Filter Maintenance Programs

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Agenda

- Reasons to conduct filter maintenance
- Maintenance program checklist
- Regulatory requirements for filters
- Common filter designs
- Maintenance activities
- Physical observations
- Filtration and backwash metrics
- Questions

Filtration Needs Pretreatment

- Pretreatment conditioning upstream of filtration affects filter performance
  - Permanganate oxidation
  - Coagulation and flocculation
  - Sedimentation
- 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 2 NTU

Clarification and sedimentation are important to successful filtration

Introduction to Filter Maintenance

- Written program of procedures for filter maintenance activities
- Filter maintenance training
- Specialized maintenance procedures
- Forms and reporting activities
- Some contractor services may be needed
  - Acid solubility
  - Grain size distribution (sieve analysis)
  - Microscopic examinations of media
  - Media cleaning services

Reasons for Filter Maintenance

- Continued use of filter media for long service
  - Average media life about 25 years
  - Well maintained can last up to 45 years
  - Excessive wear and media loss shortens life
- Successful filtration and low turbidity filtered water
- Protect against water-borne disease
  - Microbes
  - Parasites (Giardia, Cryptosporidium, etc.)
- Prevent excessive filter media mineralization
  - Iron, manganese, calcium carbonate, mud ball accumulations

Reasons for Filter Maintenance

- Verify current media conditions
  - Mineralization (acid solubility analysis)
  - Grain size distribution (sieve analysis)
  - Wear and granularity (microscopic analysis)
- Conformance with expected operations
  - Specific filtration and backwash metrics
- Reduce washwater usage
  - Washwater costs average $0.35/1,000 gallons to $0.89/1,000 gallons in most treatment plants

Filter Maintenance Checklist

- Filters are particle removal units
  - Too many particles in applied water reduces efficiency and deteriorates filter media
  - Inefficient backwash leaves too many particles in the media and can results in mud ball accumulations
- Maintenance frequency (5-year intervals)
  - Maintain filters each year to meet 5-year maintenance interval for all filters (10/5 = 2 filters per year)
  - Problems can be corrected when found
  - Media can be cleaned as necessary
    - Remove mud balls
    - Acid wash to remove scale

Filter Maintenance Checklist

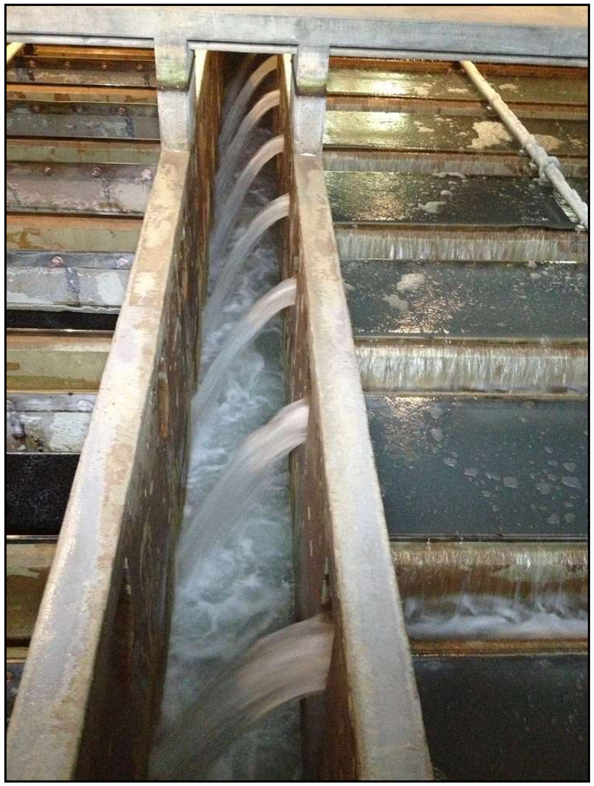
- Water quality is as good as the worst filter
  - Correct poor performing filters when found to maintain overall performance and integrity
- Individual filter turbidity monitoring in required by law
  - Can indicate poor performing filters
  - Requirements for continuous filter monitoring of filters in service, do you have a replacement turbidimeter?
  - Turbidimeter flowrate regulated by manufacturer and optimization best practices (EPA requirements)
    - 250 mL/minute to 750 mL/minute

Filter Maintenance Checklist

- Changes in filter rate impact performance
  - Increased flow rate increase effluent turbidity, reduce flow changes for more consistent turbidity readings
  - Adjust filters in service according to plant production rate
- Verify media conditions at least annually
  - Media changes over time, does it still meet design specifications?
  - Mineralization changes media size, shape, and transitional flow
  - Media loss is common but should not be excessive, measure filter bed depth
  - Analyze media from filters under maintenance

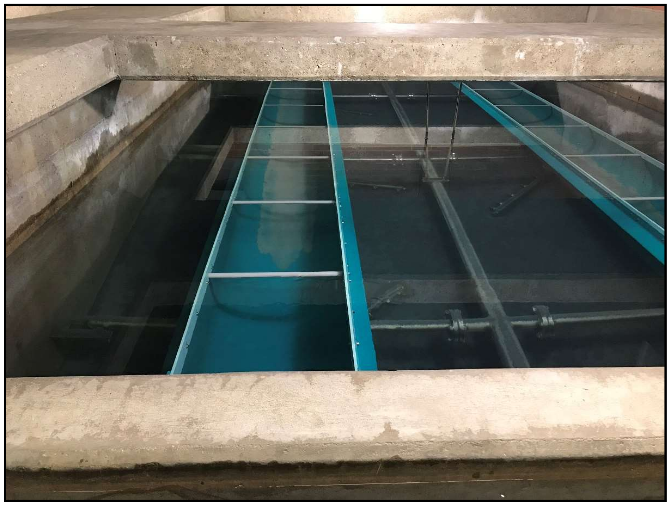
Filter Maintenance Checklist

- Water temperature affects backwash rates
  - Adjust backwash as needed to maintain bed expansion and media cleaning
  - Can program this into SCADA with a temperature curve
- Verify backwash duration and usage
  - Duration testing for each filter under maintenance
  - Adjust backwash times as necessary
  - Washwater usage should conform to established metrics



Filter Maintenance Checklist

- Filter ripening
  - Gravity compaction technique is most efficient method
  - Filter-to-waste (minimize wasted water)
  - Do filters produce 0.10 NTU or less within the first 15 minutes of operation?
- Floc retention profiles tell a story
  - Conduct filter coring and develop retention profiles for each filter under maintenance
  - Adjust operations as suggested from profiles



Filter Maintenance Checklist

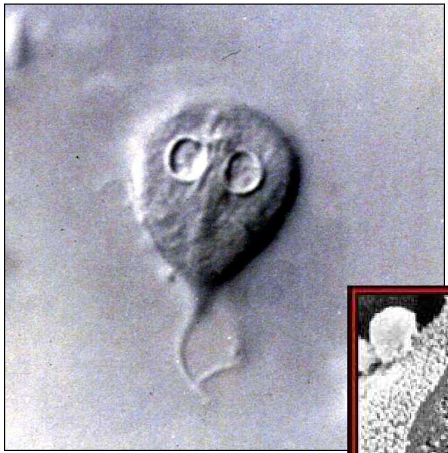
- Bed expansion is crucial for filter maintenance
  - Proper expansion for media cleaning 30% to 35%
  - Restratification of media layers (second low-rate wash)
  - Overexpansion results in filter problems and media loss
- Maintenance training needed
  - Staff need training to conduct filter maintenance properly
  - Pays off in filter performance
  - Procedures and reporting important to successful maintenance

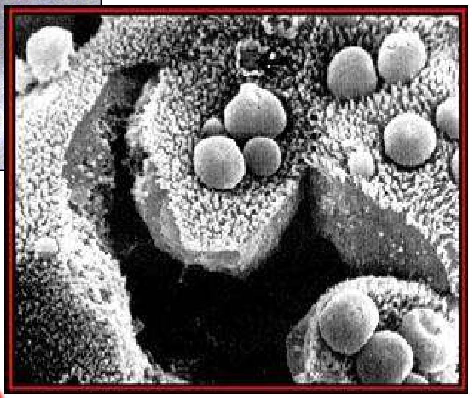
Regulatory Requirements for Filters

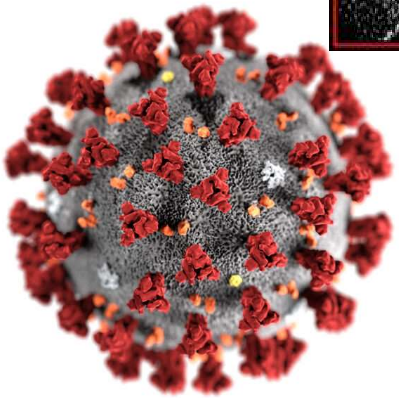
Turbidity Standards	Turbidity Limit
Before 1962	10 NTU (USPHS)
1962 to 1976	5 NTU
1977 to 1993	1 NTU (SWDA 1974)
1993 to 2002	0.5 NTU
IESWTR (2002)	0.3 NTU
LT1ESTWR (2006)	0.3 NTU
AWWA Partnership	0.1 NTU

Regulatory Requirements for Filters

- Turbidity directly related to microbial contamination
  - Stated in 1974
  - SDWA Amendments 1976 - turbidity is a treatment technique for bacteria control
  - CT requirements established in 1989 for Giardia, viruses, Legionella, etc. (effective 1993)
  - CT requirements established in 2006 for Cryptosporidium

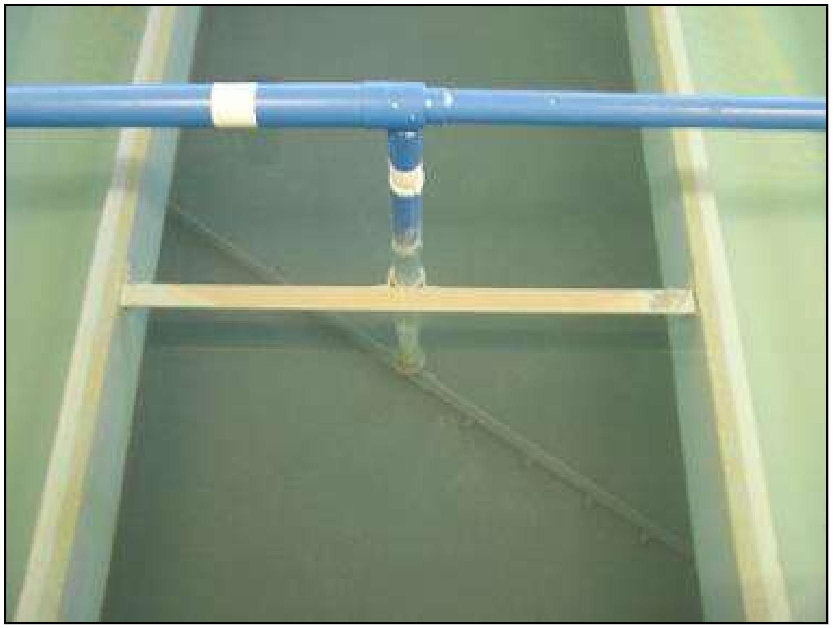






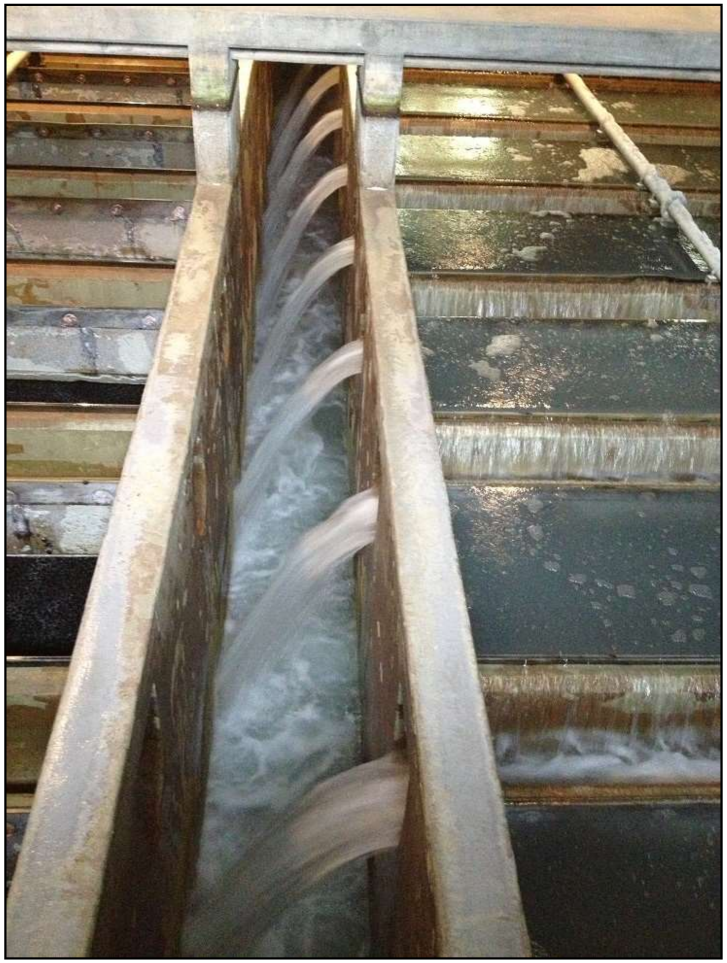
Regulatory Requirements for Filters

- SWTR 1989
  - 0.5 NTU in 95% of samples
  - At not time exceed 5 NTU
- IESWTR 1998
  - effective January 2002
  - 0.3 NTU in 95% of samples
  - at no time exceed 1 NTU
- FBRR 2001
  - All recycle to head of plant must be coagulated



Regulatory Requirements for Filters

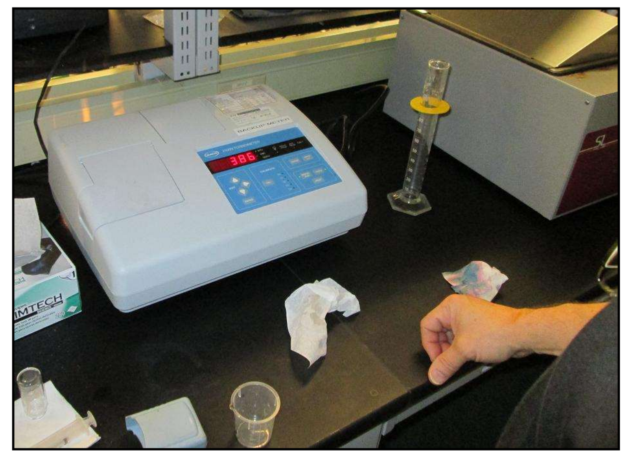
- LT1ESWTR - Jan. 2004-2005
  - Finalized 0.3 NTU limits for water systems
  - Individual FE turbidity monitoring
- LT2ESWTR - Jan. 2006
  - CT requirements - disinfection requirements for cryptosporidium



Regulatory Requirements for Filters

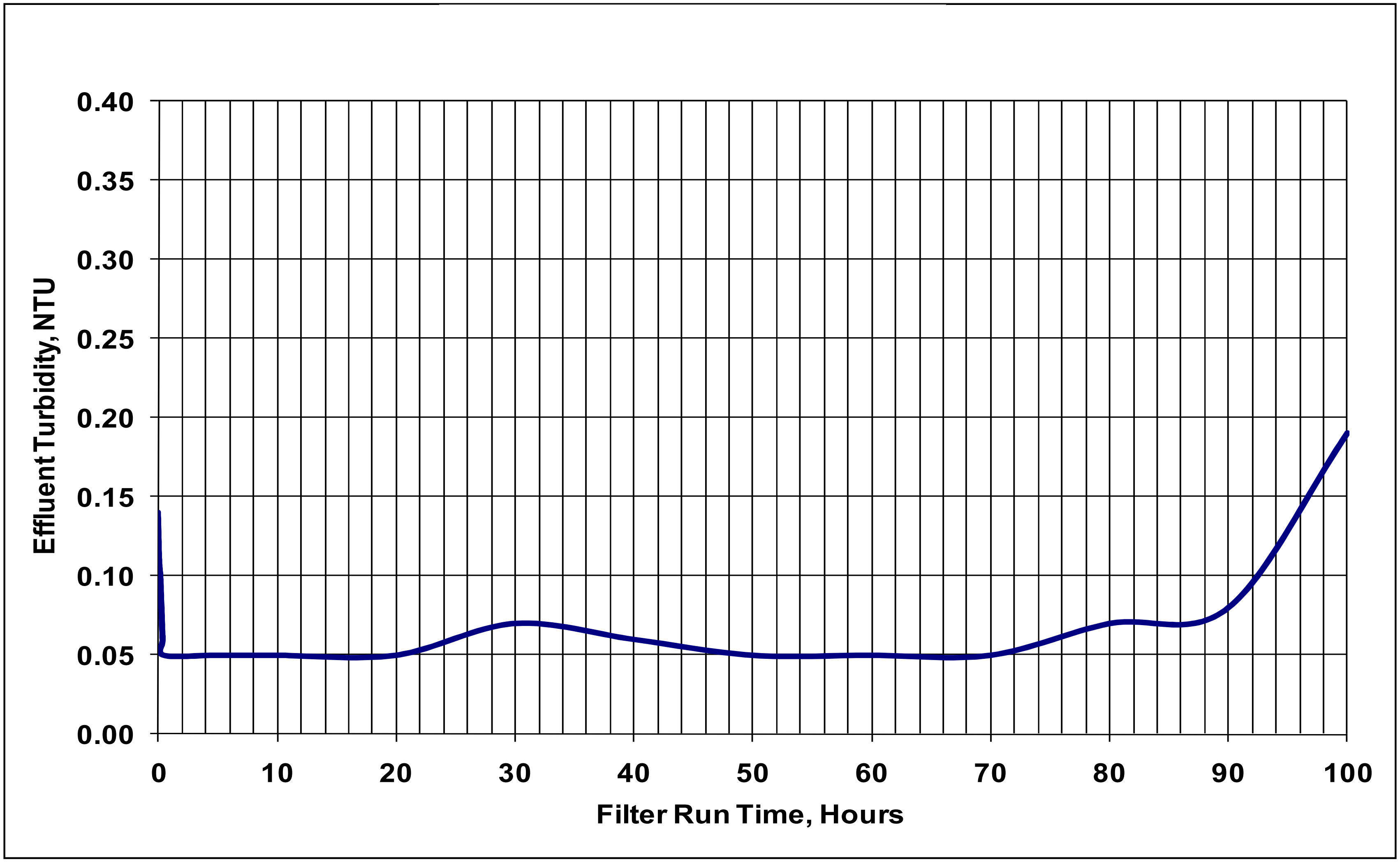
IESWTR: Large Systems

- Monitoring of individual filters
- Exceptions reporting for individual filters
  - >1 NTU in 2 consecutive samples taken 15 minutes apart
  - >0.5 NTU between end of 1st four hours after backwash or offline and end of filter run



Prepare filter profile

Regulatory Requirements for Filters



Regulatory Requirements for Filters

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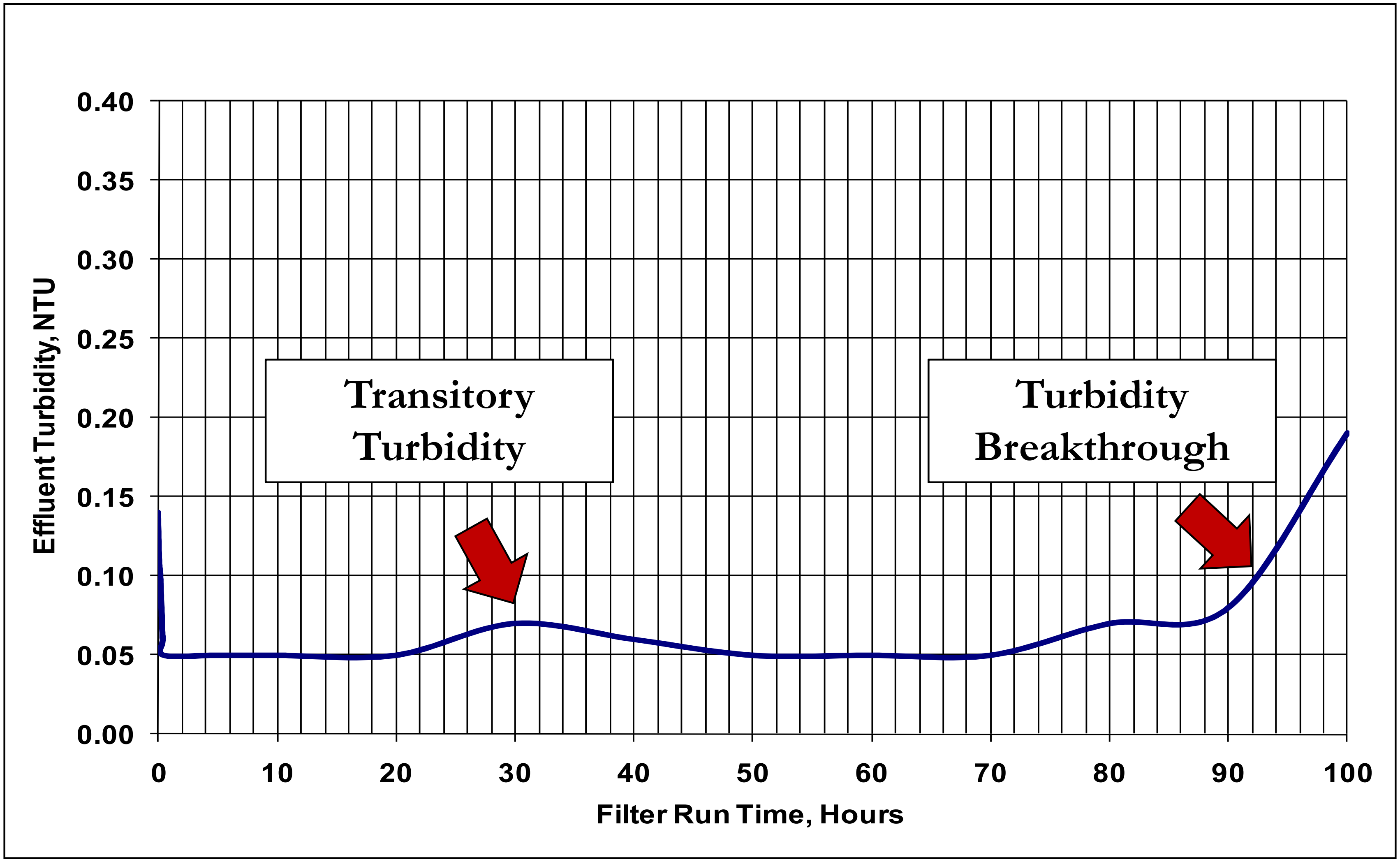


Regulatory Requirements for Filters

IESWTR: Large Systems

- Exceptions reporting for individual filters
  - >1 NTU in 2 consecutive samples for 3 consecutive months (self assessment)
  - >2 NTU in 2 consecutive samples for 2 consecutive months (CPE required)

  CPE requirements are quite extensive

  -USEPA guidance manual developed

Regulatory Requirements for Filters

IESWTR: Large Systems

- Produce filter profile within 7 days
- Complete self assessment within 14 days
- Complete CPE by third party within 30 days

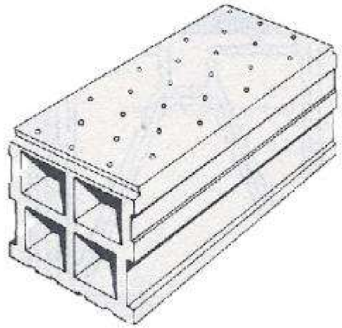
Common Filter Design

- Gravity filtration most common
- Pressure filtration common for GW plants

Common Filter Design

- Approved filter rates up to 4 gpm/ft^2
- Established operating goals 2 gpm/ft^2
  - Adjust filters in service according to production flows
  - May have filters in standby (switch during backwash)
- Minimum filtration rates 1.4 gpm/ft^2
  - Maintain depth filtration
  - <1.4 gpm/ft^2 results in surface filtration and short run times

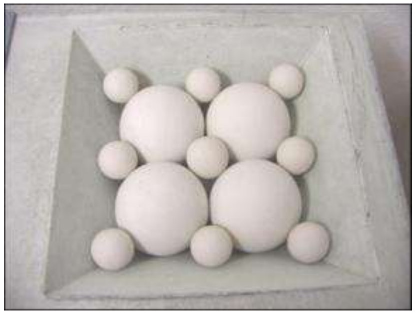
Common Underdrain Systems



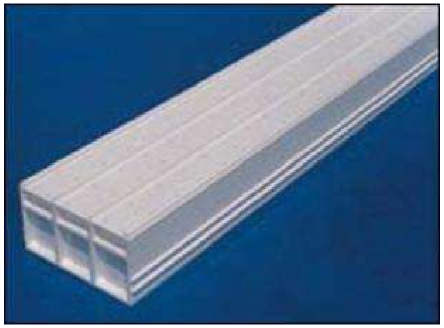
Clay dual lateral block

Plastic trilateral block

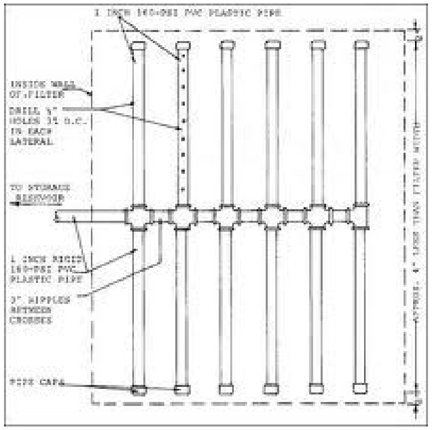
Fixed nozzle



Wheeler underdrain



Plastic low-profile block



Pipe lateral system

Slotted screen (plate)

Common Filter Media

Filter Sand

Anthracite

GAC Media

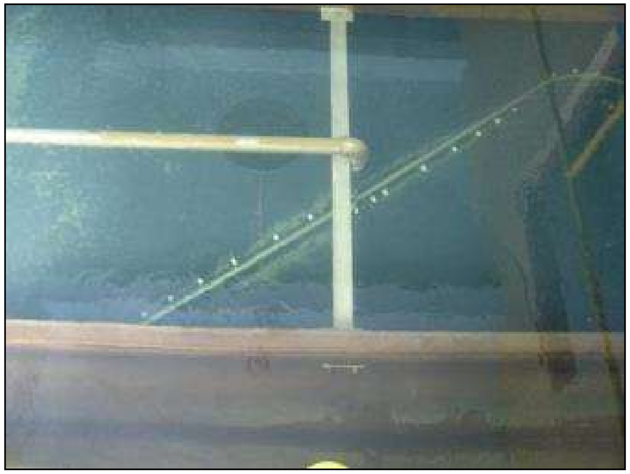
Garnet Sand

Media Considerations

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

Common Surface Wash

- Surface wash sweeps
  - Leopold #2 bearings and sweep arms
  - Plastic nozzles with rubber caps or without
  - Operated by plant water pressure
    - 0.5 gpm/ft^2 to 2.0 gpm/ft^2
  - Positioned at 2-inches above media surface



Common Air Scour

- Air blown into underdrain
  - 2 scfm/ft^2 to 5 scfm/ft^2
  - 2 minutes to 5 minutes typical operation
  - Large filters need to delay backwash flow up to 5 minutes to release air before backwash
  - Violent agitation of media to remove strained suspended solids/scale
  - Can result in media loss or breakage

Maintenance Activities

- Physical observations
  - Take photos (camera phone works well)
  - Mud balls
  - Media build-up in corners
  - Media separation at sidewalls
  - Media loss
  - Media level
  - Media mounding or ridges
  - Microscopic analysis (if necessary)
  - Sweep nozzles (operation and wear)
  - Sweep rotates freely (bearing check)

Maintenance Activities

- Mud Balls, media build-up, media separation
  - Accumulations of aluminum hydroxide floc and suspended solids

Maintenance Activities

- Media loss
  - Beak-up of anthracite and loss during backwash
  - Over expansion more than 50% during backwash
  - Measure bed depth to confirm actual bed
  - Lost media can impair filter performance
    - Check L/D_{10} ratios
  - Add anthracite media once loss exceeds minimum L/D_{10} ratio

Maintenance Activities

- Media mounding or ridges
  - Mounding suggests mud ball accumulations or gravel displacement

  - Ridges on media surface from break in underdrain system

Maintenance Activities

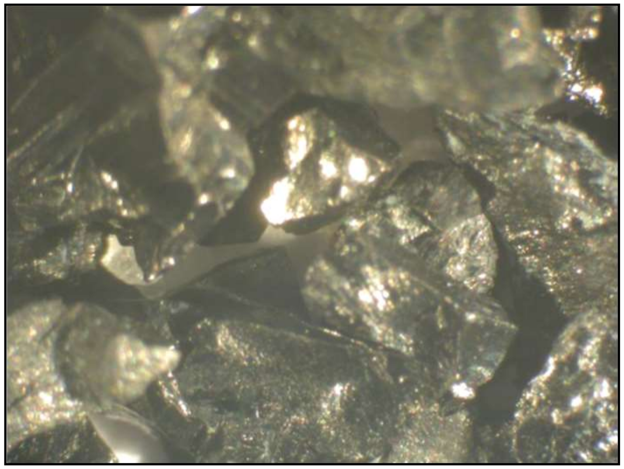
- Mineralization
  - Mineral deposits on media surface can result in growth
  - Deposits alter weight, shape, backwash requirements

Highly mineralized filter media

Maintenance Activities

- Microscopic analysis

Sharp jagged edges, better fluid transport



Worn rounded edges, restricts filter flow

Maintenance Activities

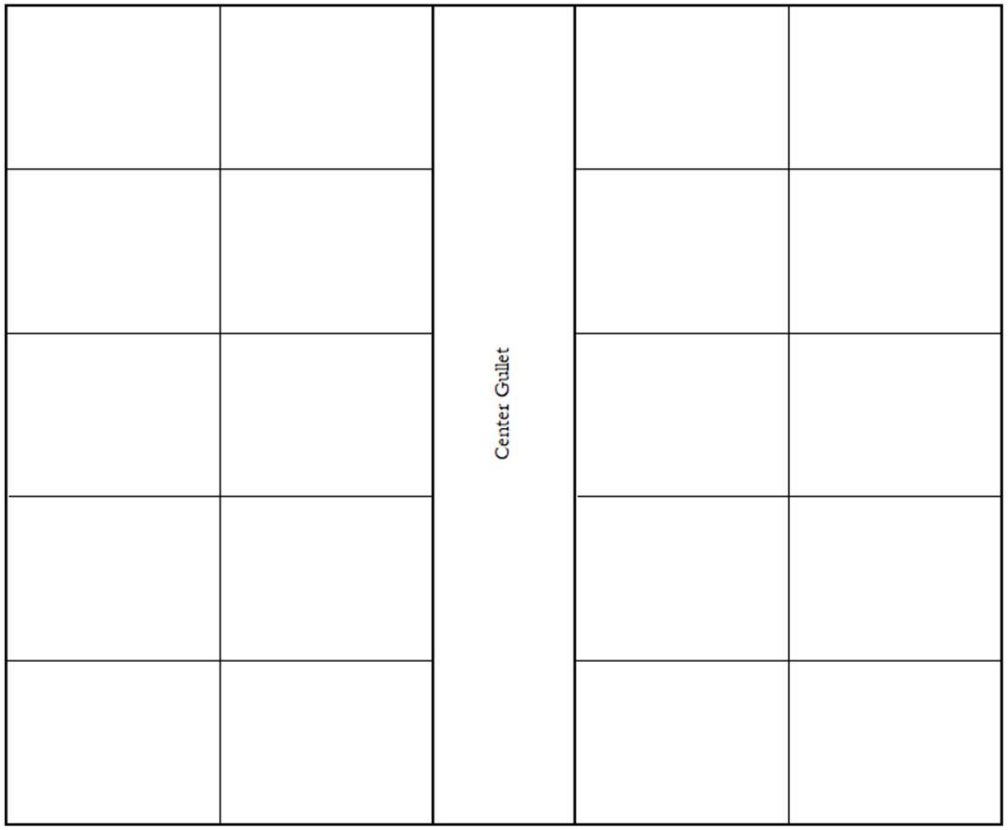
- Surface wash sweep checks
  - Rotate freely by hand
  - Bearing failures can occur
  - Sweep arms and nozzles check
  - Any possible leaks or broken nozzles (replace as needed)
  - Check down pipes and positioning

Maintenance Activities

- Bed depth measurements
  - Overall depth (probing)
  - Depth anthracite layer
  - Depth mixed media interface layer
  - Depth sand layer
  - Distance from media to bottom of wash troughs
  - Distance from media to sweep arms
  - L/D_{10} ratio
  - D_{90}/D_{10} ratio

Maintenance Activities

- Bed depth measurements
  - Overall depth (probing)
  - Measure all areas in imaginary grid and record

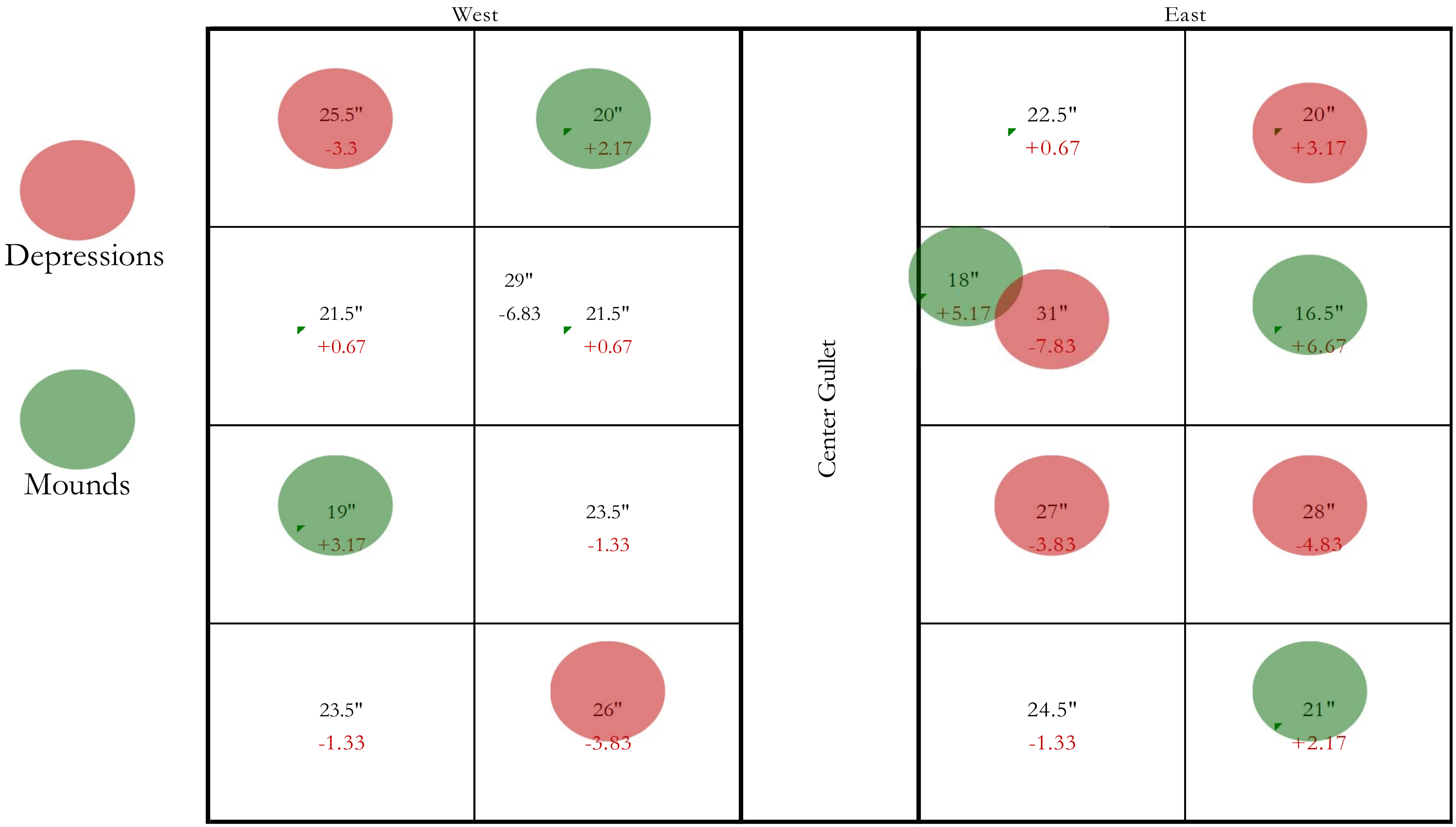


Average media depth -inches
Average media difference -inches
Top media to bottom wash troughs -inches
Top media to surface sweeps -inches

Maintenance Activities

FILTER BOX GRID MAP

FILTER 1



Maintenance Activities

- Depth of different layers
  - Excavate and measure individual layers and interfacial mixing zone
  - Record anthracite (or GAC) depth
  - Record mixed media depth
    - 2-inches to 8-inches common
  - Record filter sand depth

Maintenance Activities

- 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

  - Filters may need topped off to regain bed depth

Maintenance Activities

- 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
  - Anthracite/sand ratio - 3.0
  - GAC/sand ratio - 5.0

Maintenance Activities

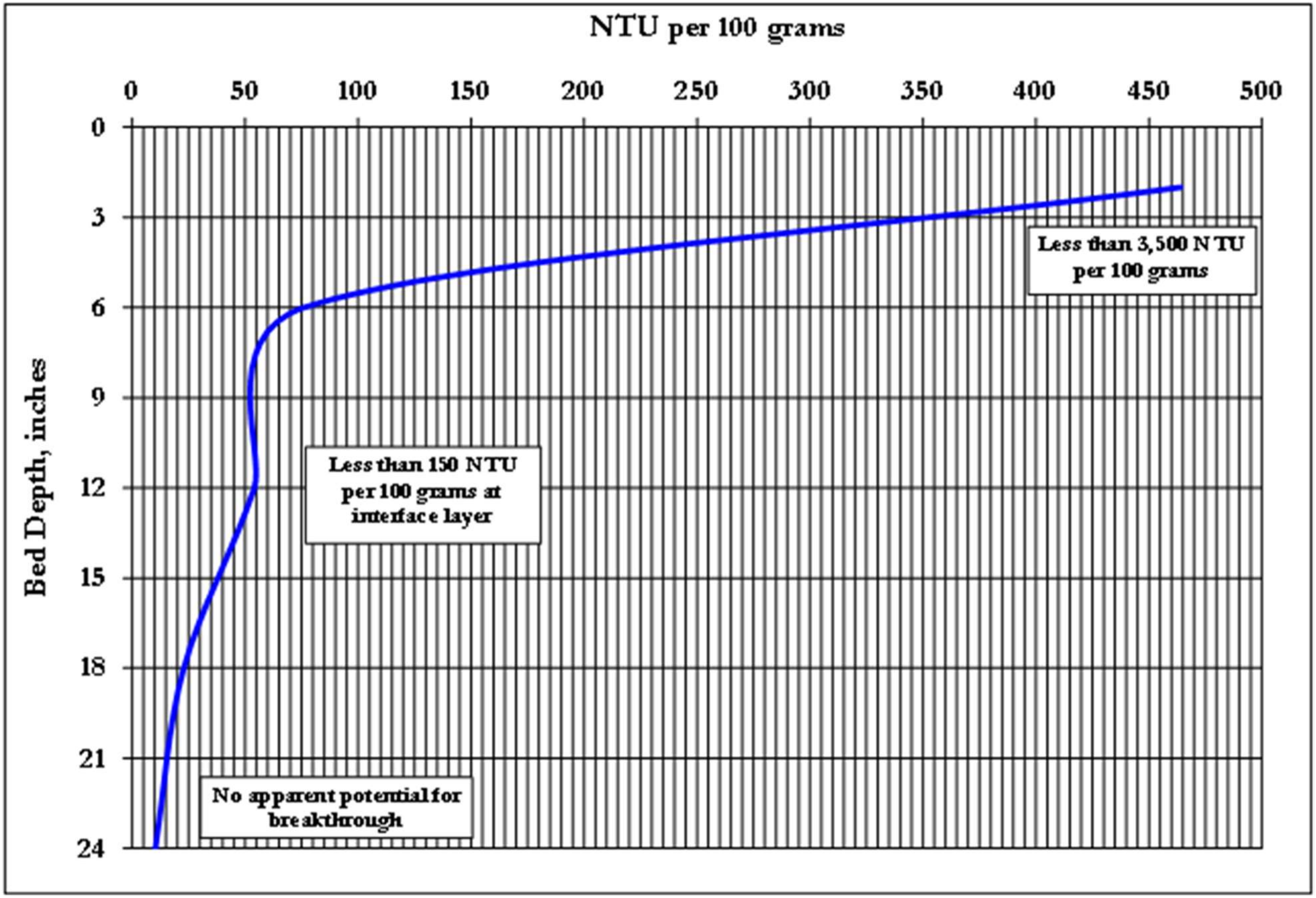
- Filter Coring Techniques
  - Extract core samples at different depths
  - Define filter behavior during run cycles
  - Define media cleaning efficient after backwash
  - Observe mineralization
  - Observe media loss
  - Observe other filter operating issues
    - Mud balls, ridging, mounding, displacement

Maintenance Activities

- Filter Coring Techniques
  - Top 2-inches
  - 2-inches to 6-inches
  - 6-inches to 12-inches
  - 12-inches to 18-inches
  - 18-inches to 24-inches
  - Extract media from each core depth
  - Place core samples in plastic baggies and mark each bag

  - Core dirty filter
  - Re-core clean filter
  - Prepare floc retention profiles

Maintenance Activities



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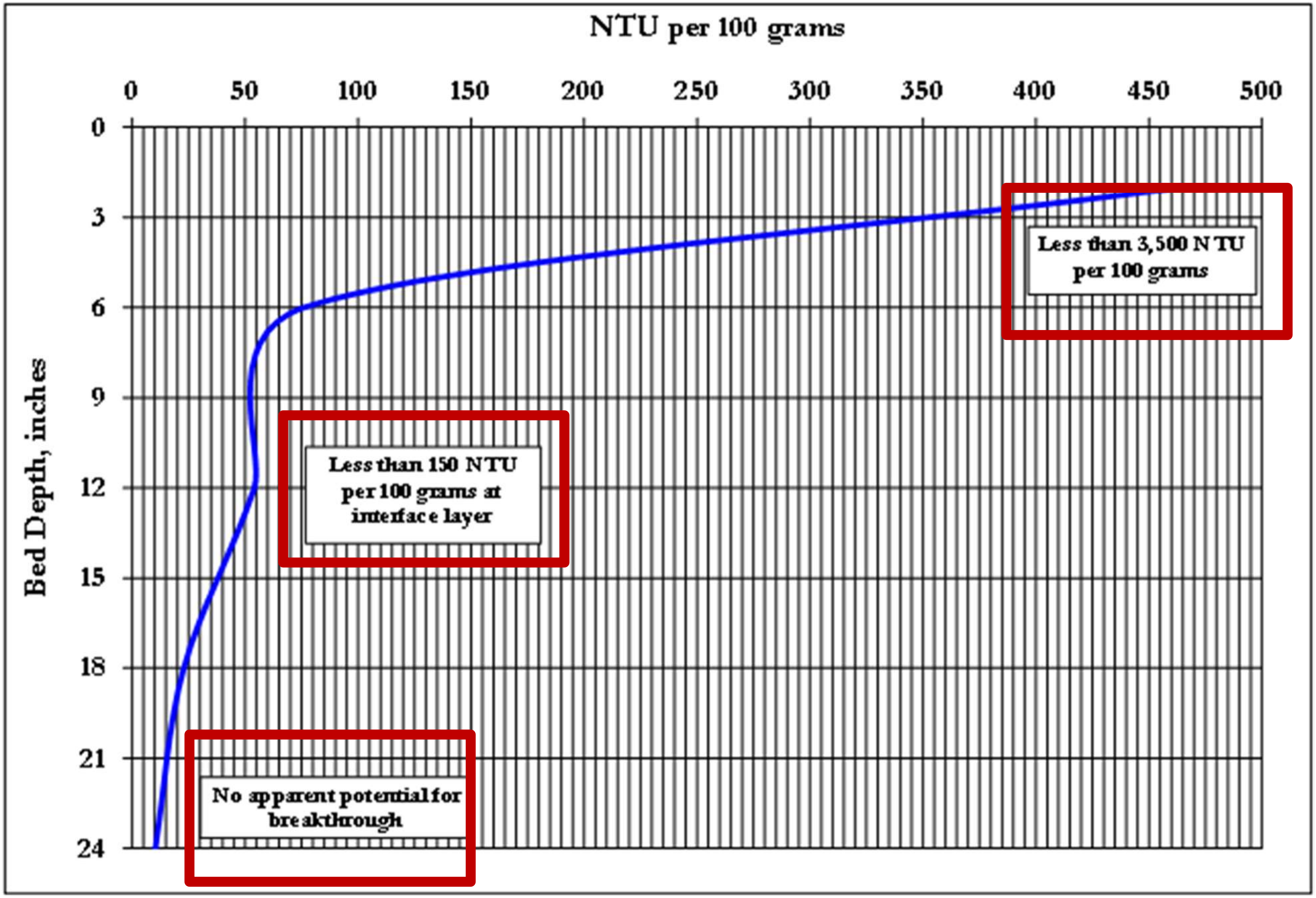

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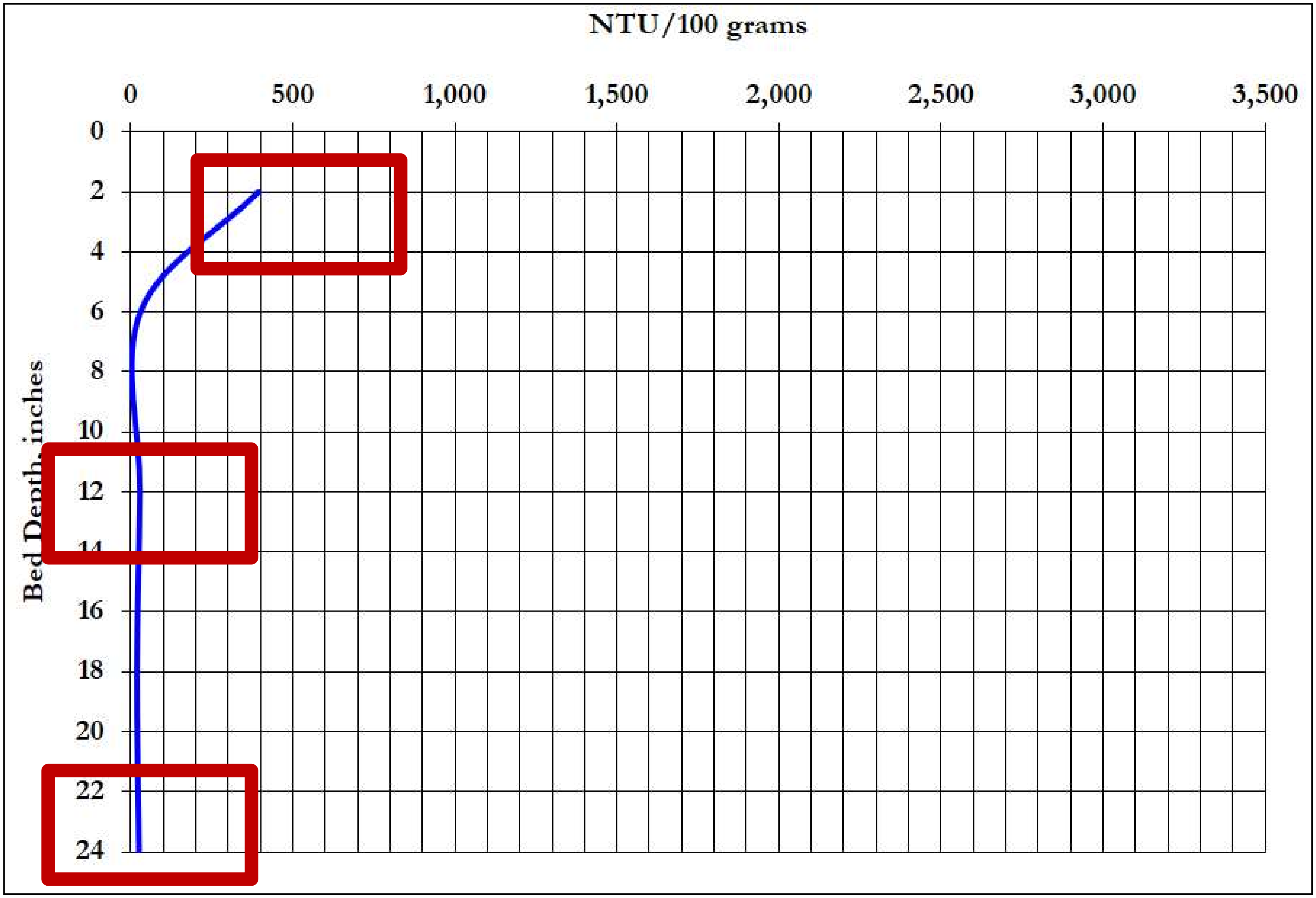

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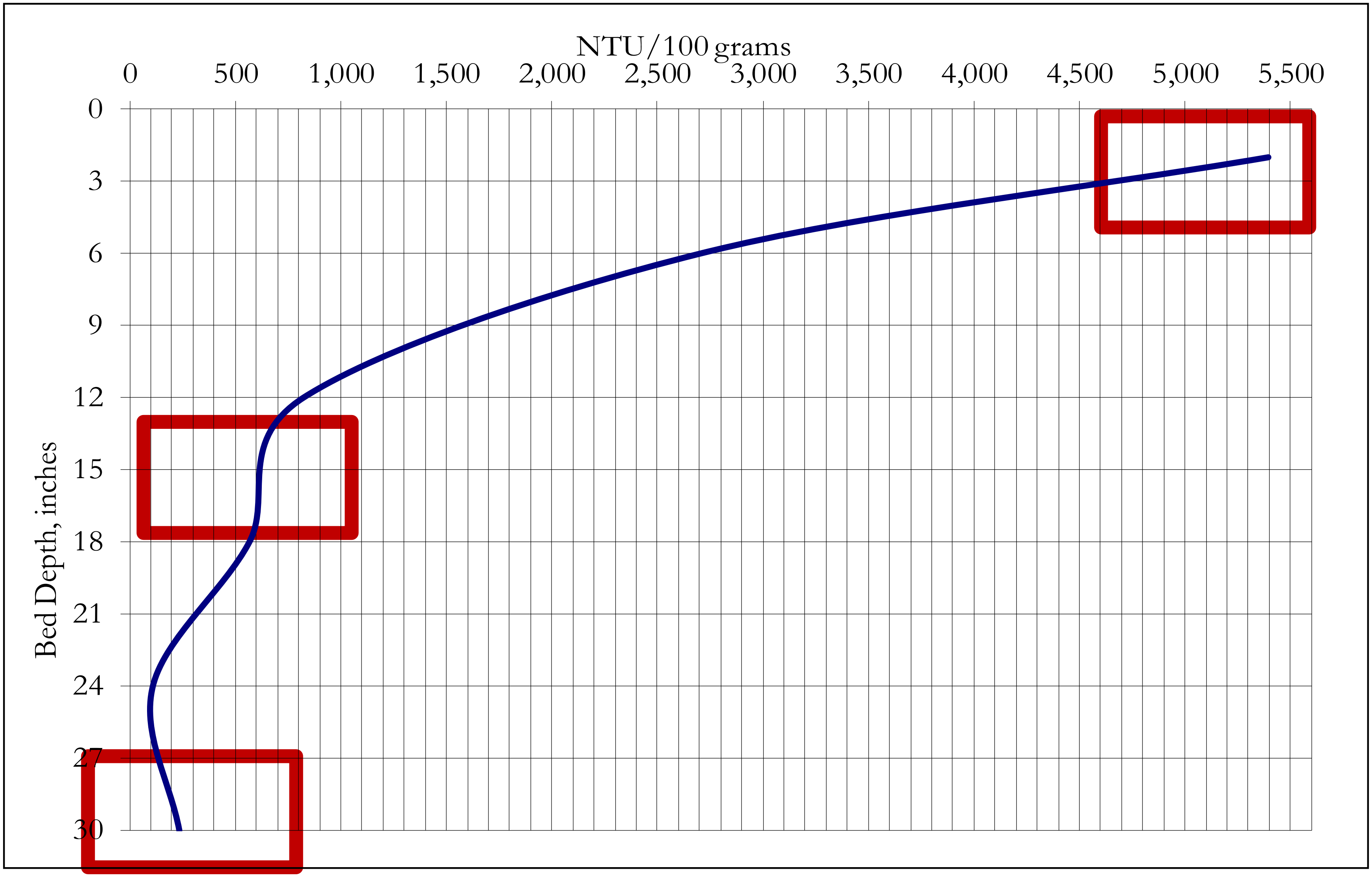

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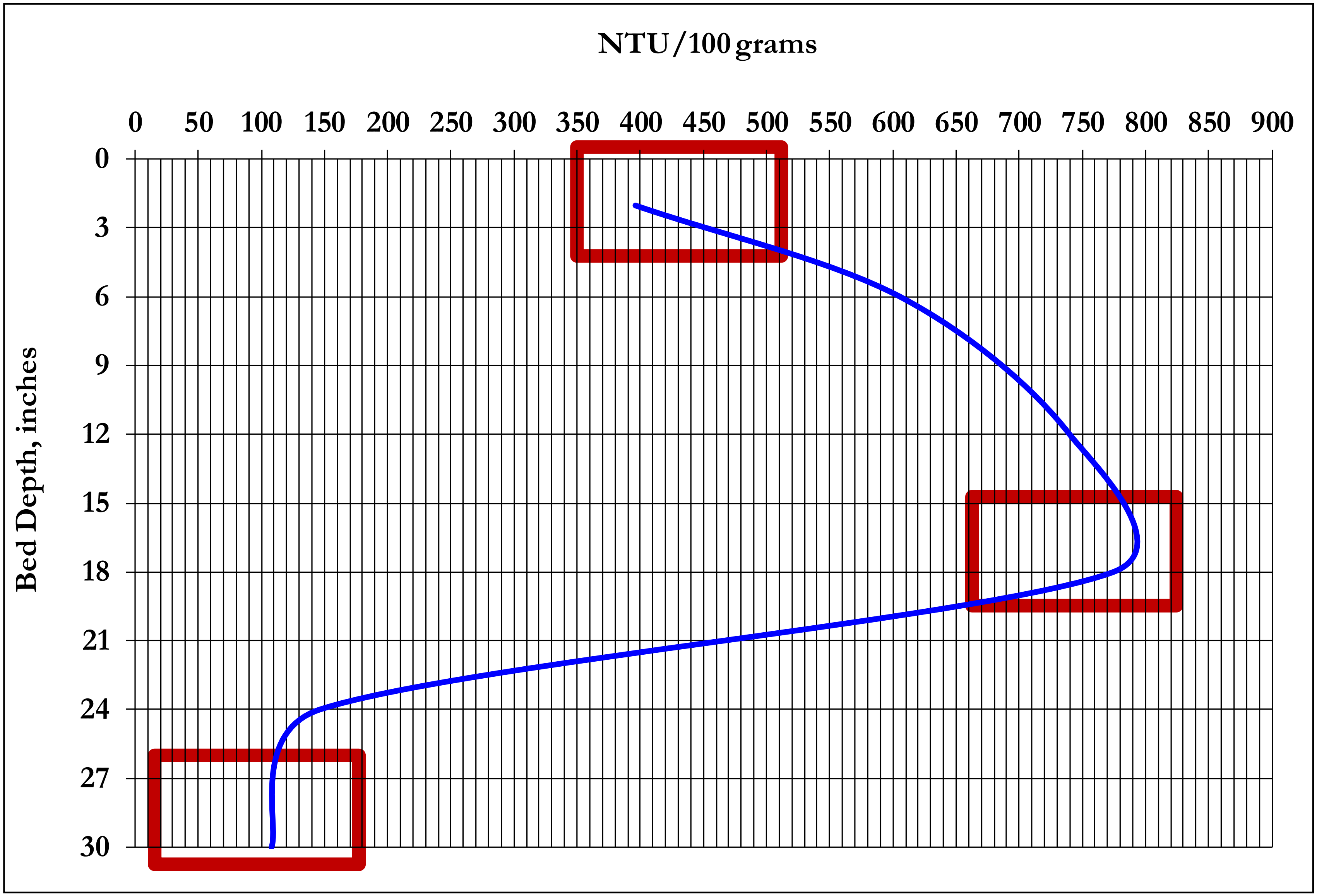

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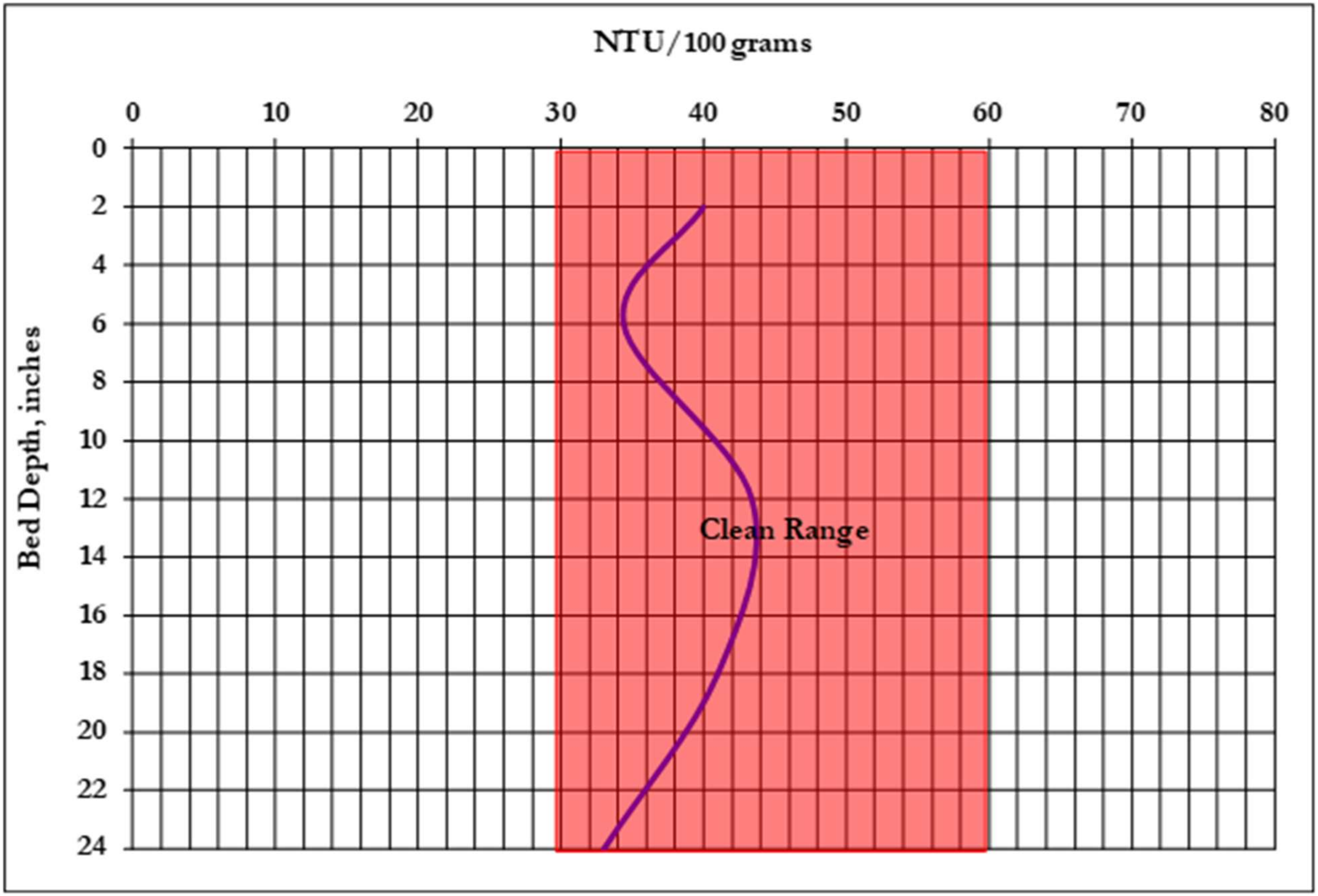

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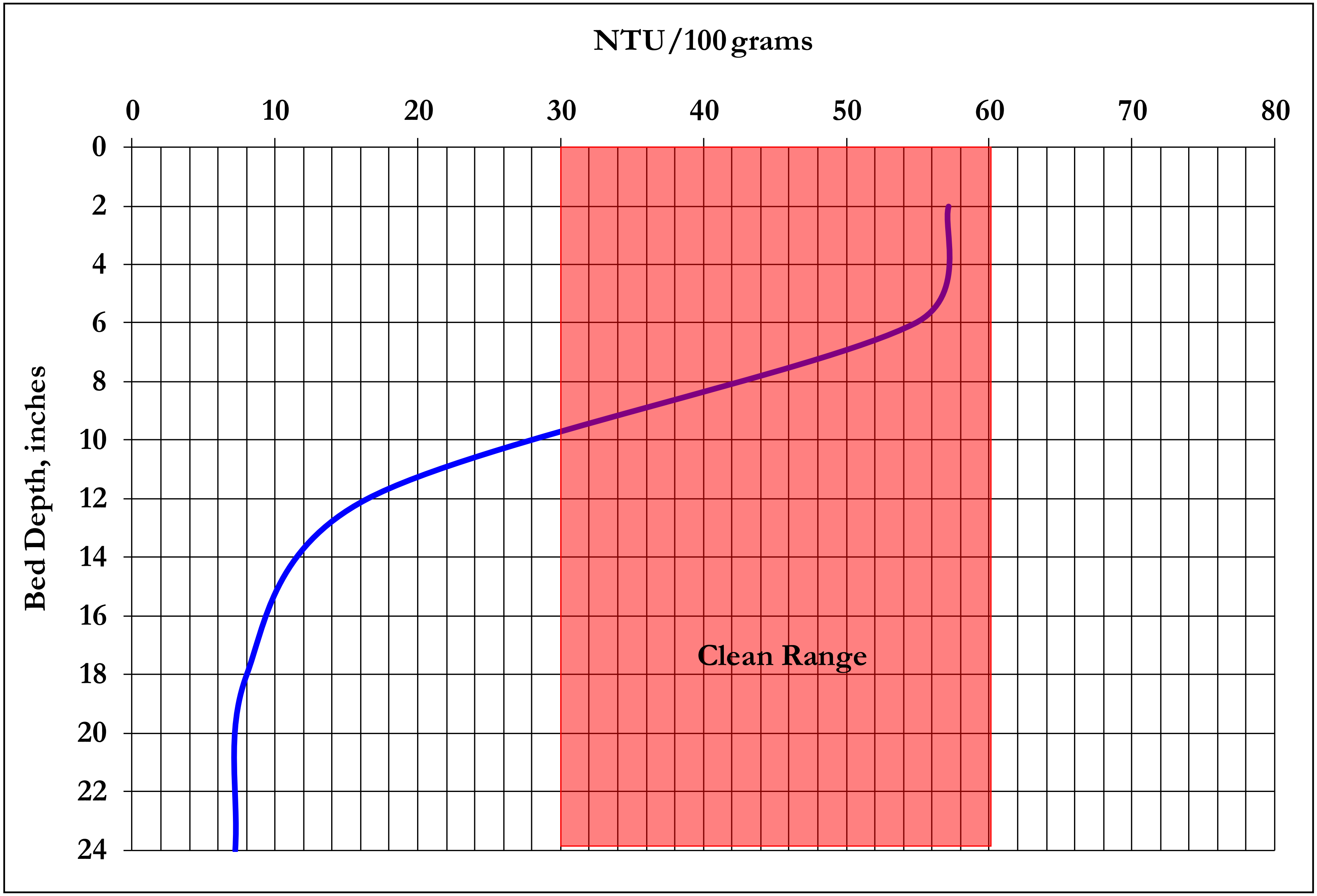

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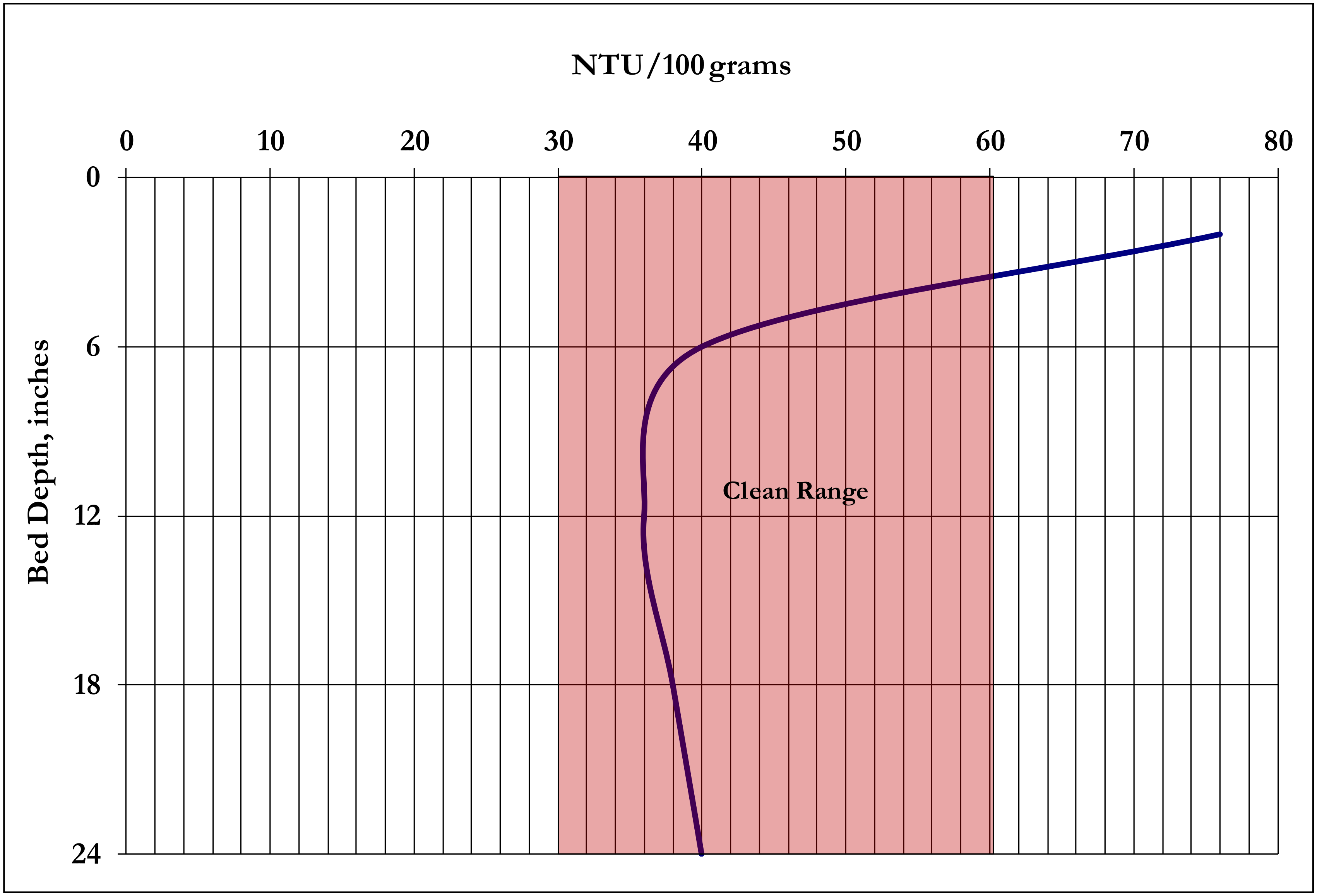

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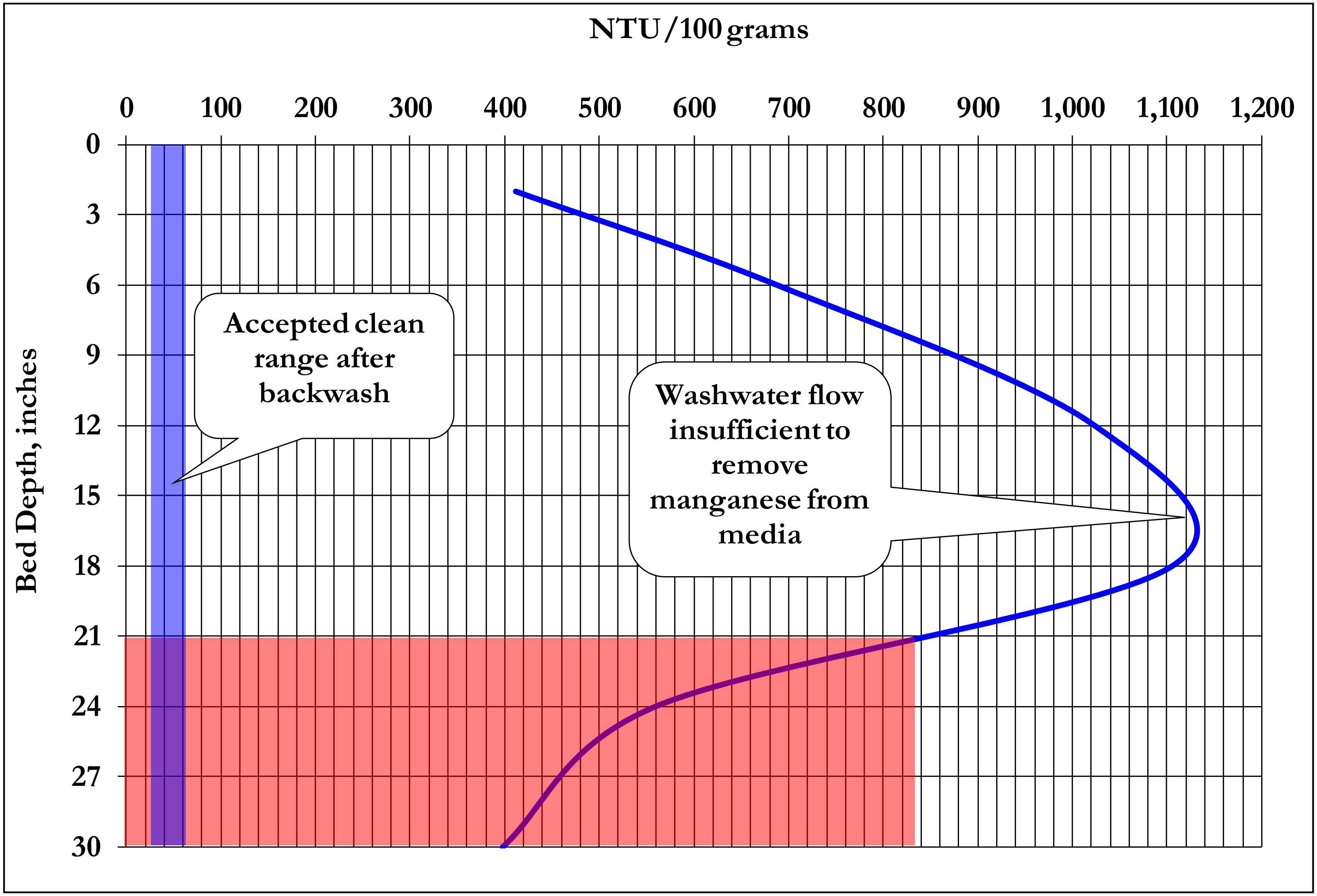
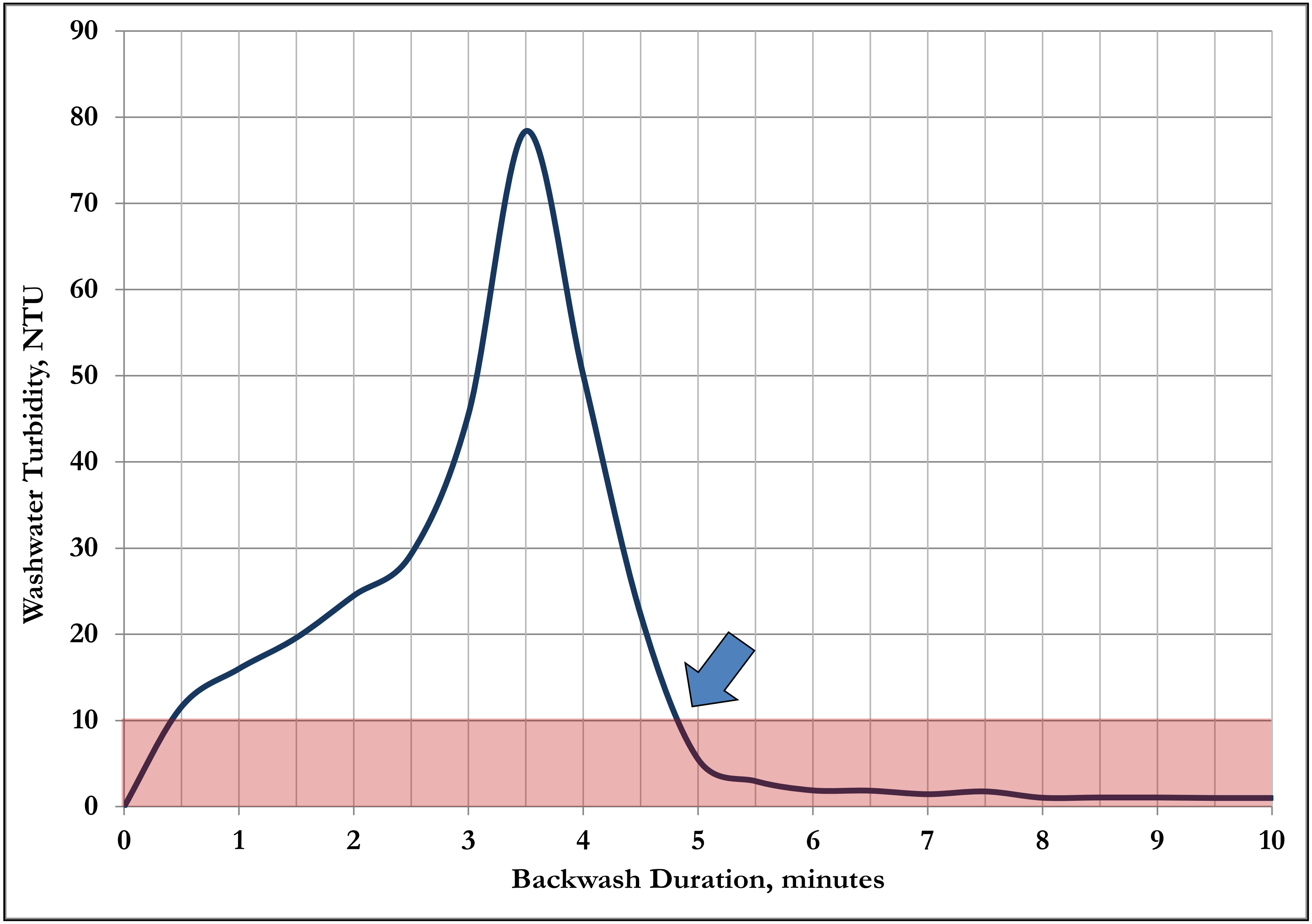


Maintenance Activities

- Backwash Duration Testing
  - Collection every 30 seconds during backwash
  - Analyze turbidity in samples and record
  - Graph data to develop duration curve
  - Normal backwash range from **6 minutes to 8 minutes** total length
  - Over-washing leads to media loss, poor ripening techniques, and wastes washwater

Maintenance Activities



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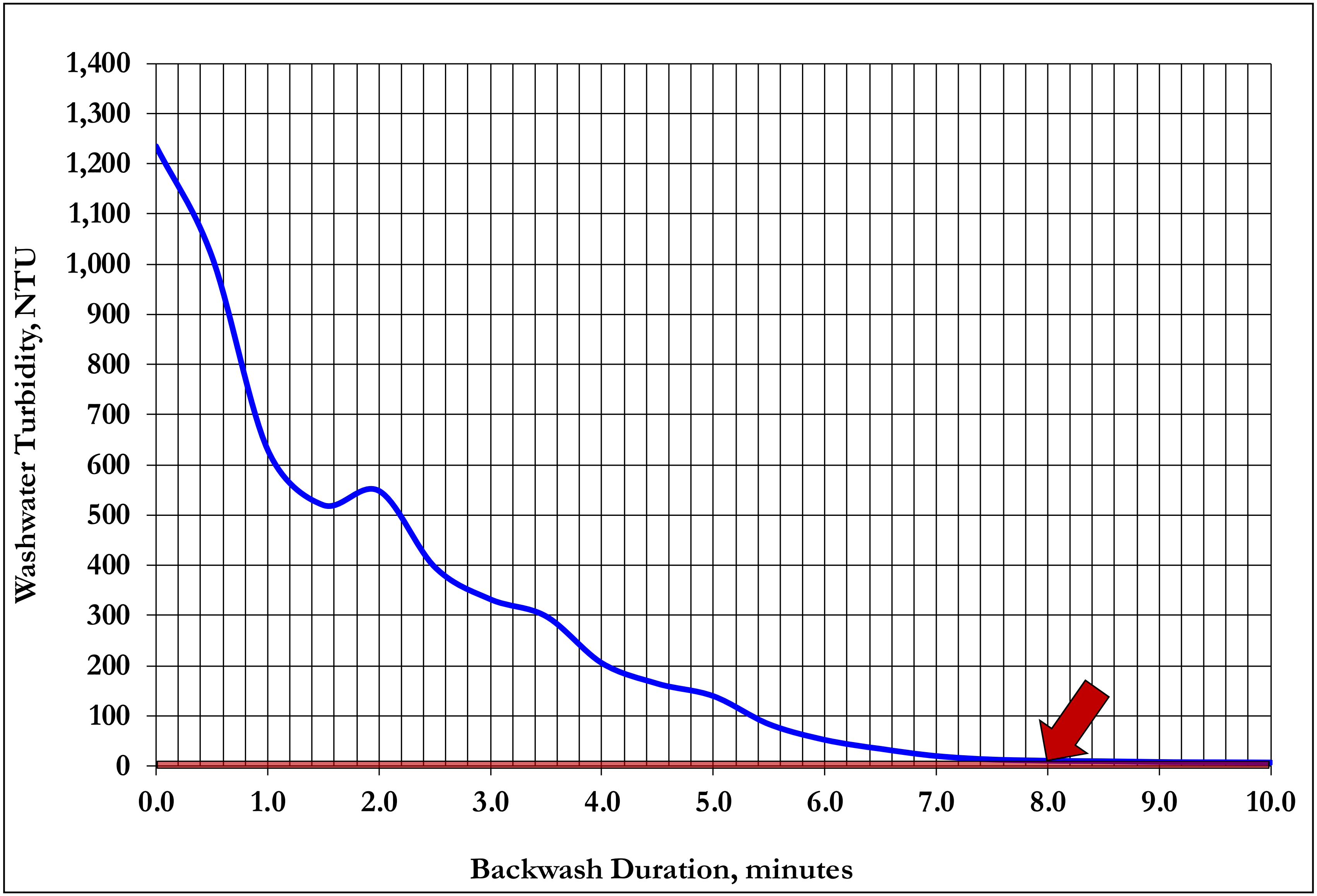

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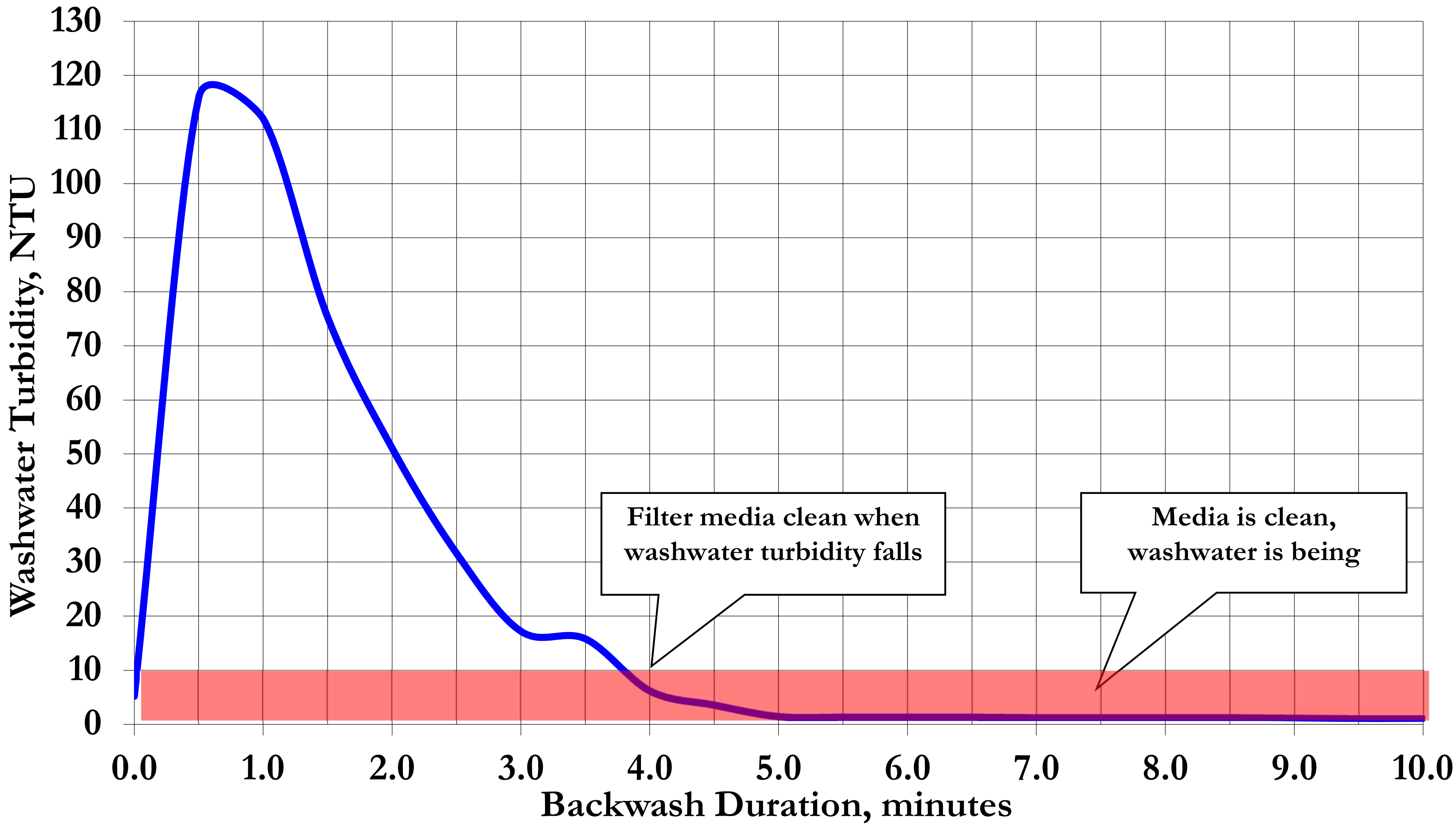
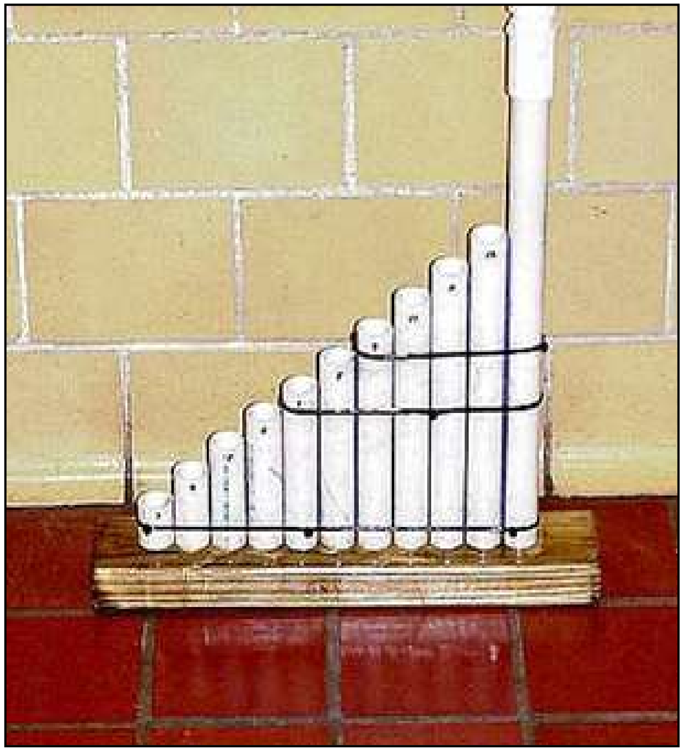


Maintenance Activities

- Bed Expansion Testing
  - After backwash, check bed expansion
  - Place and secure bed expansion tool
  - Conduct another short backwash until reach high-rate flow
  - Observe and record measured media expansion
  - Calculate actual bed expansion

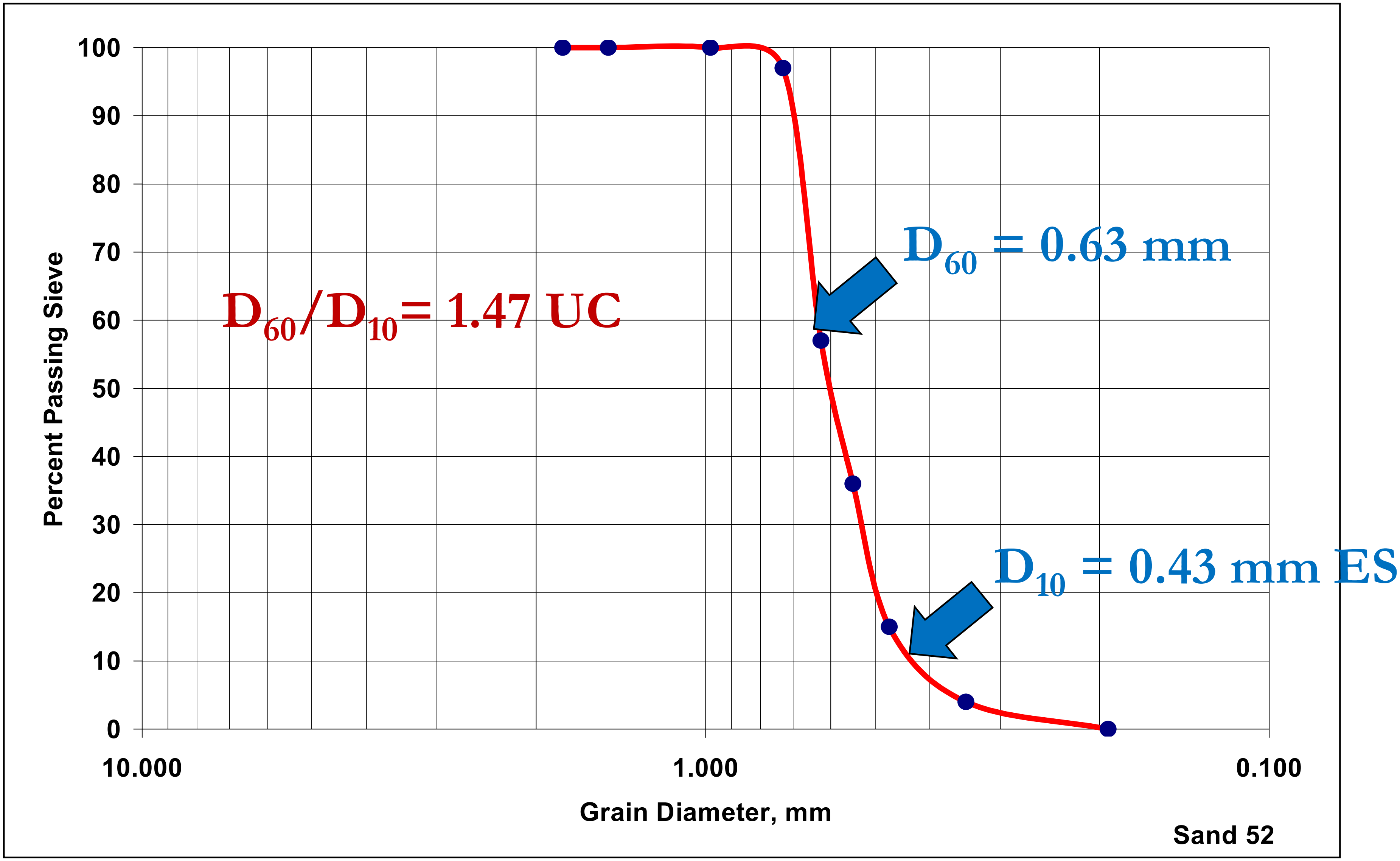


Maintenance Activities

Maintenance Activities

- Sieve analysis and grain size distribution
  - Collect samples of anthracite only and sand only
  - Need about a gallon baggie of each media
  - Contact materials testing lab to conduct grain size distribution
    - Solar Testing Labs
    - Bowser Morner
  - Grain size distribution reports will be prepared once the analysis is completed
    - Defines D_{10} – effective size
    - Defines D_{60} values
    - Defines anthracite D_{90} values
    - Sometimes provide ES and UC for the media

Maintenance Activities



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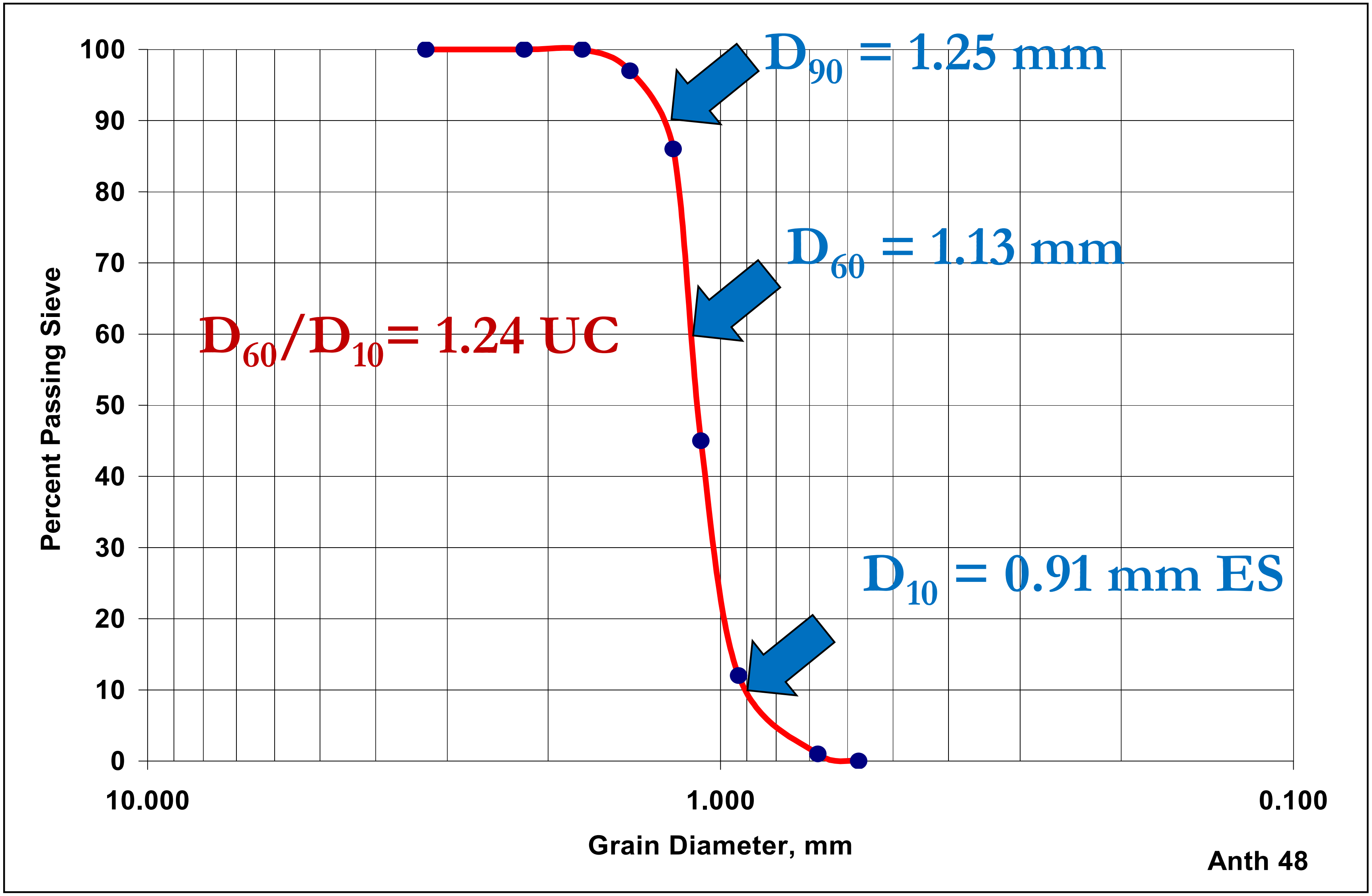


Maintenance Activities

- Acid solubility
  - Samples acid washed with hydrochloric acid to estimate mineralization
    - Calcium, magnesium, iron, manganese, aluminum, etc.
  - Procedures in AWWA B100, Section 5.3
  - Should be less than 5% (AWWA)
  - Should be less than 2% (most filters)

Filtration Metrics

- Best practices and optimization goals
  - Filter effluent turbidity
  - Filtration rate
  - Filter run times
  - Head loss
  - Gross Water Production (GWP)
  - Filter Efficiency
  - Solids loadings
  - Washwater usage
  - Backwash duration

Excess fluidization due to gravel displacement

Filtration Metrics

- Filter effluent turbidity must be <0.3 NTU in 95% of samples taken
  - Check records average and maximum NTU
  - Check turbidimeter flow rates (adjust as needed)
    - 250 mL/min to 750 mL/min

Filtration Metrics

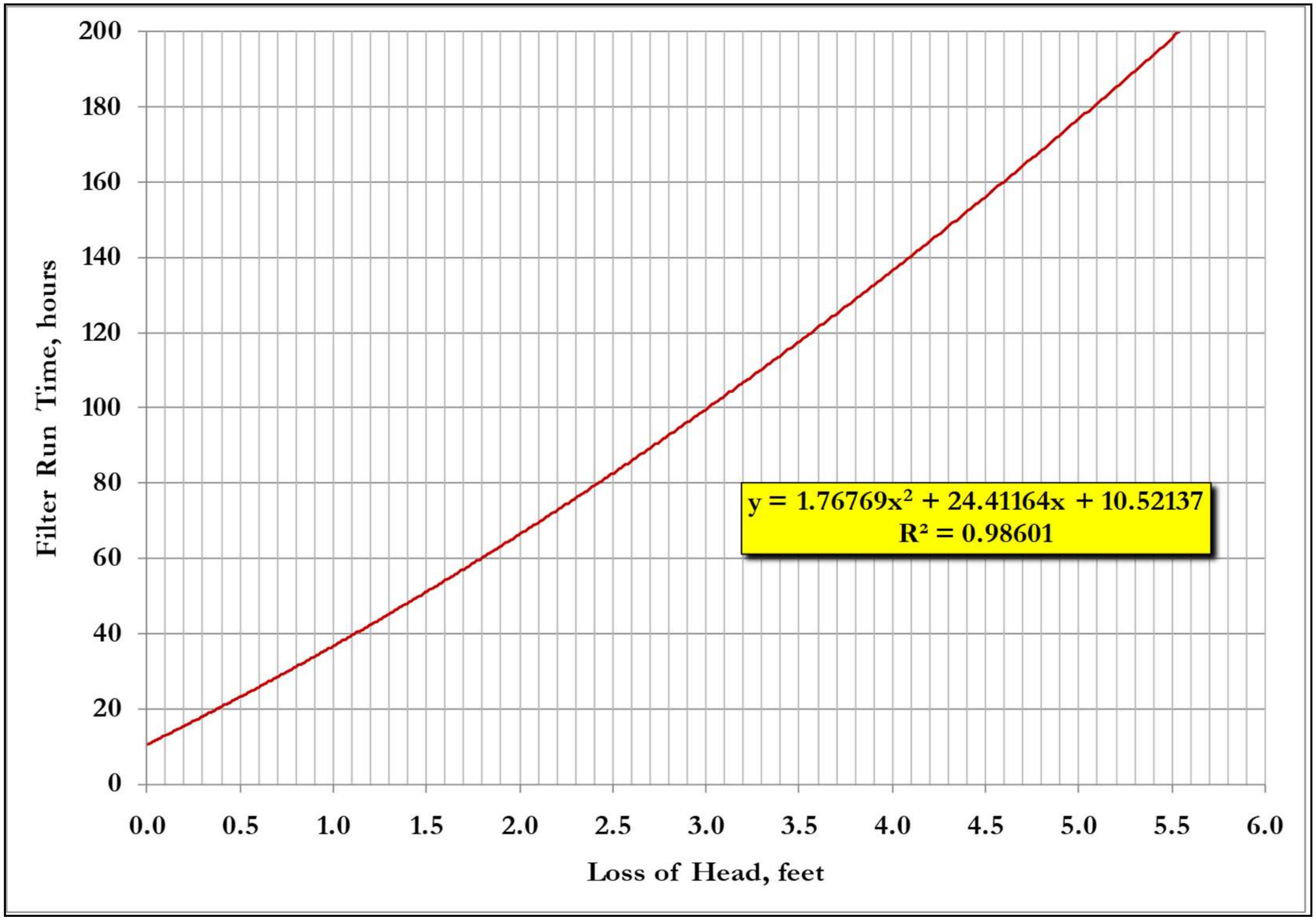
- Filtration rates must be maintained greater than 1.4 gpm/ft^2
  - Helps produce depth filtration and not surface filtration
  - Establish current rate at 2 gpm/ft^2

Filtration Metrics

- Filter run times should be greater than 72 hours
  - Dual media filter capable of run times more than 250 hours depending on settled water quality
  - Run times may vary from 72 hours to 250 hours
  - Run times more than 180 hours should be correlated to solids loadings, GWP, and head losses

Filtration Metrics

- Head loss measurements increase with run time



Filtration Metrics

- Gross Water Production (GWP)
  - Should be greater than 10,000 gallons per ft^2 per run
  - GWP more than 10,000 $gal/ft^2/run$ have been recorded

  - $GWP, \frac{\frac{gal}{ft^2}}{run} = filtration\, rate \left(\frac{gpm}{ft^2}\right) * 60 * filter\, run\, time\, (hours)$

  - **2.0 $gpm/ft^2*60*96$ hours = 11,520 $gal/ft^2/run$**

Filtration Metrics

- Solids Loadings
  - Should be less than 0.18 pounds per cubic foot media
  - Calculated from total gallons filtered and settled water turbidity
  - $Settled\ water\ turbidity\ (NTU) * 1.5 * \frac{total\ gallons\ filtered\ water}{1{,}000{,}000} * 8.34 = lbs\ solids$
  - $Solids\ loading, \frac{lbs}{ft^3} = \frac{lbs\ solids}{1{,}400\ ft^3}$
  - 0.58 NTU settled water
  - $0.58\ NTU * 1.5 * \frac{10{,}080{,}000\ total\ gallons\ filtered\ water}{1{,}000{,}000} * 8.34 = 73.14\ lbs\ solids$
  - $Solids\ loading, \frac{lbs}{ft^3} = \frac{73.14\ lbs\ solids}{1{,}400\ ft^3} = 0.052\ lbs/ft3$

Filtration Metrics

- Washwater Usage
  - Should be less than 150 gal/ft^2
  - 82,000 gallons washwater/700 ft^2 = 117 gal/ft^2

Filtration Metrics

- Filter Efficiency
  - Should be greater than 95%
  - $1 - \left(\frac{gallons\ washwater\ used}{total\ gallons\ water\ filtered}\right) * 100$
  - 1-(82,000 gallons washwater/10,080,000 gallons filtered)*100 = 99.2%

Questions

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