 34 inches. The resultant percent bed expansion would be 22 percent.

unexpanded measurement = 41 *inches*
expanded measurement = 34.5 *inches*
bed expansion = 6.5 *inches*

*bed expansion (percent) = (*6.5 *inches /* 30 *inches)* * 100 = 22 *percent*

Use of the Floc Retention Analysis procedure may be warranted if the filter is meeting backwash expansion and backwash rate guidelines while still not achieving turbidity performance criteria. (Kawamura, 1991, Wolfe & Pizzi, 1998.) The Floc Retention Analysis procedure allows for an extremely in-depth analysis of backwash practices.

5.6 Assessing Condition Of Support Media/Underdrains

Maintaining the integrity of the support gravels and underdrains is extremely important to the performance of a rapid granular filter. Disrupted or unevenly placed support media can lead to rapid deterioration of the filtered water quality noticeable by quick turbidity breakthroughs and excessively short filter runs (Peck, Smith). Should disruption of the support media be significant, the impacted area of the filter may act as a “short-circuit” allowing particulates and any microbial pathogens which are present to pass directly into the clearwell. Filter support gravels can become disrupted by various means including sudden violent backwash, excessive backwashing flow rates, or uneven flow distribution during backwash.

The condition of the support gravel is assessed in three steps. The first step consists of visually inspecting the filter during a backwash for the presence of excessive air boiling or noticeable vortexing as the filter is drained. The second step entails determining whether filter media has ever been found in the clearwell. This should be determined visually or by reviewing recent clearwell maintenance records. Clearwell inspections should be only be conducted following appropriate safety procedures while minimizing negative impacts on necessary plant operations. Clearwells containing a significant amount of filter media may indicate a greater problem than just disrupted support gravels. The problem may be attributed to a severe issue with the filter underdrain system. An in-depth assessment of the underdrains typically involves excavation of the entire filter bed. Systems should use best professional judgement and seek additional guidance if undertaking an underdrain assessment, as it is outside the scope of "typical" filter self assessment. The third step is the most common method of assessing the placement of filter support media. This method involves "mapping" of the filter using a steel or solid probe. The mapping procedure involves a systematic probing through the filter media down to the support gravels of a drained filter at various locations in a grid-like manner. At each probe location, the depth of penetration into the filter is measured against a fixed reference point such as the wash water troughs. The distance from the fixed reference point to the top of the support gravels should deviate less than 2 inches. **Care should be taken during the filter probing not to disrupt the support gravel.**

Example

Operators, while draining a poor performing filter, observed vortexing occurring at the far end of the filter. The operators constructed a support gravel placement grid by probing through the media down to the support gravel every 2 feet throughout the filter using a 6 feet long aluminum rod that had been marked at 1-inch intervals. The operator using the probe measured the depth of probe penetration against the wash water trough. Examination of the grid (shown in Table 5-5) indicated that the support gravels were extremely disrupted at the far end of the filter.

Table 5-5. Example Filter Support Gravel Placement Grid

Depth of Filter Support Gravels (in inches)
Measured from the Wash Water Trough

			Filter Control Panel		
	2 ft	**4 ft**	**6 ft**	**8 ft**	**10 ft**
2 ft	41	40.75	41	41	41
4 ft	40.75	40.5	41	41	40.75
6 ft	41	41.25	40.75	41	41
8 ft	40.75	41	41	40.75	40.75
10 ft	41	41	40.5	40.5	40.75
12 ft	41	**46**	**46.5**	41	41
14 ft	40.75	**46**	**46.25**	39	40.75
16 ft	41	39	38.75	37	40.75
18 ft	40.75	41.25	40.75	41	41

5.7 Assessing Rate-Of-Flow Controllers & Filter Valve Infrastructure

The rate-of-flow controllers and ancillary valving related to the filter can also have an impact on filter performance. Hydraulic changes (such as those caused by filter bumping) cause filters to shed particles. Maintaining the rate-of-flow controllers is important in minimizing hydraulic changes in the filter. Figure 5-6 shows on-line turbidity measurements for two filters in a treatment plant. Each of the two filters had rate-of-flow controller problems that became more evident as headloss built up in the filters. Just prior to initiating backwash in filter 4 the rate-of-flow controllers were opening and closing constantly "seeking" the correct position. This was first apparent to the filter evaluation team who observed constant turbidity fluctuations of the filter effluent during a filter performance review. Improperly seated valves can also have similar impacts on filter performance. Backwash valves may leak and allow wash water to compromise filter effluent coming from the filters remaining in operation. All filter assessments should include an evaluation of all the rate-of-flow controllers and filter valving.

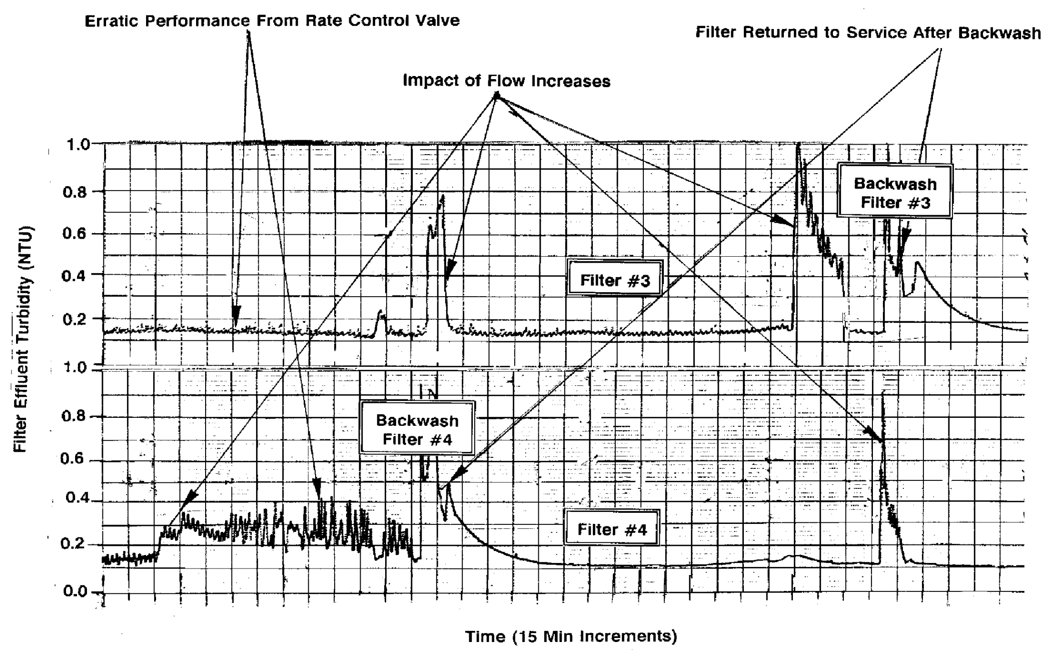

Figure 5-6. On-Line Turbidimeters Showing Performance Problems Due to Inoperable Rate-of-Flow Controllers

5.8 References

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