Filter Inspection and Optimization Case Studies

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OTCO Class 3&4 Workshop

August 5, 2015

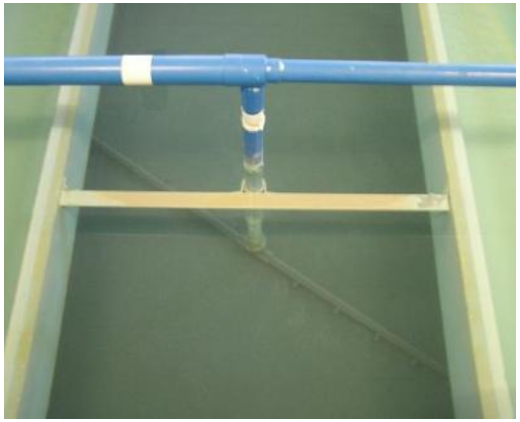
Agenda

- Filtration inspection and maintenance basics
- Filter performance indicators
- Filter coring and evaluations
- 3 Case studies
- Summary
- Questions

Filtration Inspection and Maintenance Basics

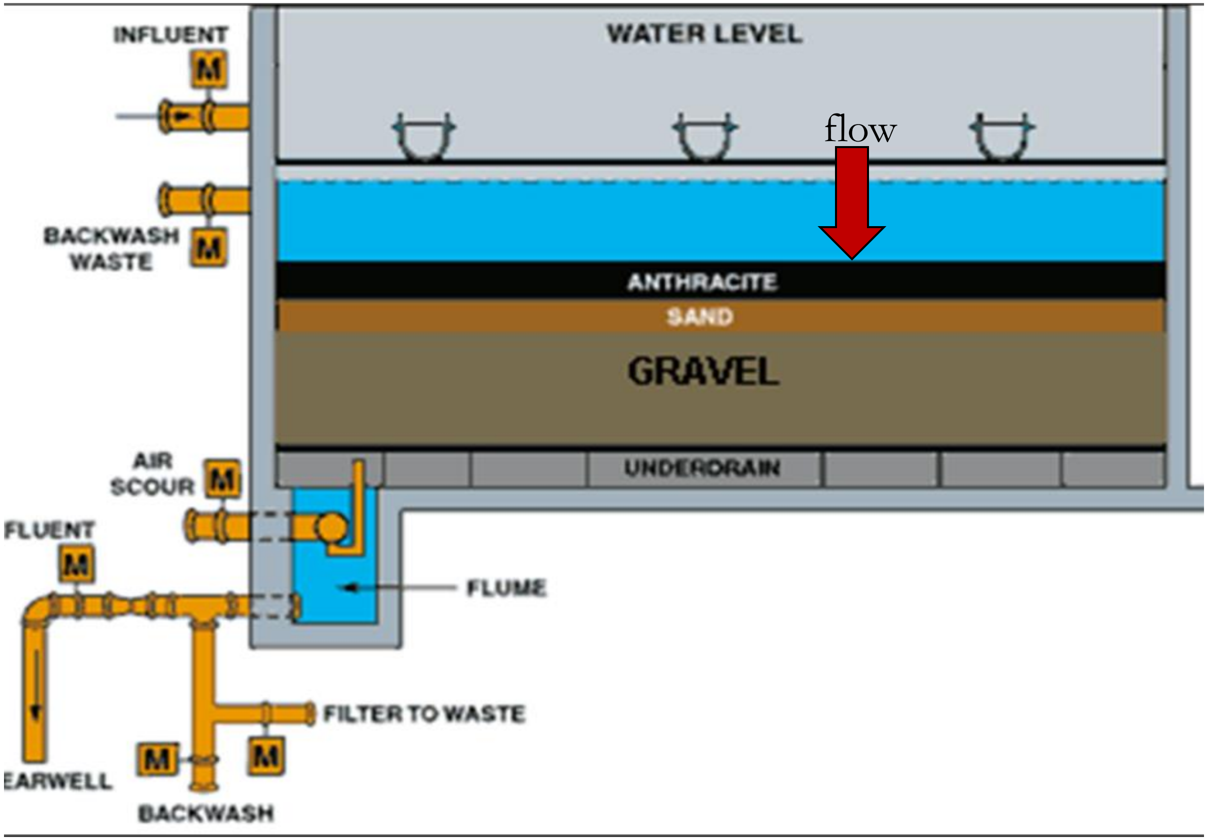
- Pretreatment conditioning upstream of filtration affects filter performance
  - Softening
  - Iron/manganese removal
  - Clarification
- Problems in pretreatment often translate to filter operating problems
  - High head loss
  - Turbidity breakthrough
  - Shortened run times
  - Long filter ripening times
  - Excessive solids accumulations after backwashes
  - Cementing of media
  - Mud ball formations

Settled water clarity should be less than 3 NTU



Clarification and sedimentation are important to successful filtration

Filtration Inspection and Maintenance Basics



Filters are particle collectors - particle accumulations cause head loss requiring media cleaning to remove the accumulated solids

Major components of filters include:

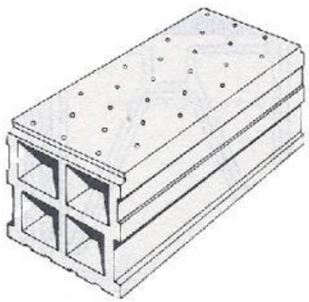
- Filter box
- Underdrain system
- Support media (gravel or media supporting underdrain)
- Filter media (garnet sand, filter sand, anthracite, GAC, etc.)
- Washwater troughs
- Air scour or surface wash system
- Backwash system
- Operating controls and instrumentation

Filtration Inspection and Maintenance Basics

- Media contains about 30 percent void space used for hydraulic transport and for particle capture
- Pore size generally 0.1% of ES
  - 0.45 mm ES has 0.45 μm pore size
- Once voids are filled, filter needs to be backwashed
  - High head loss and reduced flow occur
  - Potential for turbidity breakthrough
- Surface wash or air scour operations improve media cleaning
- Bed expansion during backwash allows media grains to rub each other removing particles
  - Avoid under-expansion or over-expansion

Filter under backwash

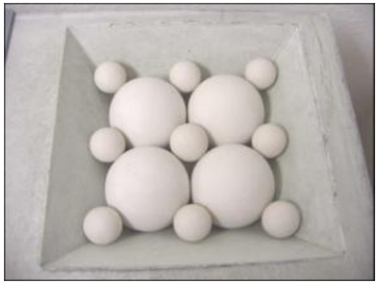
Common Underdrain Systems



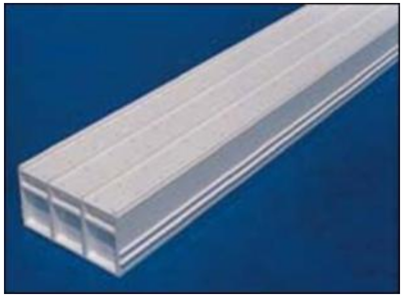
Clay dual lateral block

Plastic trilateral block

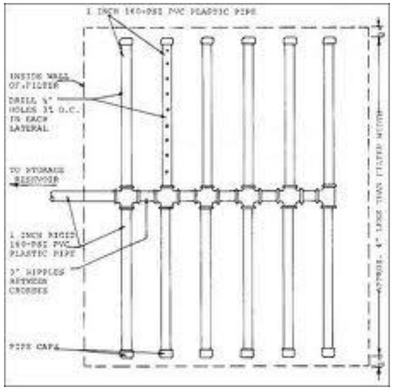
Fixed nozzle



Wheeler underdrain



Plastic low profile block



Pipe lateral system

Slotted screen (plate)

Filter Media

Filter Sand

Anthracite

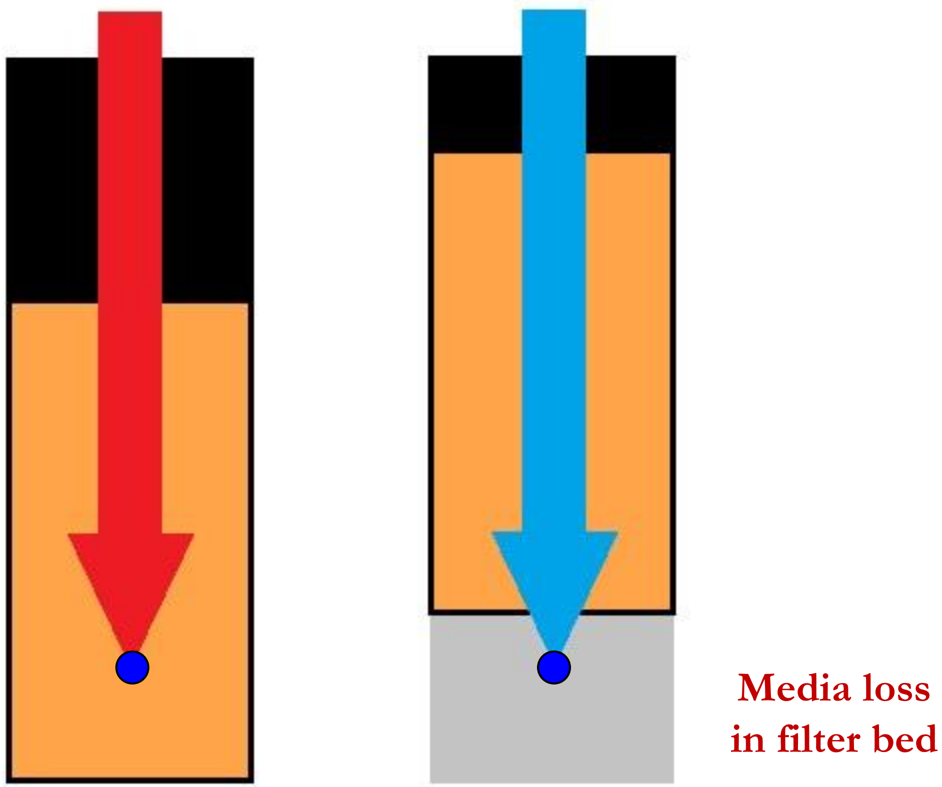
GAC Media

Garnet Sand

Media Considerations

- Effective Size
- Uniformity coefficient
- L/D_{10} ratio
- D_{90}/D_{10} ratio
- Critical bed depth
- Media placement
- Settled water quality
- Media life

Filter Media and Particle Removal



- **Bed depth** in a filter is critical for particle removal
- Insufficient bed depth often results in turbidity breakthrough
- Replenishing media to original bed depth reclaims filter performance

Filter Media and Bed Depth

- L/D_{10} ratio helps maintain proper bed depth
  - Layer depth (mm) divided by ES
  - Summation of layers is L/D_{10} for the filter bed
  - L/D_{10} ratio >1,000 recommended
  - As media loss occurs periodic “topping off” of the filter bed is needed

Filter Media and Bed Depth

- D_{90}/D_{10} ratio help define interfacial mixing zone
  - Larger diameter anthracite ES (D_{90}) divided by smaller diameter sand ES (D_{10}) predicts mixing at interface layer (2-inches to 8-inches common)
  - Transition zone to assist in filter run length and particle capture
  - High ratios tend to result in nearly complete mixing
    - Larger monomedia and higher effluent turbidity
  - Low ratios tend to result in individual stratification
    - Low turbidity effluent, but shortened run times

Filter Performance Indicators

Primary Performance

- Effluent turbidity
- Head loss
- Filter efficiency
- Run time
- Washwater consumption
- Dissolved iron/manganese mineralization
- Carbonate deposition (softening)
- Exceedance reporting

Filter Performance Indicators

Primary Performance

- Effluent turbidity
- Head loss
- Filter efficiency
- Run time
- Washwater consumption
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Optimized Performance

- Gross water production
- Washwater usage
- Solids loading capacity
- Backwash duration
- Filter coring and evaluation
- Sieve analysis
- Microscopic analysis
- Acid solubility
- Filter-to-waste
- Gravel profiles
- Floc retention profiles
- Bed expansion

Filter Performance Indicators

Run times

- Up to 48 hrs monomedia
- 72 hrs or more dual media and multi-media filters
- Up to 200 hrs accomplished in well-optimized filters

Filter efficiency

- Calculated values using water filtered and washwater volume
- >95% target
- >99% in well-optimized filters

Filter Performance Indicators

Washwater consumption

- 2% to 4% of monthly raw water production typical
- 1% or less in well-optimized filters

Carbonate Deposition

- Less than 8 mg/L carbonate drop across filter media in precipitative softening plants

Filter Performance Indicators

Gross water production

- Up to 5,000 gal/ft^2/run monomedia
- Up to 10,000 gal/ft^2/run dual media and multi-media
- Up to 20,000 gal/ft^2/run well-optimized filters

Washwater Usage

- 100 gal/ft^2 to 150 gal/ft^2
- Less than 100 gal/ft^2 well-optimized filters

Filter Performance Indicators

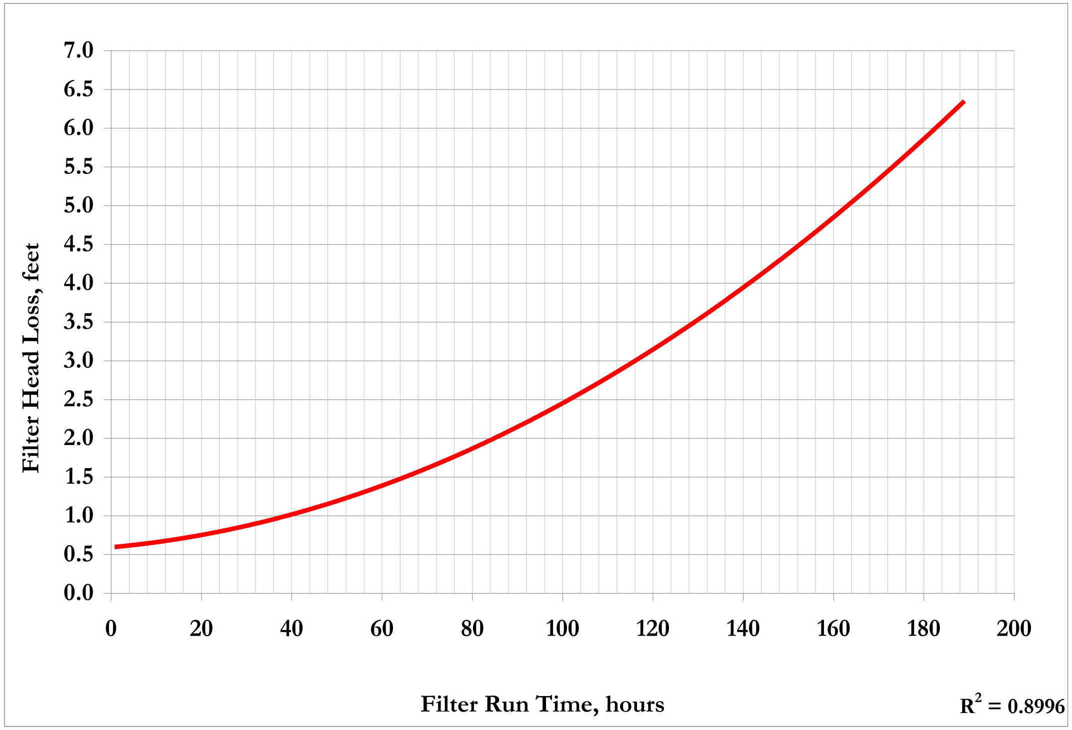
Solids Loading Capacity

- 0.14 pounds/ft^3 typical
- Up to 0.20 pounds/ft^3 for well-operated filters
- Up to 0.34 pounds/ft^3 for well-optimized filters

Bed Expansion

- 30% minimum for media cleaning
- 35% maximum for media cleaning
- 50% leads to excessive media loss
- 60% results in disruption of gravel layers

Filter Performance Indicators



Head loss

- 5 feet to 6 feet common terminal head loss
- Generally increases with run time
- Common head loss at end of run less than 3.5 feet

Filter Rates

- > 1.4 gpm/sf
- Better performance near approved filter rate
  - 2 gpm/sf or greater

Filter Coring and Evaluations

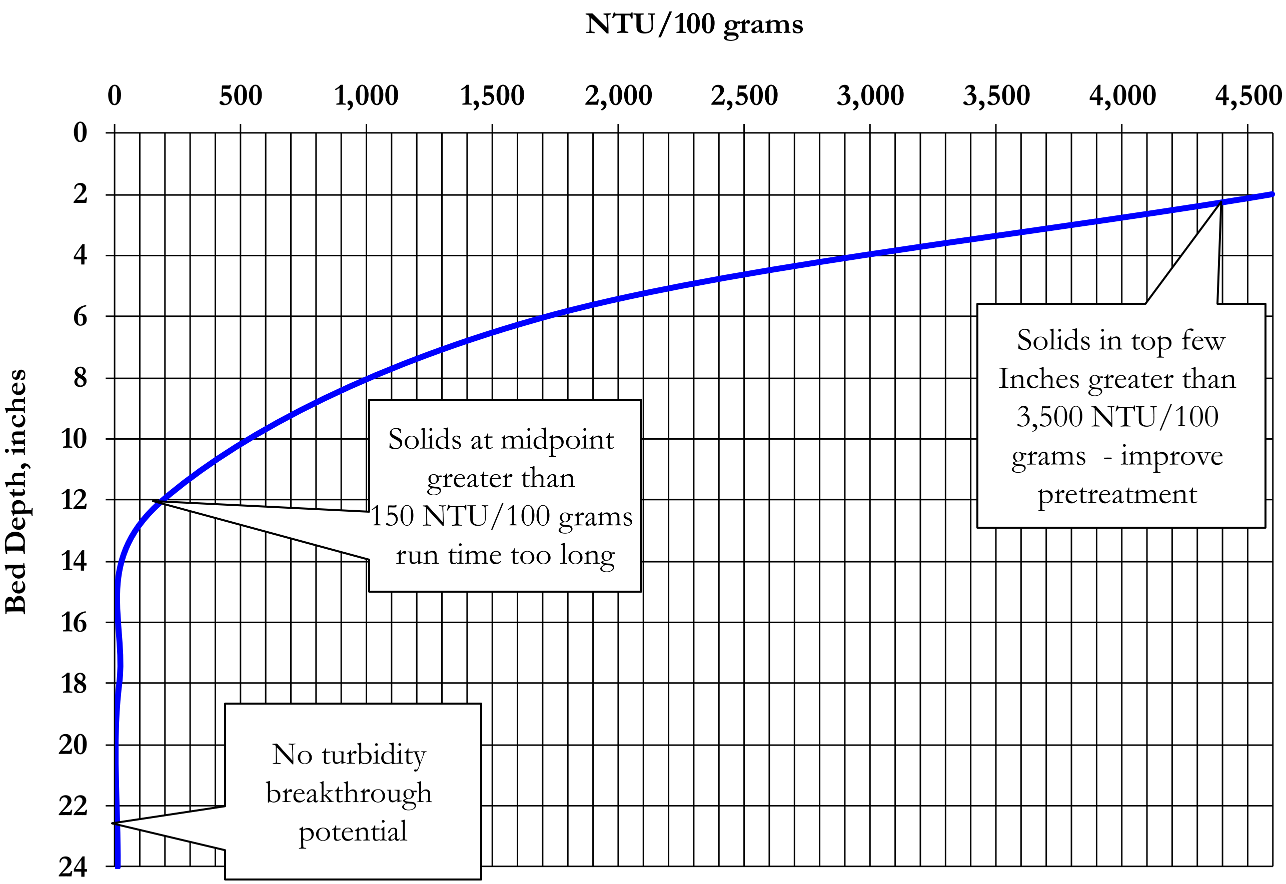
- Define behavior of filters using scientific indicators
- Adjust performance based on indicator values according to established optimization standards
- Floc retention profiles
  - Before backwash demonstrates particle removal, evaluates run time, illustrates whether breakthrough could occur
  - After backwash demonstrates potential surface wash (or air scour) adjustments, evaluates bed expansion, illustrates cleanliness from backwash
- Backwash duration assessments
  - Define duration of backwash sequence and washwater needs for media cleaning

Filter Coring and Evaluations

Media coring in filter bed

- Extraction of media at different depths with a simple coring device
- Analysis of core samples by washing and turbidity measurements
- Graphical evaluations of floc retention before and after backwash
- Backwash duration assessments by collecting washwater for turbidity measurements

Filter Coring and Evaluations



Typical Floc Retention Profile Before Backwash

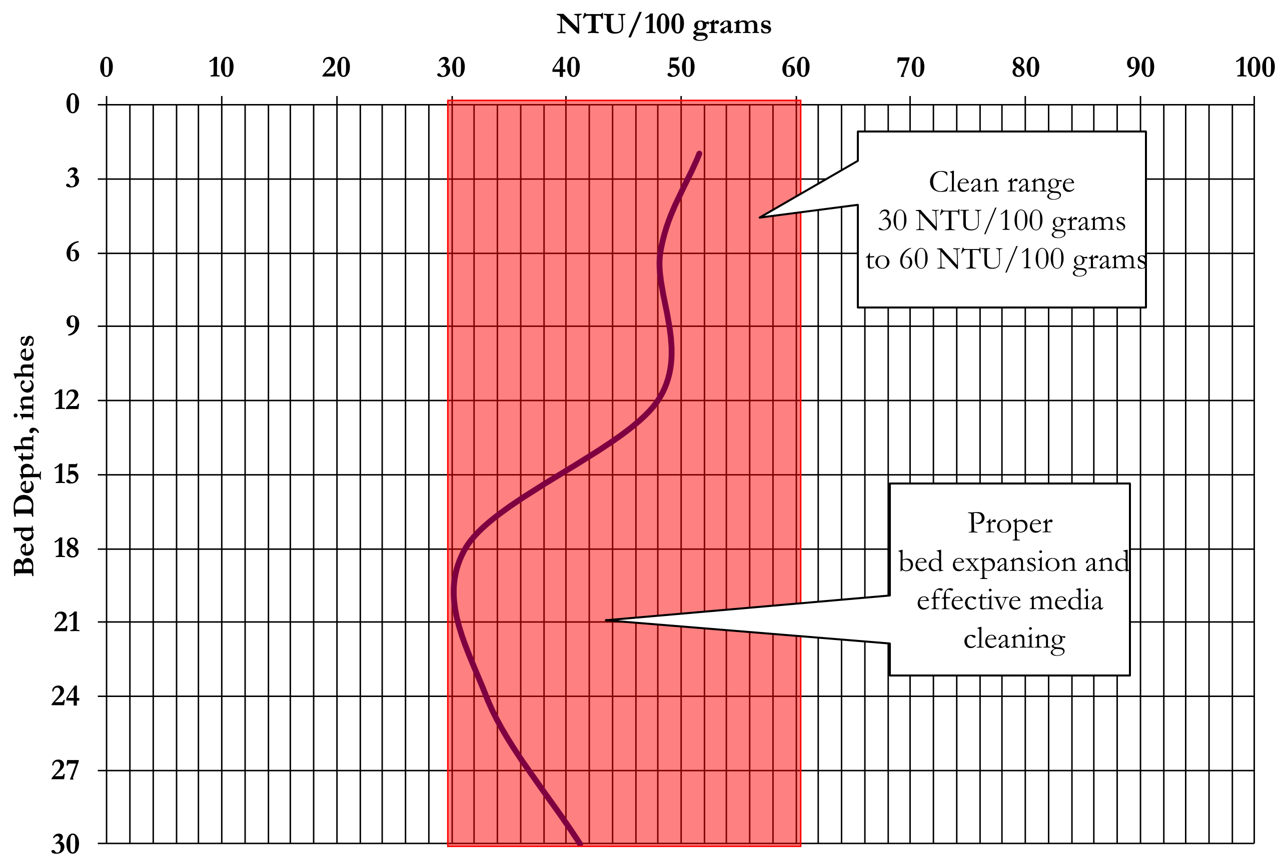
Primary observations needed

- Top few inches
- Midpoint for monomedia filters
- Midpoint of interface layer for dual media (or multi-media) filters
- Bottom few inches

Filter Coring and Evaluations

Primary observations

- Solids retained fall within clean range (30 to 60) throughout depth
- Bed expansion was 31%



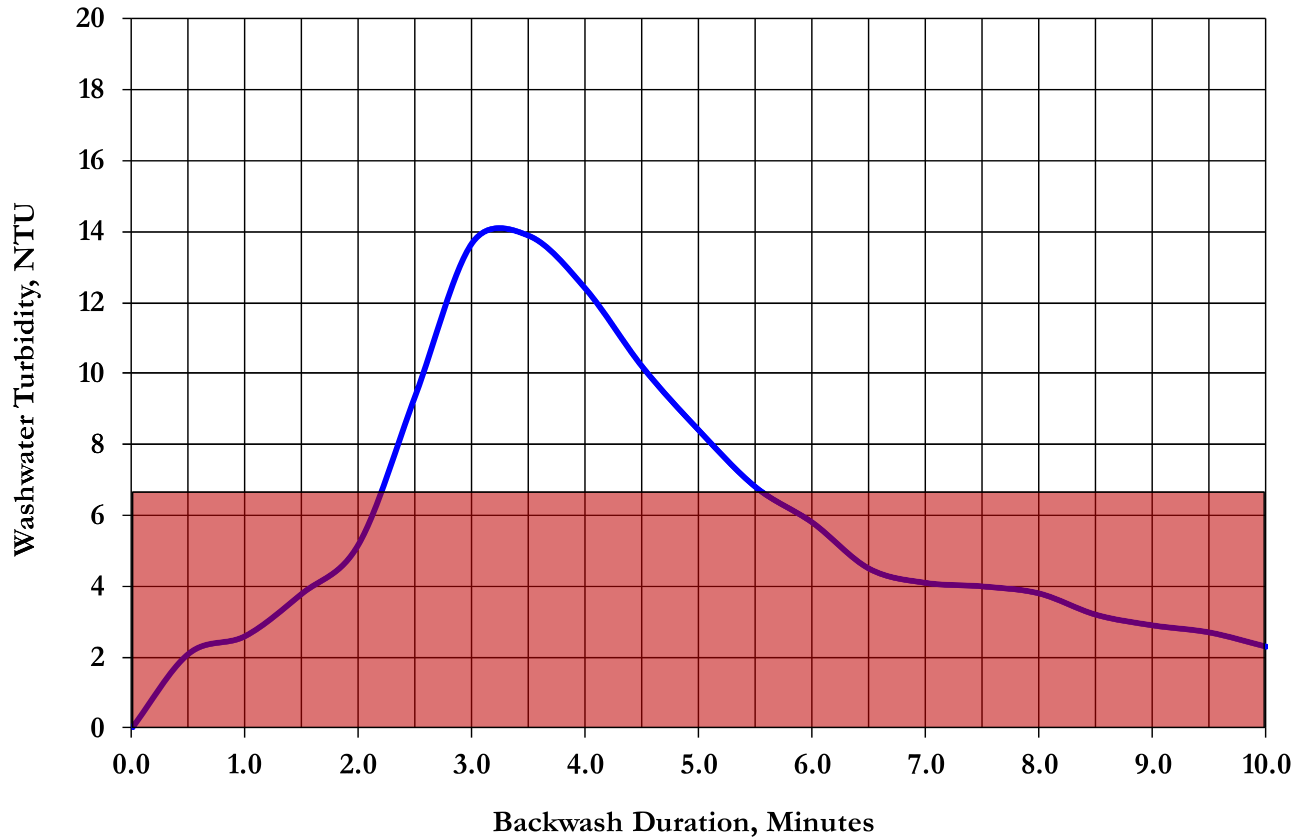
Typical Floc Retention Profile After Backwash

Backwash Duration Evaluations

- Typical backwash should be about 6 minutes to 8 minutes
  - Most plants over-wash filters based on sight, not scientific data
    - Wastes washwater and increases operating costs
  - 40% to 85% reductions in washwater have been accomplished
- Backwash duration tests define backwash length
  - Terminate backwash once washwater turbidity falls below 10 NTU
  - Washwater turbidimeters not responsive enough for automated backwash termination

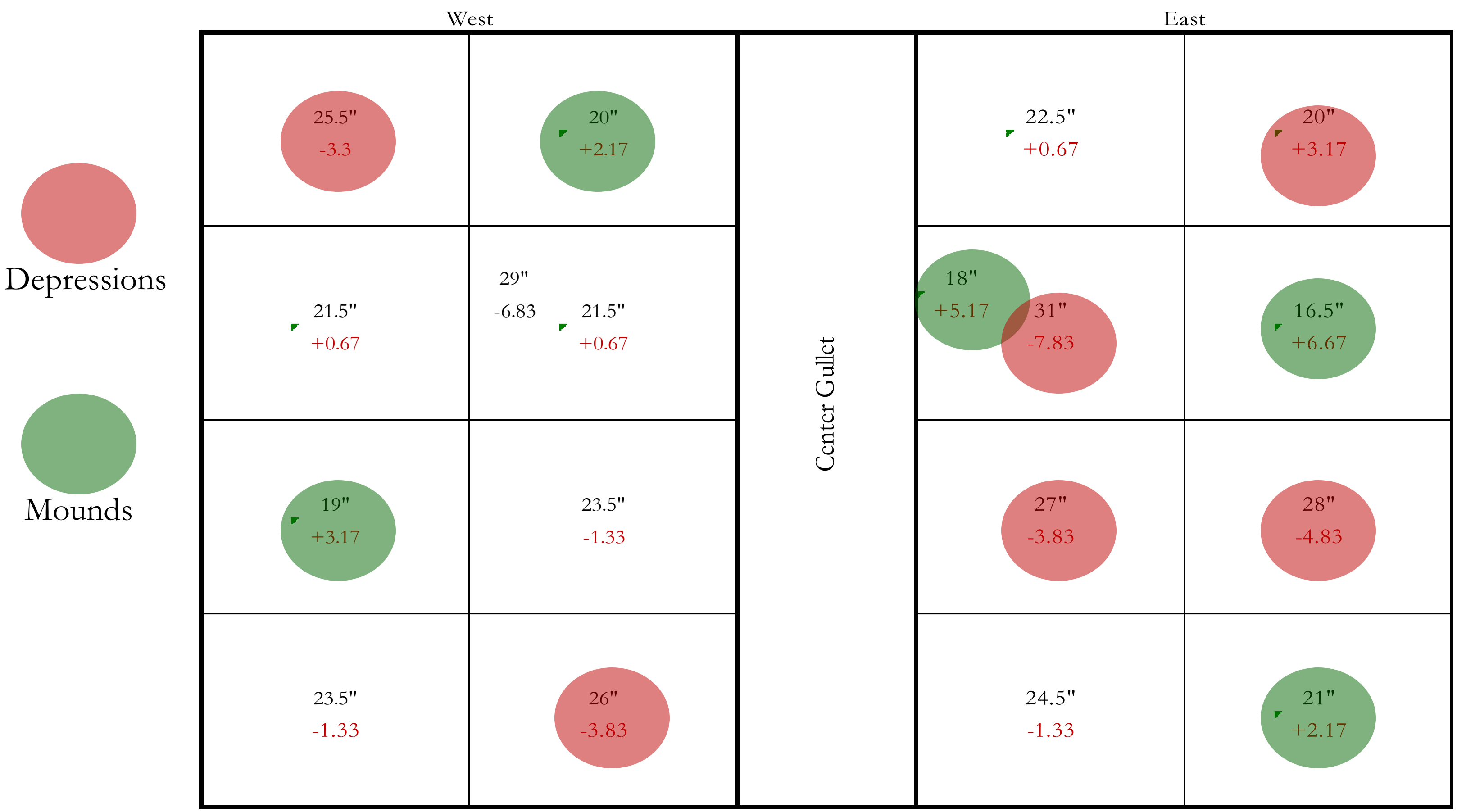
Backwash Duration Evaluations

- Normal backwash was 11 minutes
- Duration curve demonstrates a 6 minute backwash is needed for media cleaning
- Extending backwash only wastes water and fails to remove more solids



Backwash Duration Curve

Gravel Profiling Maps



Gravel Profiling Maps

Depressions

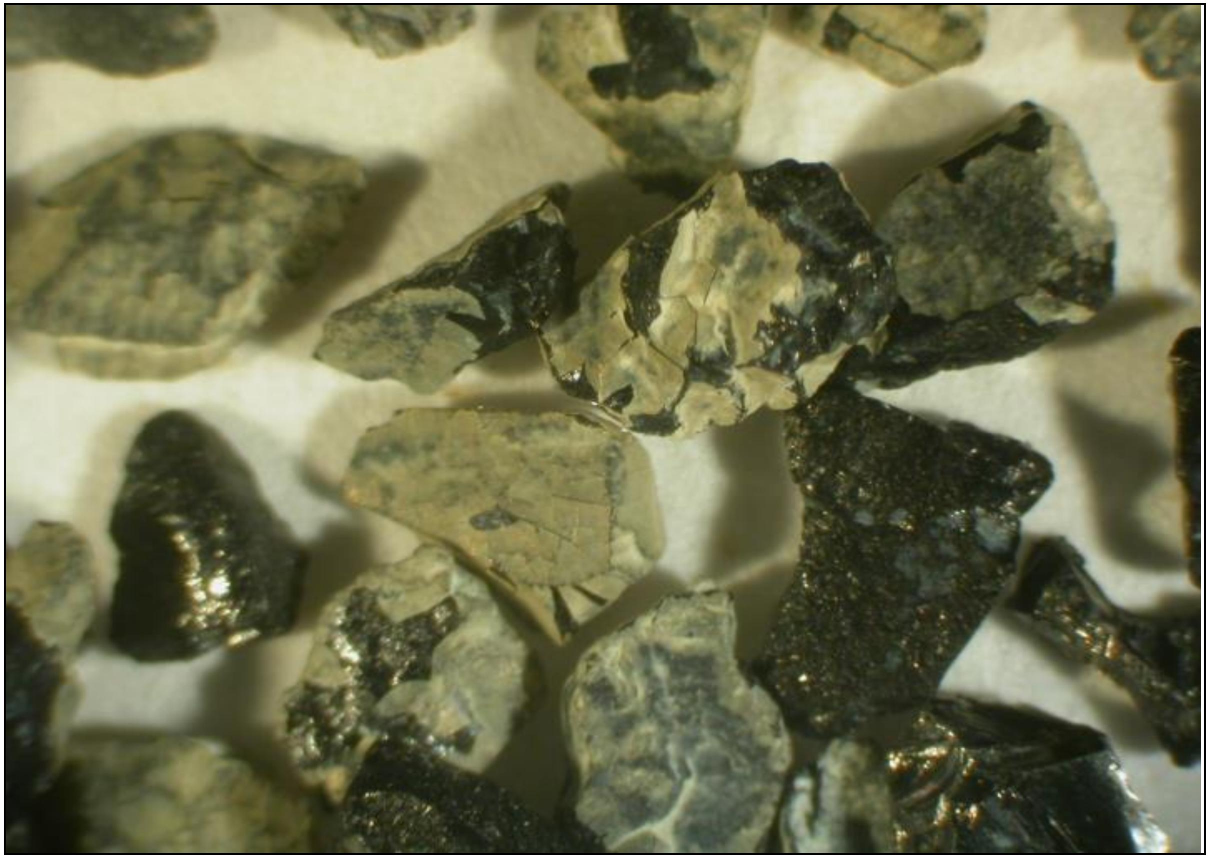
Mounds

23-inches +0.4-inches	23.5-inches -0.1-inches	Center Gullet	25-inches -1.5-inches	24-inches -0.5-inches
23.5-inches -0.1-inches	23.5-inches -0.1-inches		23.5-inches +0-inches	22.5-inches +1.0-inches
23.5-inches -0.1-inches	24-inches -0.6-inches		24-inches -0.5-inches	24-inches -0.5-inches
23.5-inches -0.1-inches	23.5-inches -0.1-inches		23.5-inches +0-inches	23.5-inches +0-inches

Sieve Analysis/Acid Solubility

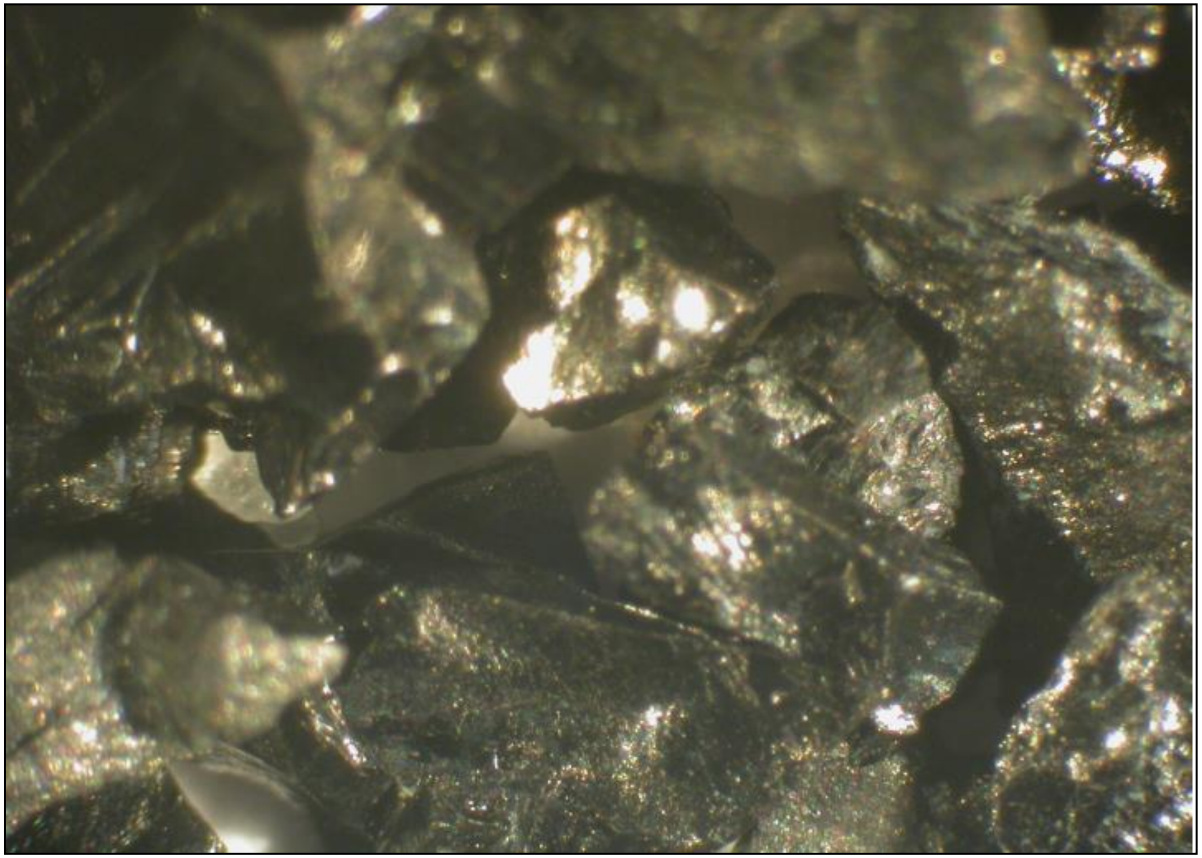
- Analyzed periodically to confirm media condition
  - Indicates media growth or anthracite (GAC) breakage due to excessive surface wash and /or backwash
  - Indicates deposition of materials on media surface
- Effective size changes
  - Exceed 10% of original media size - consider media replacement or acid washing
  - Reduced anthracite/GAC size - adjust surface wash operations
- Changes in acid solubility
  - Less than 1% per year acceptable
  - Greater than 5% - adjust chemical pretreatment or consider acid washing media
  - Greater than 15% - consider replacing media

Microscopic Analysis



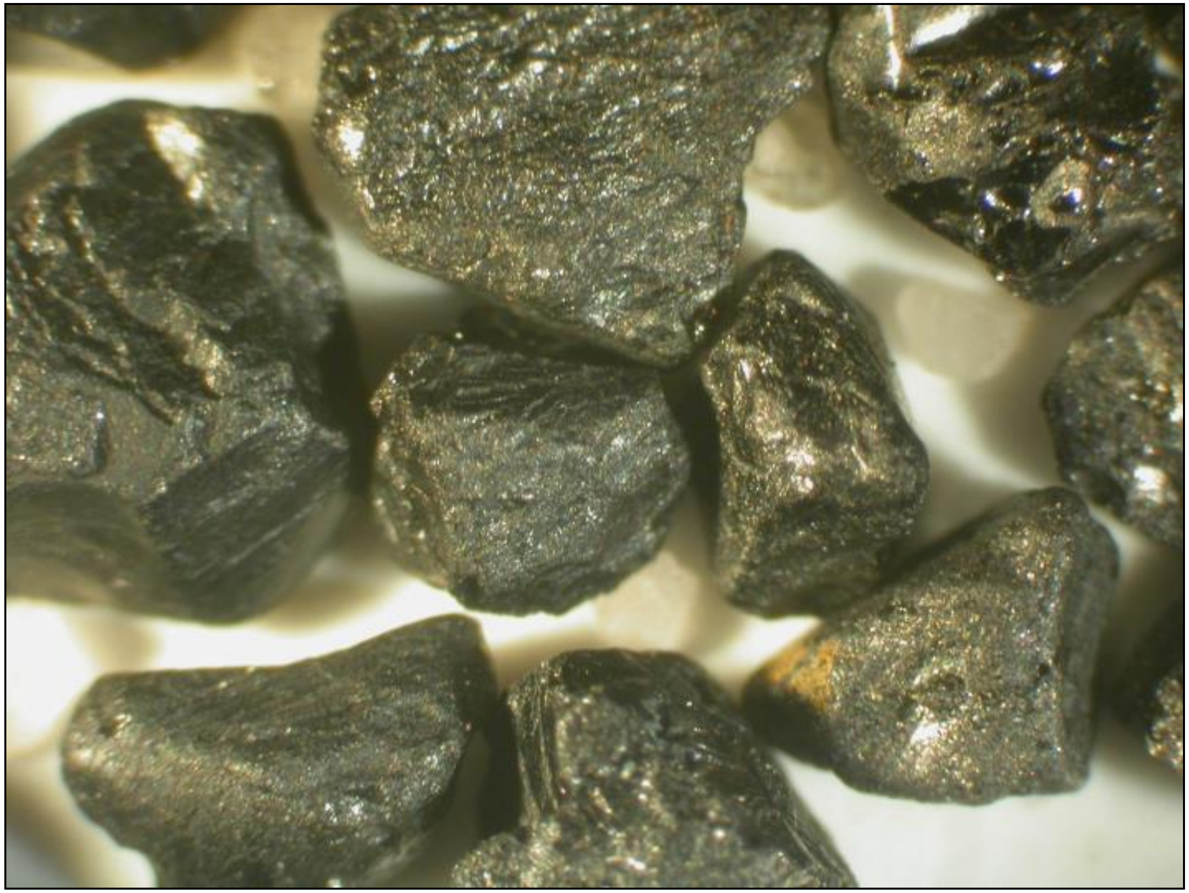
Anthracite media with carbonate deposits

Microscopic Analysis



Clean anthracite media with sharp edges, shiny surfaces

Microscopic Analysis



Washed anthracite media with worn, rounded edges

Microscopic Analysis

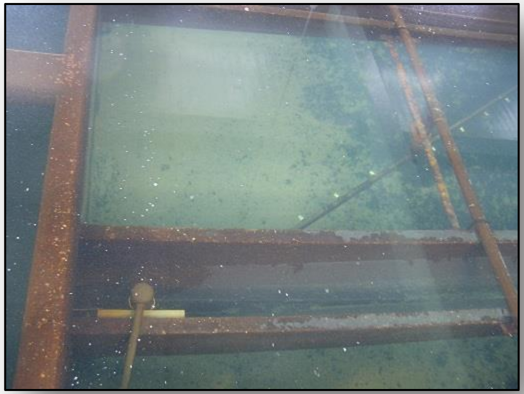
Filter sand with sharp edges

Microscopic Analysis

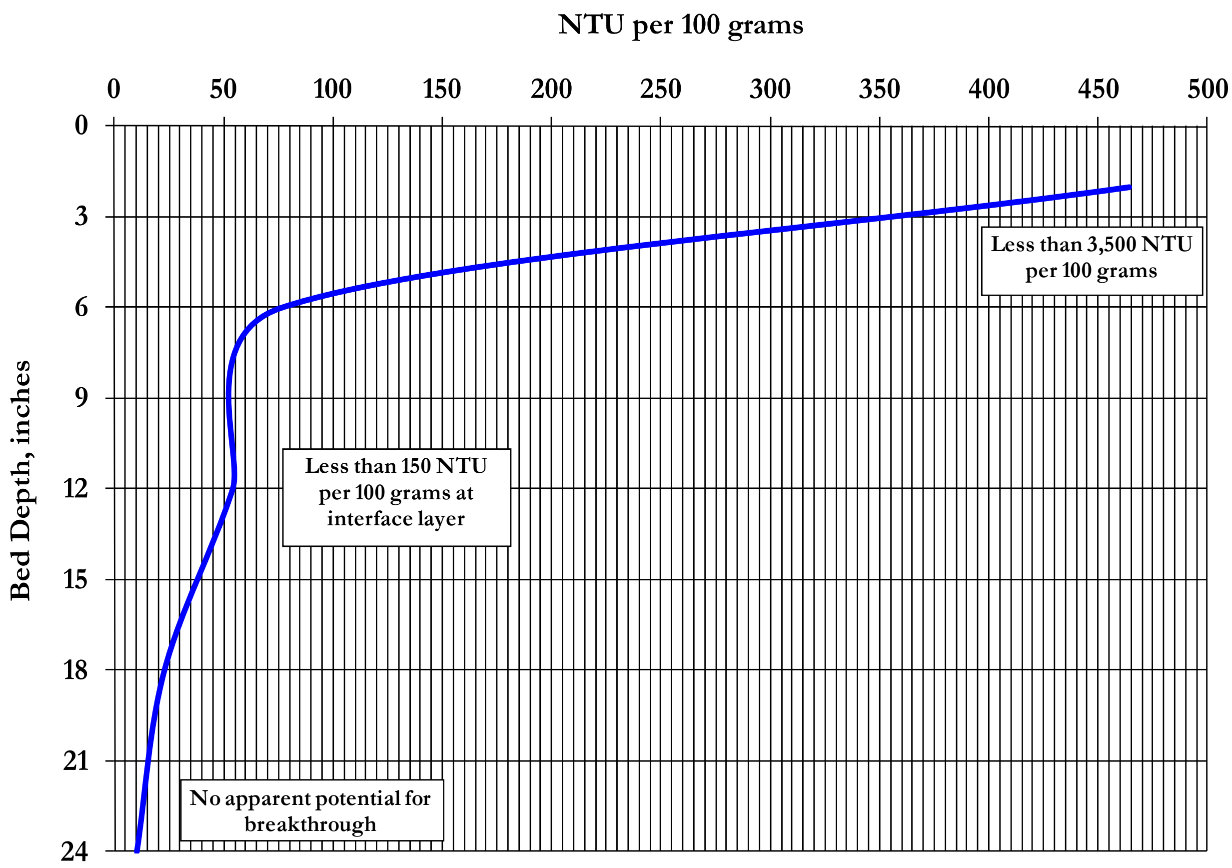
Filter sand with severely worn, rounded edges

Case Study 1 - Ohio

- Baseline operating data
  - 10 filters 740 sf each, new filter media 2009
  - L/D_{10} ratio 1,035
  - Run times 72 hours
  - Head loss < 2 feet
  - Filtration rate 1.25 gpm/ft^2
  - Average effluent turbidity 0.067 NTU
  - Solids loading 0.03 lbs/cf
    - Max turbidity at backwash 0.18 NTU
  - Filter efficiency 97.8%
  - GWP 5,600 $gal/ft^2/run$
  - Washwater usage 113 gal/ft^2
  - Filter-to-waste 2 hours at 720 gpm



Case Study 1 - Ohio



Floc Retention Before Backwash

Confirmed low solids loadings

Indicated longer run times possible

No indication of breakthrough during filter run

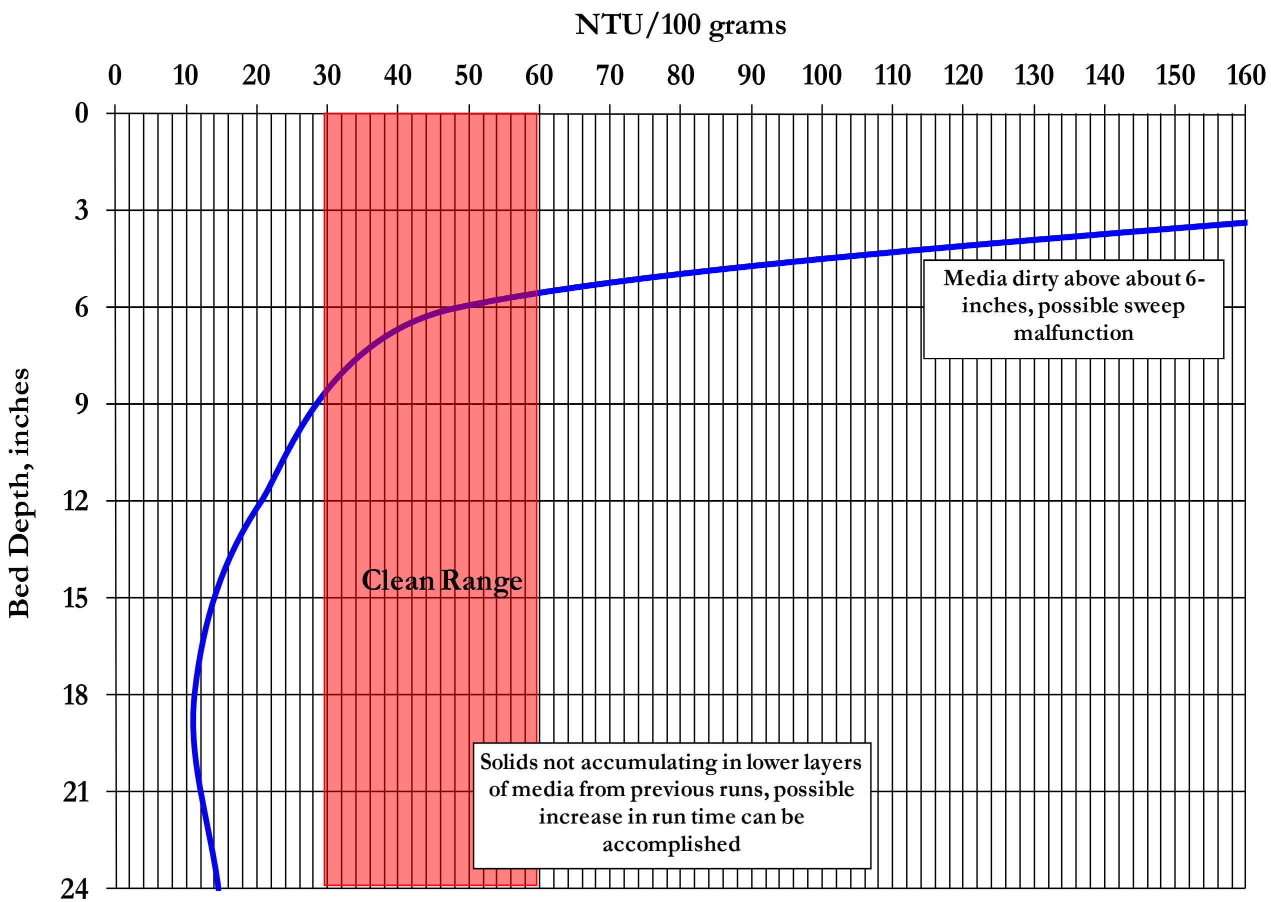
Case Study 1 - Ohio

Floc Retention After Backwash

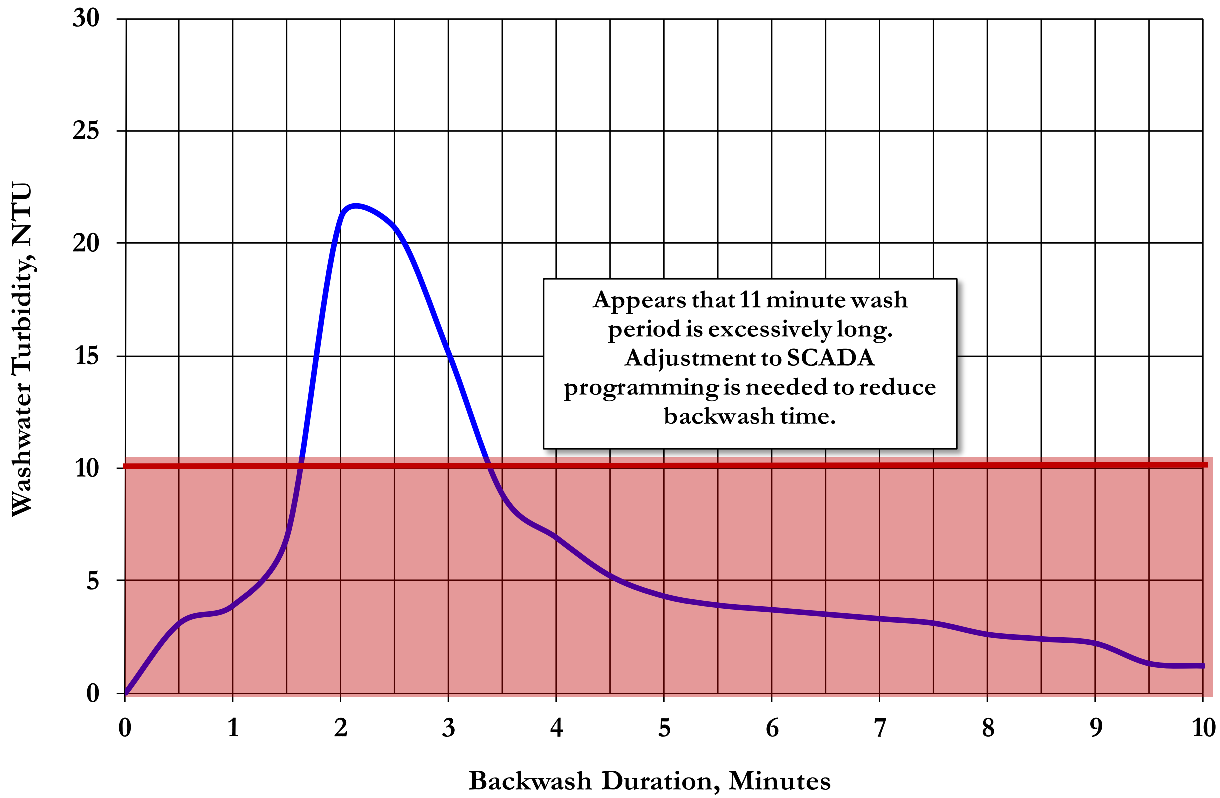
Potential issues with surface wash sweeps

Much of top layers dirty after backwash

Lower layers below clean range – likely due to low solids loading



Case Study 1 - Ohio



Backwash Duration Evaluation

11 minute wash period too long

Changes in SCADA needed to control backwash timing

Much less than 10 NTU in washwater at end of wash period

Bed expansion 25%

Case Study 1 - Ohio

Parameter	Before Optimization	Parameter	After Optimization
Filters used	10	Filters used	6
Filtration rate	1.25 gpm/sf	Filtration rate	2 gpm/sf
Run time	72 hours	Run time	160 hrs to 200 hrs
GWP	5,600 gal/ft^2/run	GWP	22,000 gal/ft^2/run
Filter efficiency	97.8%	Filter efficiency	98.5%
Washwater usage	113 gal/sf	Washwater usage	63 gal/sf
Solids loading	0.03 lbs/cf	Solids loading	0.06 lbs/cf
FTW volume	86,400 gal	FTW volume	0 gal
Average NTU	0.067	Average NTU	0.045
Max NTU	0.18	Max NTU	0.085

Case Study 1 - Ohio

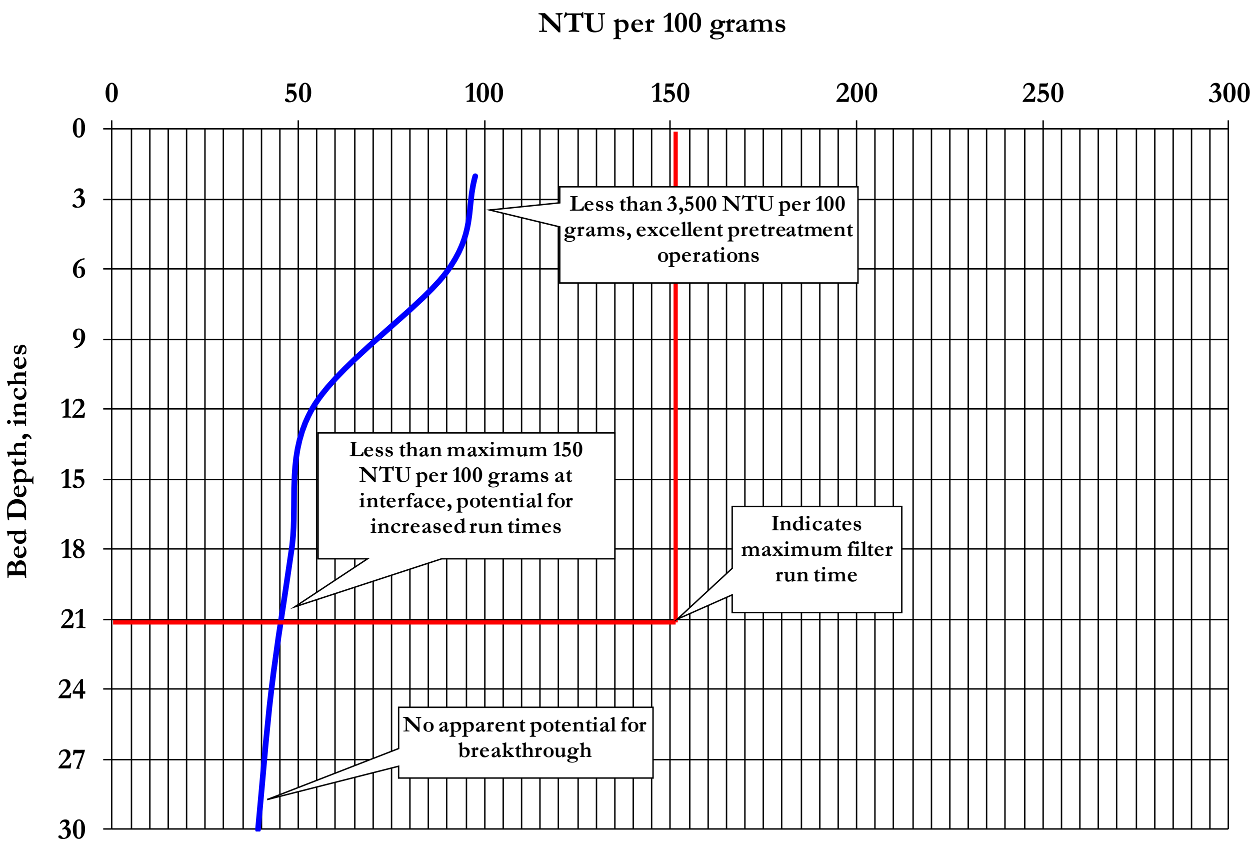
82% reduction in washwater and FTW

Parameter	Before Optimization	Parameter	After Optimization
Filters used	10	Filters used	6
Filtration rate	1.25 gpm/sf	Filtration rate	2 gpm/sf
Run time	72 hours	Run time	160 hrs to 200 hrs
GWP	5,600 gal/ft^2/run	GWP	22,000 gal/ft^2/run
Filter efficiency	97.8%	Filter efficiency	98.5%
Washwater usage	113 gal/sf	Washwater usage	63 gal/sf
Solids loading	0.03 lbs/cf	Solids loading	0.06 lbs/cf
FTW volume	86,400 gal	FTW volume	0 gal
Average NTU	0.067	Average NTU	0.045
Max NTU	0.18	Max NTU	0.085

Case Study 2 - Pennsylvania

- Baseline operating data
  - 18 filters 2,880 sf each, media replaced 1987
  - L/D_{10} ratio 1,115
  - Run times 100 hours
  - Head loss < 2 feet
  - Filtration rate 1.10 gpm/ft^2
  - Average effluent turbidity 0.034 NTU
  - Solids loading 0.07 lbs/cf
    - Max turbidity at backwash 0.13 NTU
  - Filter efficiency 97.6%
  - GWP 7,260 gal/ft^2/run
  - Washwater usage 157 gal/ft^2
  - Filter-to-waste not used

Case Study 2 - Pennsylvania



Floc Retention Before Backwash

Confirmed low solids loadings from settled water

Indicated longer run times possible

No indication of breakthrough during filter run

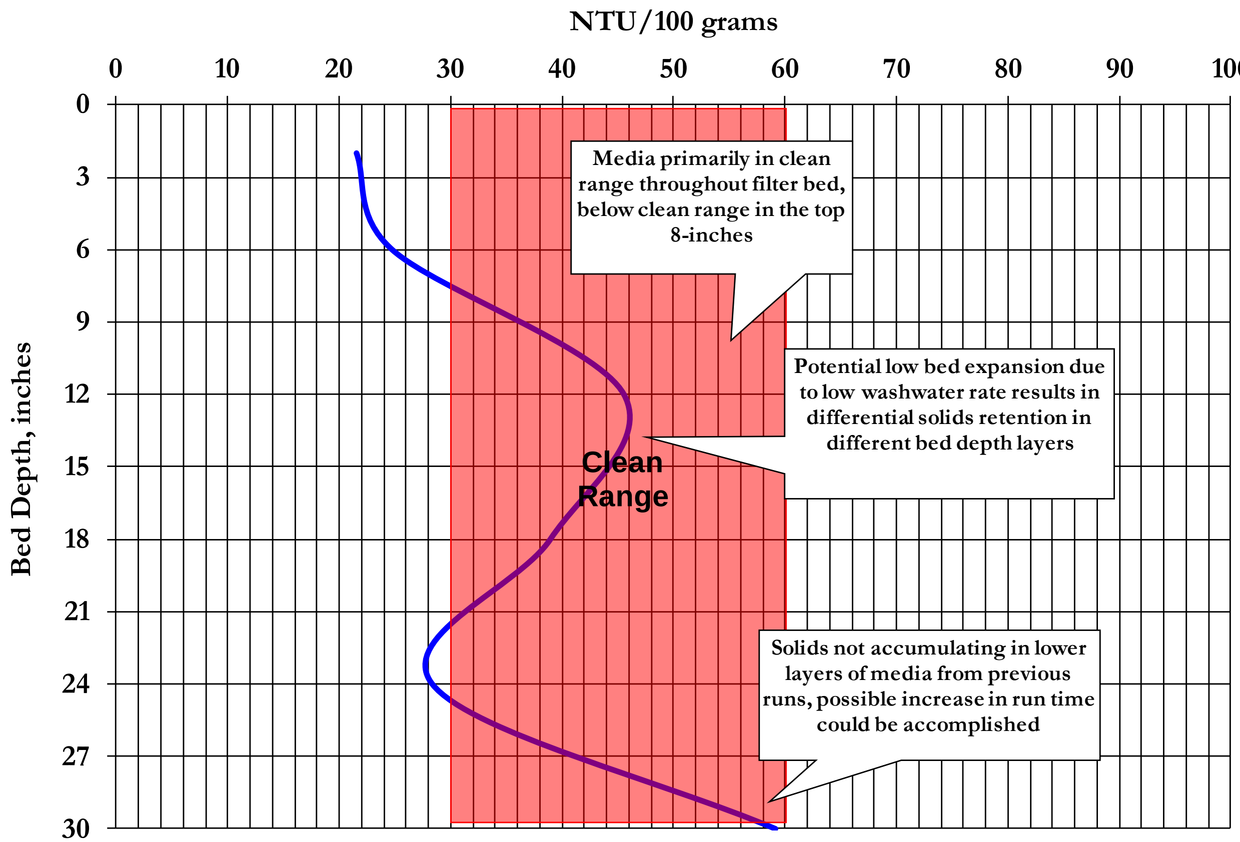
Case Study 1 - Ohio

Floc Retention After Backwash

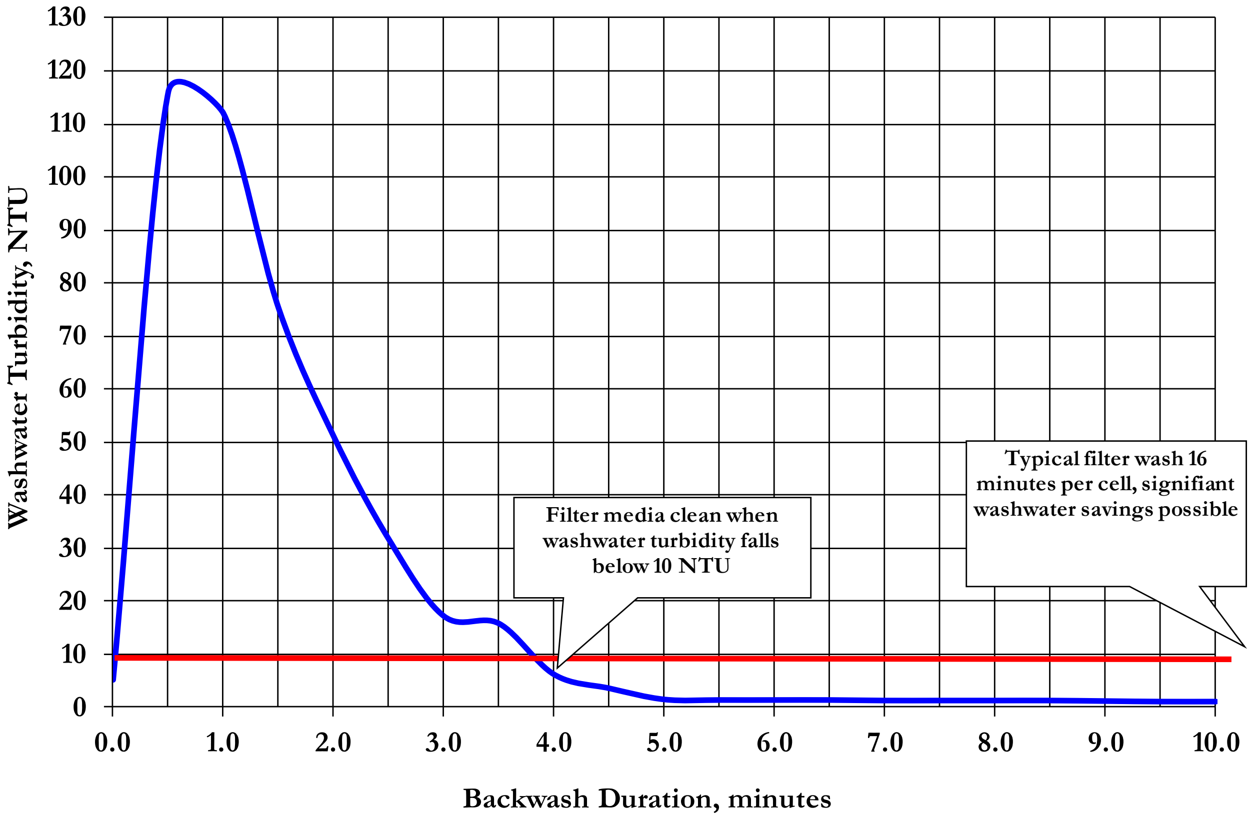
Air scour time appeared too long

Much of media fell within clean range

Lower layers not accumulating solids - likely due to low solids loading



Case Study 2 - Pennsylvania



Backwash Duration Evaluation

16 minute wash period too long - 4 minutes needed this wash cycle

Much less than 10 NTU in washwater at end of wash period (1.1 NTU end of cycle)

Bed expansion 17%

Case Study 2 - Pennsylvania

Parameter	Before Optimization	Parameter	After Optimization
Filters used	18	Filters used	6
Filtration rate	1.10 gpm/sf	Filtration rate	2 gpm/sf
Run time	100 hours	Run time	175 hours
GWP	7,260 gal/ft²/run	GWP	21,100 gal/ft²/run
Filter efficiency	97.6%	Filter efficiency	99.8%
Washwater usage	156 gal/sf	Washwater usage	47 gal/sf
Solids loading	0.07 lbs/cf	Solid loading	0.21 lbs/cf
Average NTU	0.034	Average NTU	0.035
Max NTU	0.13	Max NTU	0.069

Case Study 2 - Pennsylvania

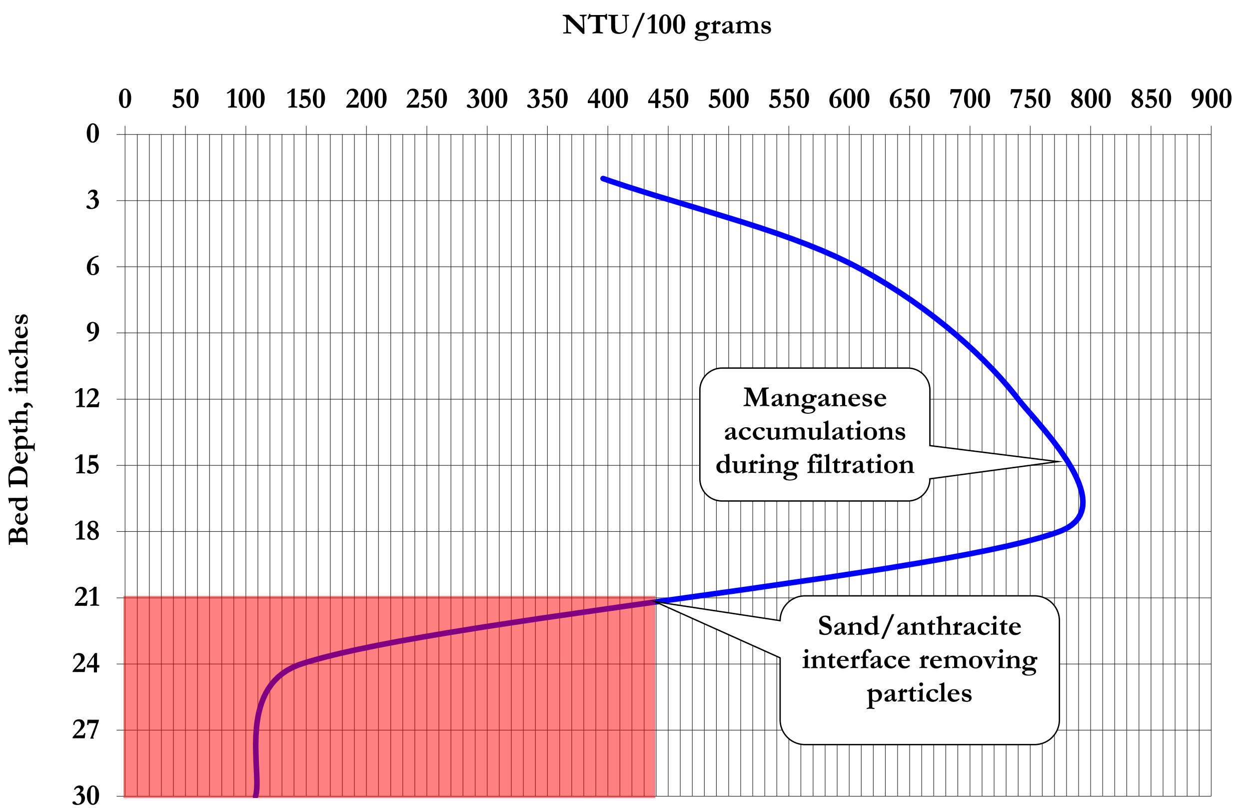
83% reduction in washwater

Parameter	Before Optimization	Parameter	After Optimization
Filters used	18	Filters used	6
Filtration rate	1.10 gpm/sf	Filtration rate	2 gpm/sf
Run time	100 hours	Run time	175 hours
GWP	7,260 gal/ft^2/run	GWP	21,100 gal/ft^2/run
Filter efficiency	97.6%	Filter efficiency	99.8%
Washwater usage	156 gal/sf	Washwater usage	47 gal/sf
Solids loading	0.07 lbs/cf	Solid loading	0.21 lbs/cf
Average NTU	0.034	Average NTU	0.035
Max NTU	0.13	Max NTU	0.069

Case Study 3 - DC area

- Baseline operating data
  - 48 filters 2,085 sf each , new filter media 1999
  - L/D_{10} ratio 1,066
  - Run times 120 hours
  - Head loss < 2 feet
  - Filtration rate 0.97 gpm/ft^2
  - Average effluent turbidity 0.045 NTU
  - Solids loading 0.04 lbs/cf
    - Max turbidity at backwash 0..075 NTU
  - Filter efficiency 94.9%
  - GWP 5,730 $gal/ft^2/run$
  - Washwater usage 293 gal/ft^2
  - Filter-to-waste 30 minutes at 800 gpm

Case Study 3 - DC area



Floc Retention Before Backwash

Anthracite acting as manganese reactor not filter media

Filter sand removing particles

No indication of breakthrough during filter run

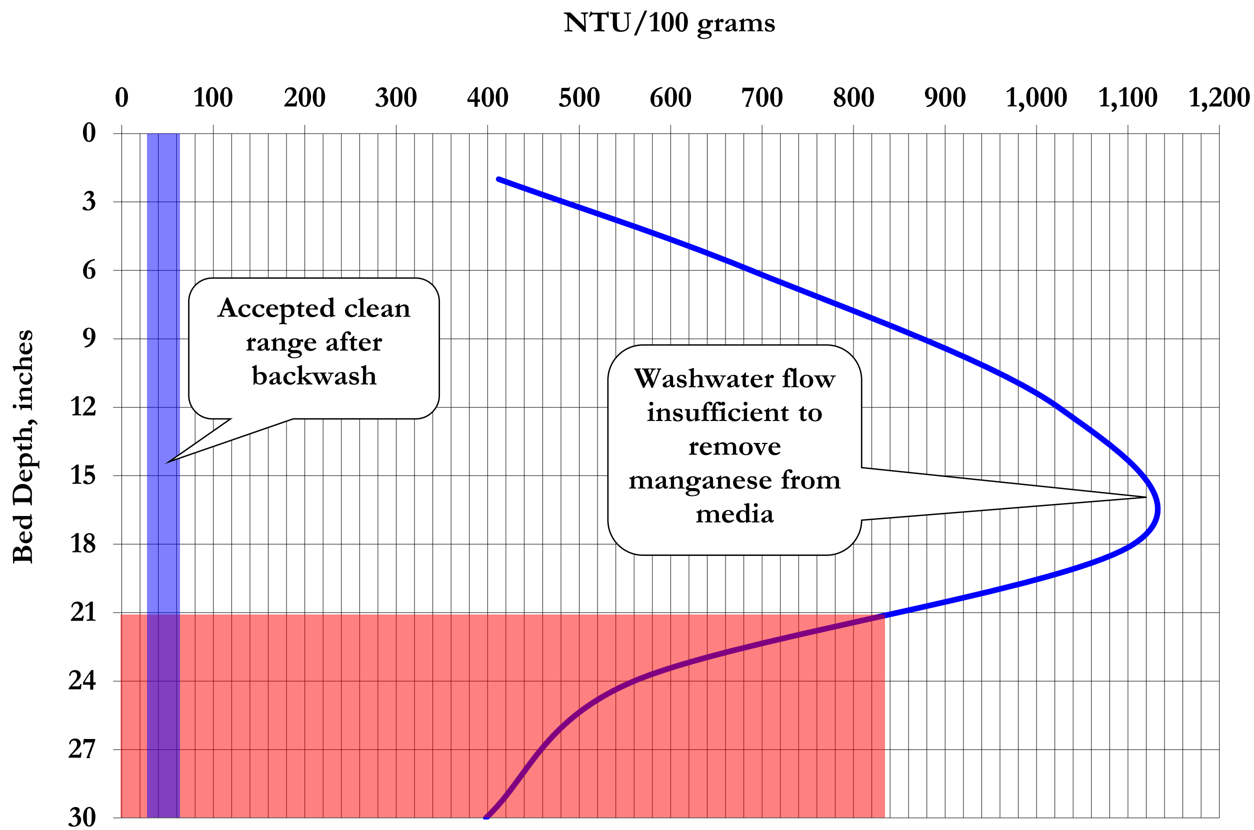
Case Study 3 - DC area

Floc Retention After Backwash

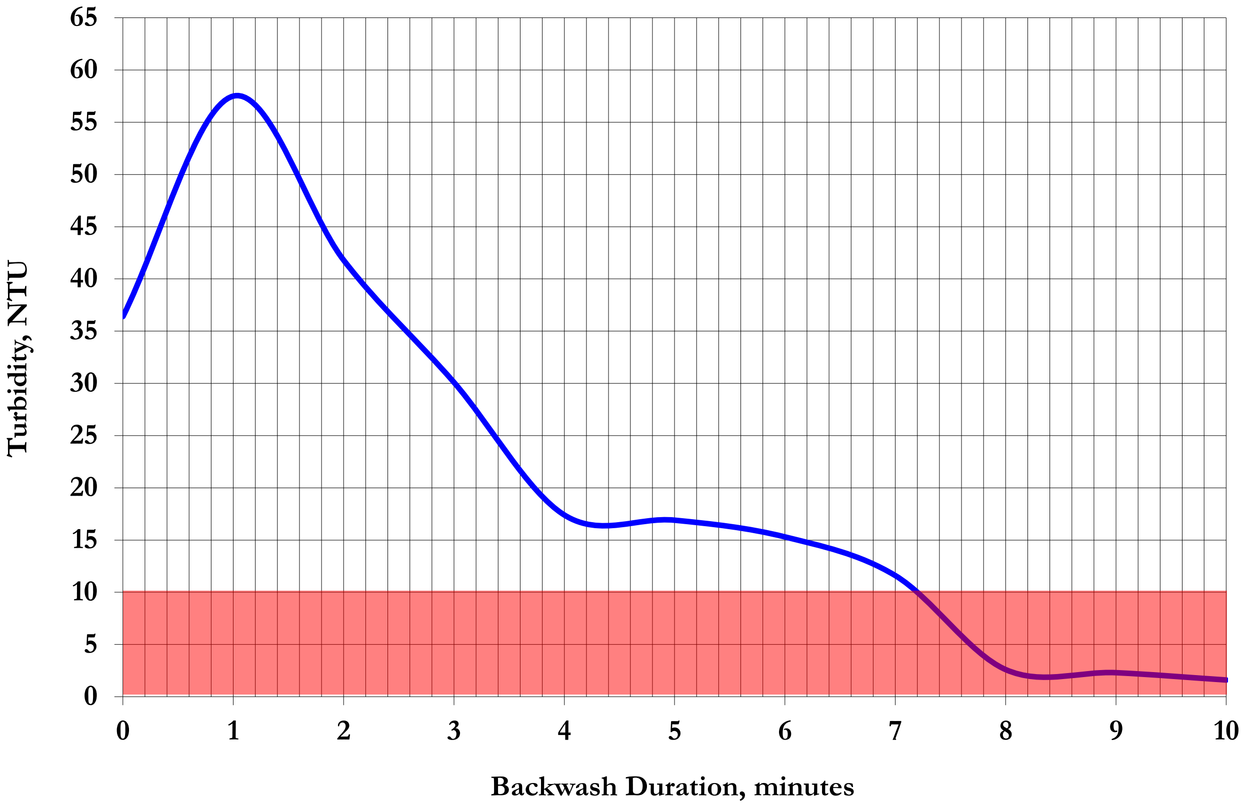
Air scour not removing manganese accumulations

Media still dirty after backwash

Media replacement likely needed due to manganese deposits



Case Study 3 - DC area



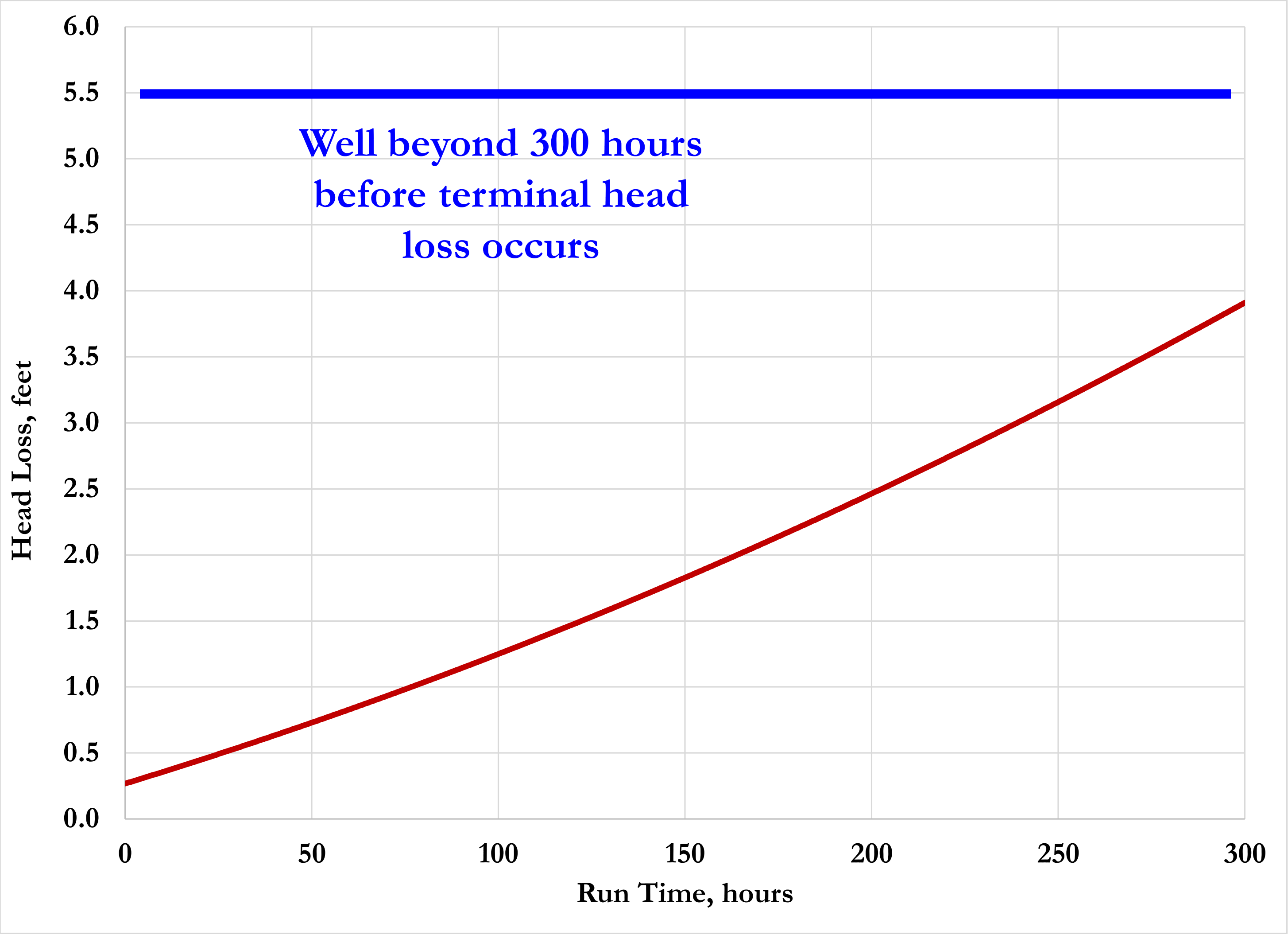
Backwash Duration Evaluation

23 minute wash period too long – 7.5 minutes needed this wash cycle

Much less than 10 NTU in washwater at end of wash period (1.1 NTU end of cycle)

Bed expansion 13%

Case Study 3 - DC area



Case Study 3 - DC area

Parameter	Before Optimization	Parameter	Suggested Optimization
Filters used	48	Filters used	13
Filtration rate	0.8 gpm/sf	Filtration rate	2 gpm/sf
Run time	120 hours	Run time	170 hours
GWP	5,730 gal/ft^2/run	GWP	20,400 gal/ft^2/run
Filter efficiency	94.9%	Filter efficiency	98.0%
Washwater usage	293 gal/sf	Washwater usage	103 gal/sf
Solids loading	0.04 lbs/cf	Solids loading	0.15 lbs/cf
Average NTU	0.045	Average NTU	Similar
Max NTU	0.075	Max NTU	Similar

Case Study 3 - DC area

50% reduction in washwater and FTW

Parameter	Before Optimization	Parameter	Suggested Optimization
Filters used	48	Filters used	13
Filtration rate	0.8 gpm/sf	Filtration rate	2 gpm/sf
Run time	120 hours	Run time	170 hours
GWP	5,730 gal/ft^2/run	GWP	20,400 gal/ft^2/run
Filter efficiency	94.9%	Filter efficiency	98.0%
Washwater usage	293 gal/sf	Washwater usage	103 gal/sf
Solids loading	0.04 lbs/cf	Solids loading	0.15 lbs/cf
Average NTU	0.045	Average NTU	Similar
Max NTU	0.075	Max NTU	Similar

Summary

- Filter inspections can reveal interesting relationships
- Most filters backwashed too long resulting in subsequent long ripening issues
- Many plants use too much washwater and excessive filter-to-waste operations
- Standby operation after backwash proven to ripen filters better than other methods
- Small media loss volumes can impact filter performance
- Worn, aged media often impacts filter performance
- Optimization pays for itself in reduced media replacement costs and reductions in washwater costs

Questions

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