Low Cost Optimization of Final Clarifiers
The Value of Knowledge-Based Tools

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Presentation Outline

- Background
- Functions of a Clarifier
- Tools for Clarifier Analysis
  - Application of State Point Analysis
- Take Home Messages

Presentation Outline

- **Background**
- Functions of a Clarifier
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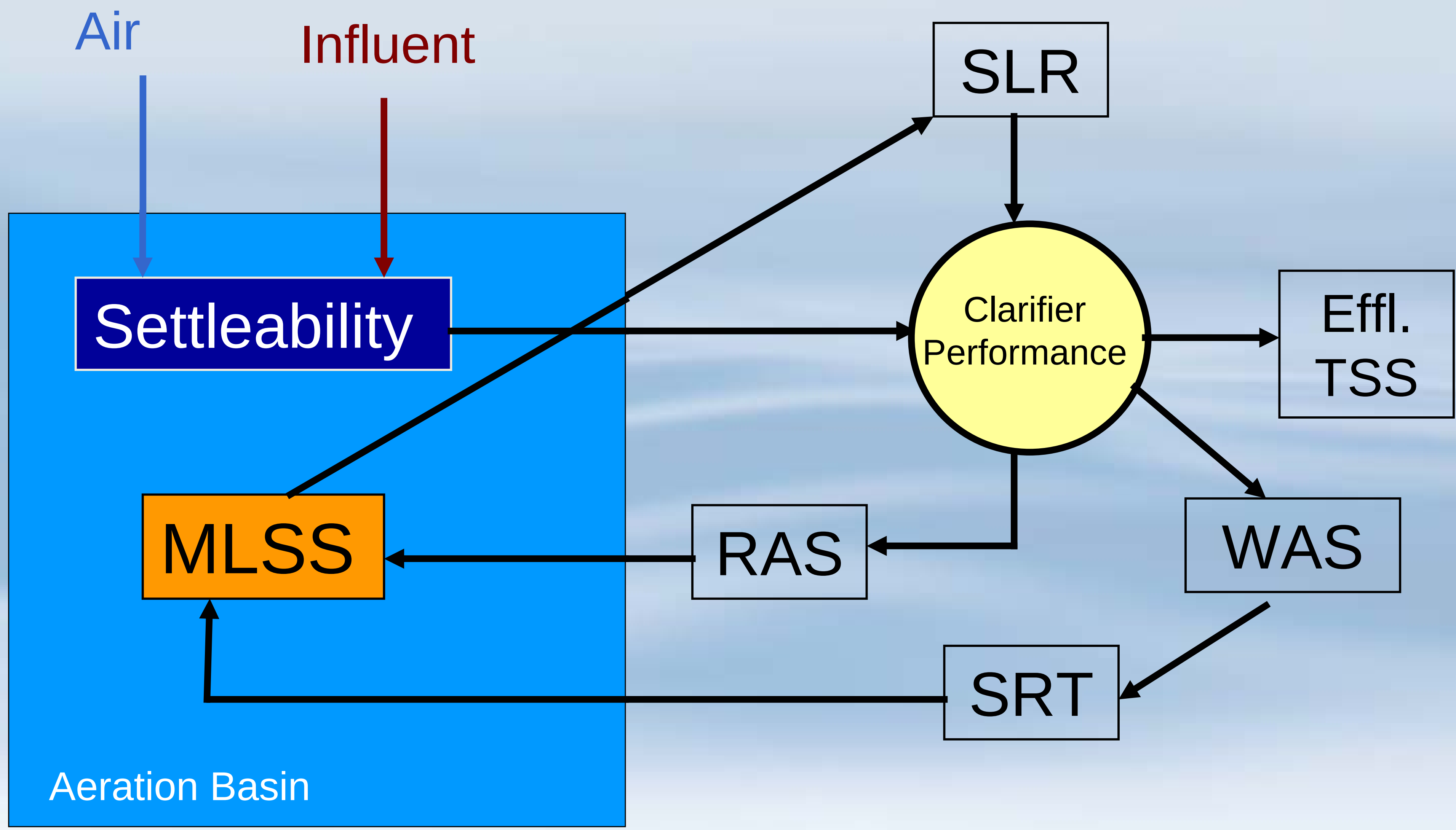
Clarifier is a Key Component of the Treatment Train

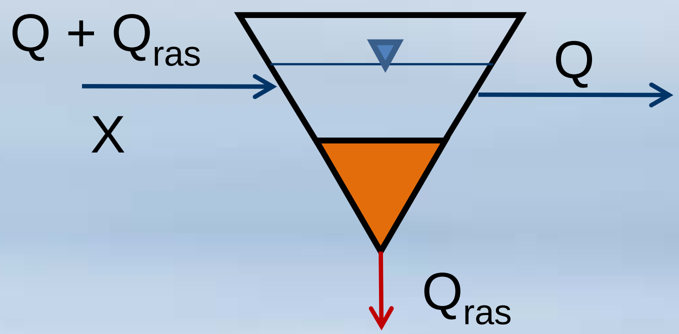
- It often limits the capacity of the entire facility
- Plays a central role in wet weather treatment
- Care should be taken in its design & operation

Clarifier Analysis should be based on a *Systems* Approach



Important Terminology

- Overflow rate (OFR), Surface overflow rate (SOR)
  - OFR = SOR = Q/A
- Underflow rate (UFR)
  - UFR = Q_{RAS}/A
- Flux: Movement of solids through the clarifier
  - Flux = Mass of solids (lb/d)/A
  - Solids loading rate (lb/d/ft^2) = [(Q + Qras)*X*8.34]/A
- State Point: Clarifier operating point
  - Defined in terms of OFR & UFR



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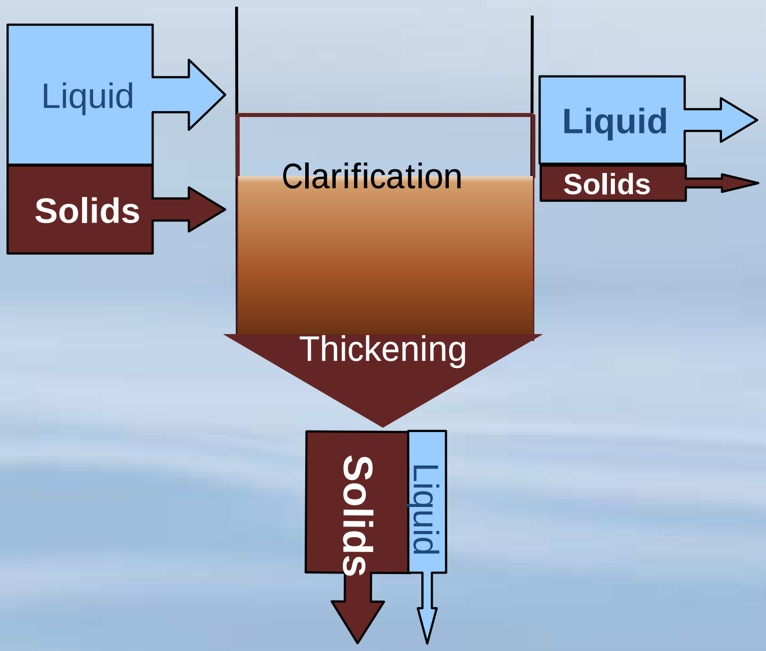
The Clarifier Must Perform Two Basic Functions

1. Clarification:
   - Solids separation
   - Involves a small fraction of the solids inventory

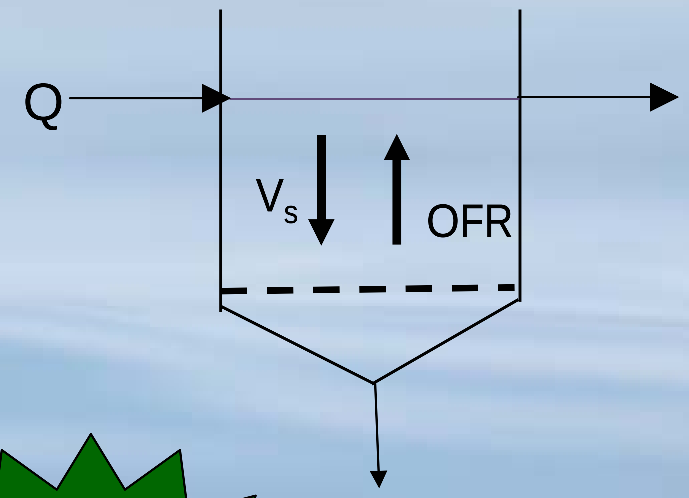


2. Thickening
   - Transport & compaction
   - Involves a majority of the solids inventory

A clarifier must perform <u>both</u> functions.

Clarification Function

- Clarification involves two velocities
  - Downward velocity of solids
    - Solids settling velocity (V_s)
  - Upward velocity of water
    - Rise velocity = Overflow rate (OFR)
      = Q/A

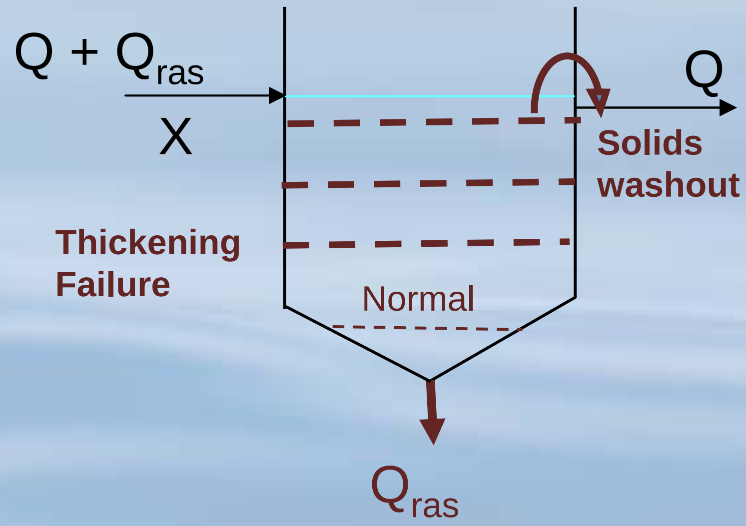


- If OFR > V_s
  - Solids carryover
  - This is clarification failure

Clarification failure means high effl. TSS

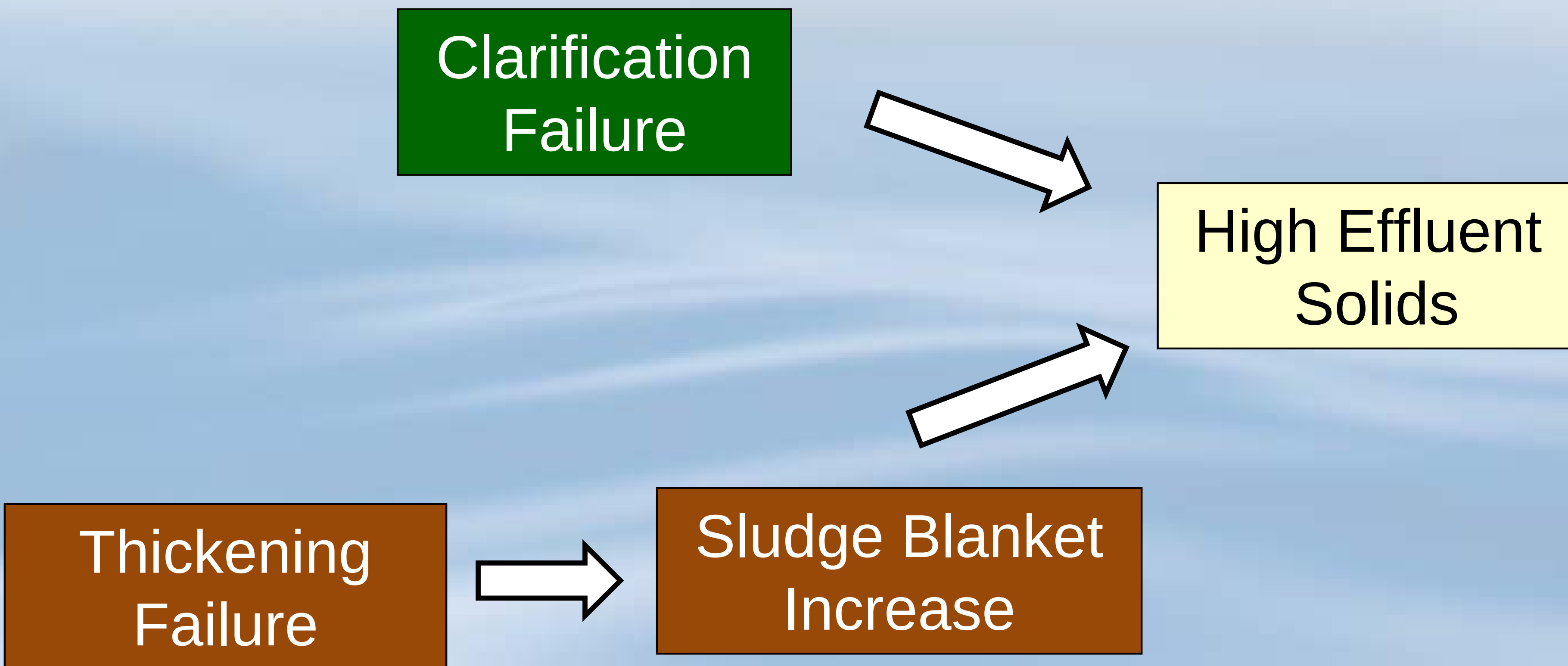
Thickening Function

- The Concept of limiting flux: Maximum rate at which solids can be conveyed to the bottom of clarifier
- If Solids in > Limiting flux
  - Solids accumulate in clarifier
  - Rising sludge blanket
  - This is thickening failure



- If this continues, sludge will reach close to effluent weir
  - Solids carryover

In Summary


Clarification Failure
High Effluent Solids
Thickening Failure
Sludge Blanket Increase

Sludge settleability is the single most important factor impacting clarifier performance

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Tools for Analyzing/ Predicting Clarifier Performance

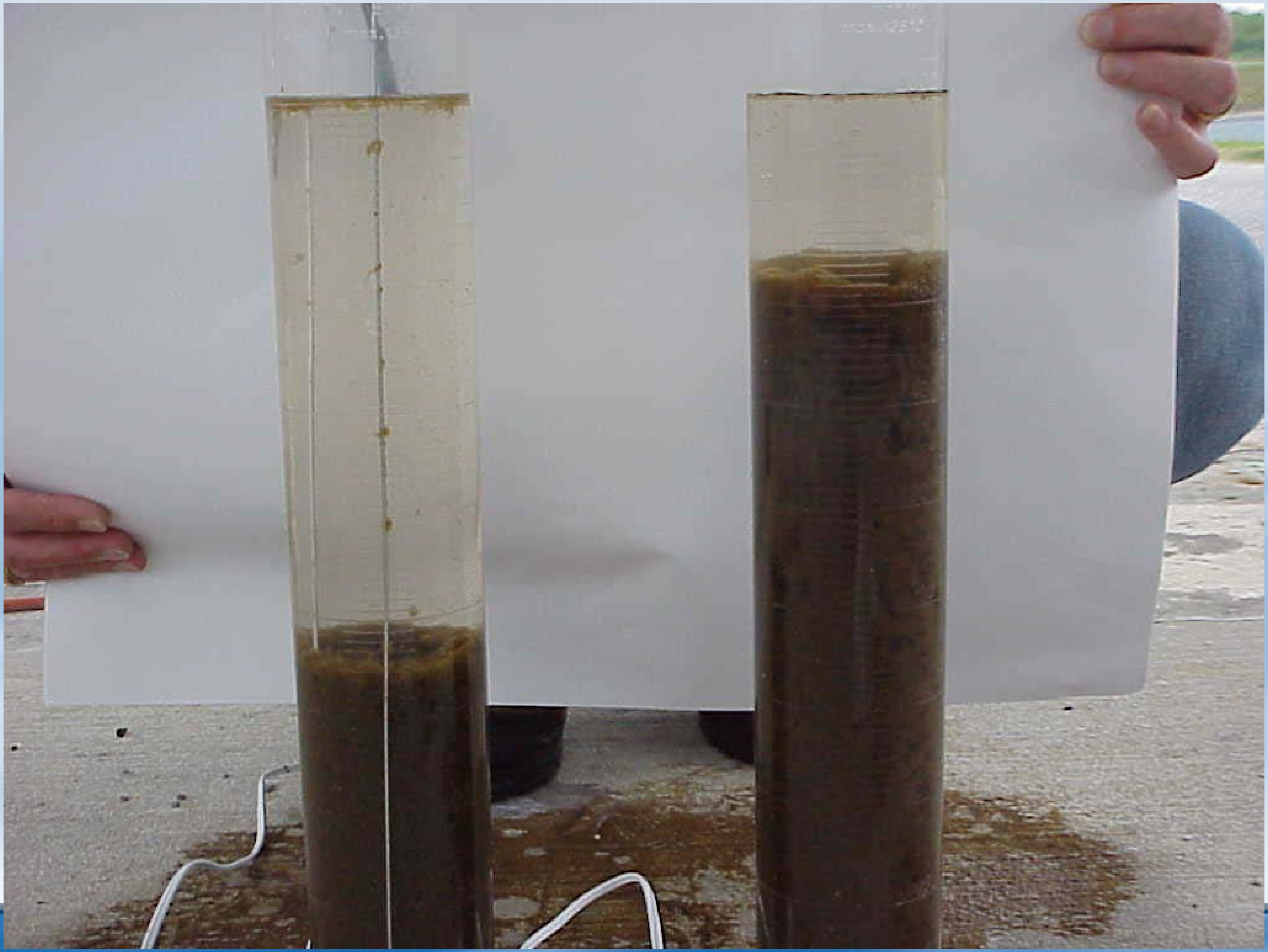
- State Point Analysis
- Daigger-Roper Operating diagram
- Keinath operating charts
- Wilson approach
- Ekama-Marais approach
- Others

State Point Analysis

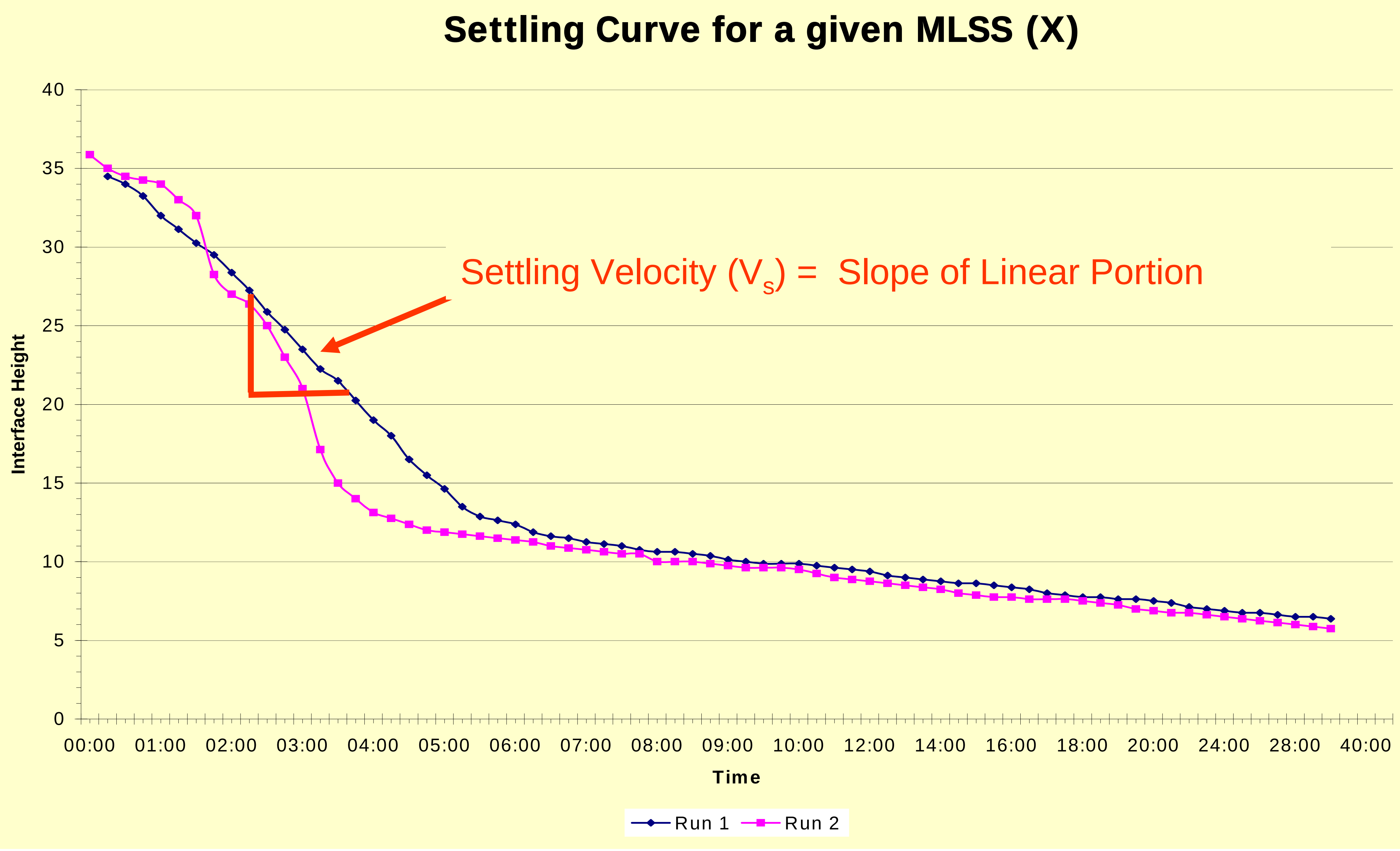
- Extension of the solids flux theory
- Keinath & Wahlberg
- CRTC protocol

Allows the behavior of the clarifier to be examined in <u>conjunction</u> with the activated sludge process

State Point Analysis Starts with Simple Settling Tests



Settling Velocity



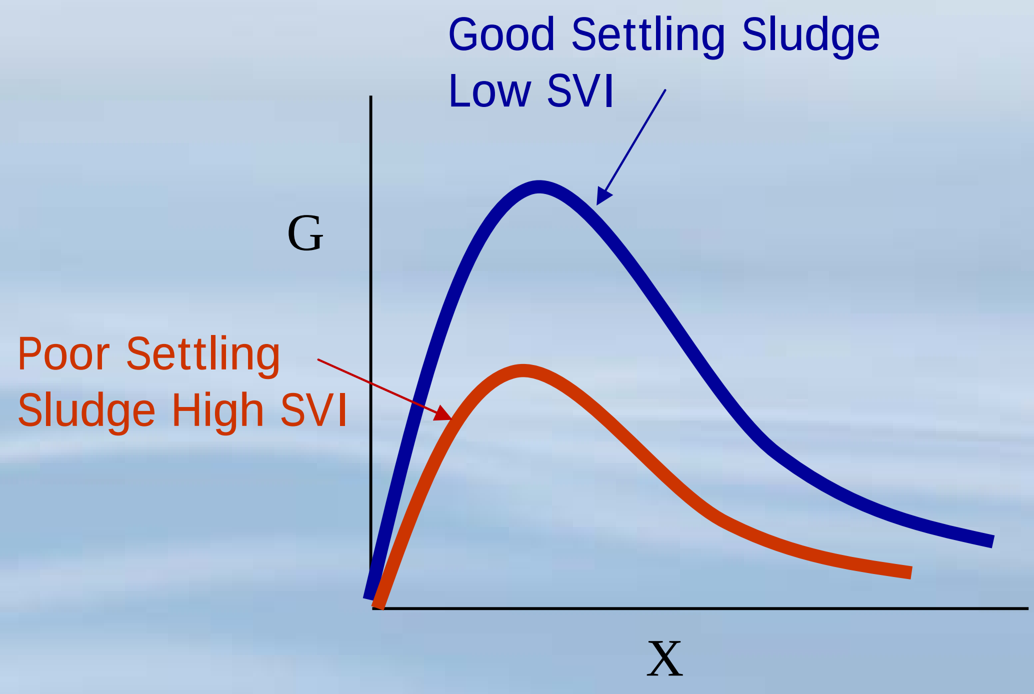
Solids Flux Theory

Vesilind Equation

$$V_s = V_0 \exp(-k\ X)$$

Solids Flux (G), kg/m^2 - h

$$G = V_s\ X$$

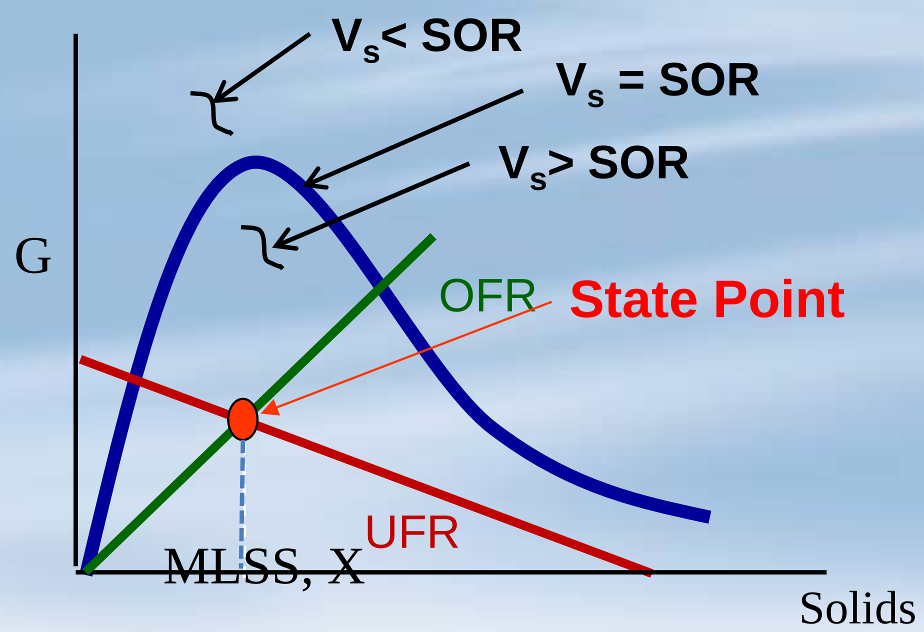


Good settleability = Greater area under the curve relative to poor settleability

State Point Analysis (SPA)

- Superimpose Clarifier Operating Parameters
  - Overflow rate (OFR=Q/A)
  - Underflow rate (UFR=Q_{ras}/A)
- Rate = Slope

State Point is Clarifier Operating Point



<u>Clarification Failure:</u> Location of the State Point

<u>Thickening Failure:</u> Location of UFR.

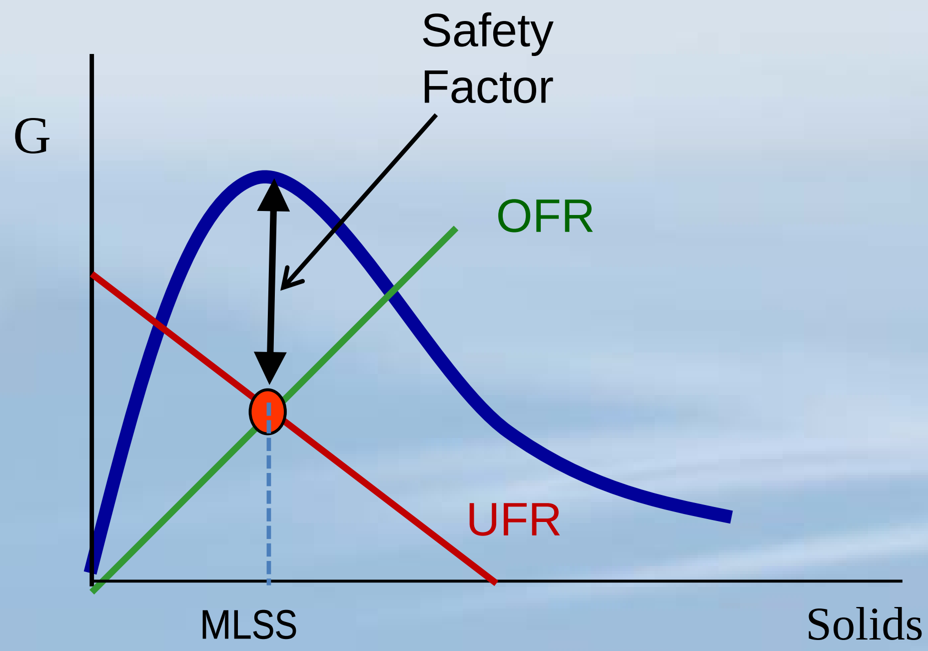
Application of SPA

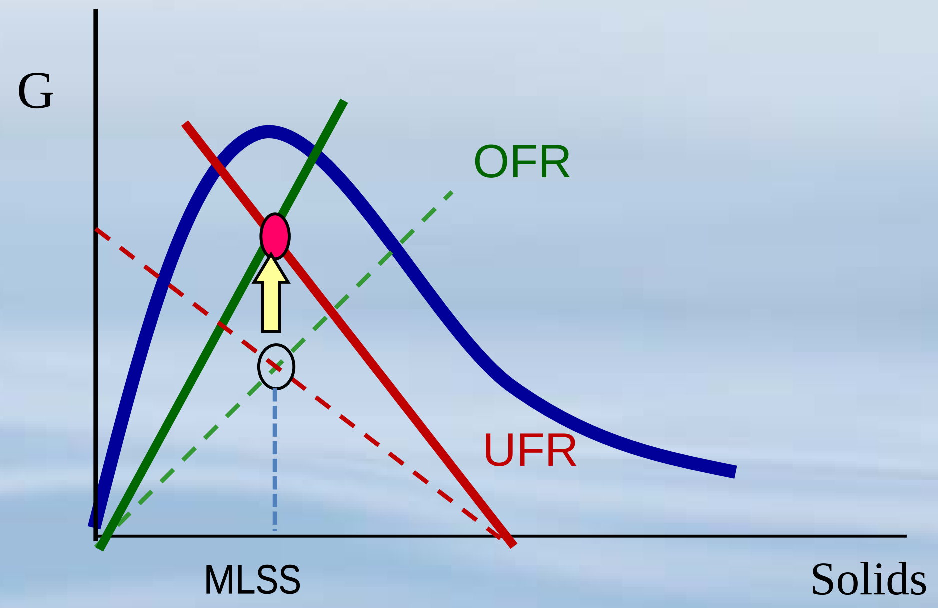
- When clarification or thickening failure occurs:
  - Operator intervenes to correct the situation & minimize the impact on the biological system

If this doesn't happen

  - Clarifier responds by self-correcting itself, but this may impact the biological process
- SPA can be used to explain these two eventualities

Application of SPA
Diurnal Flow Variation

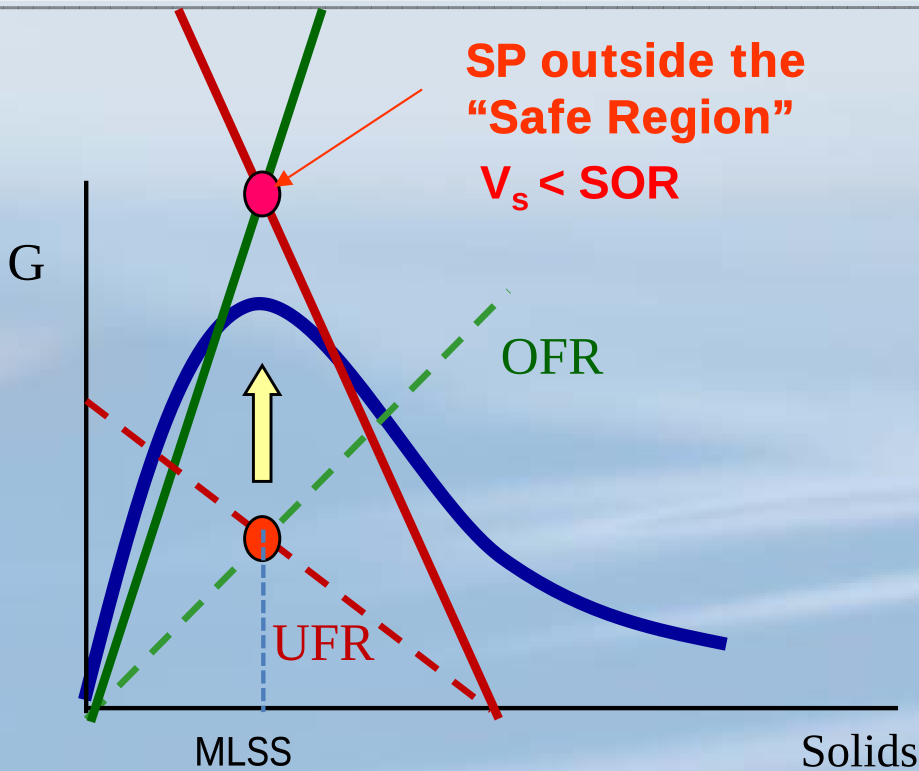


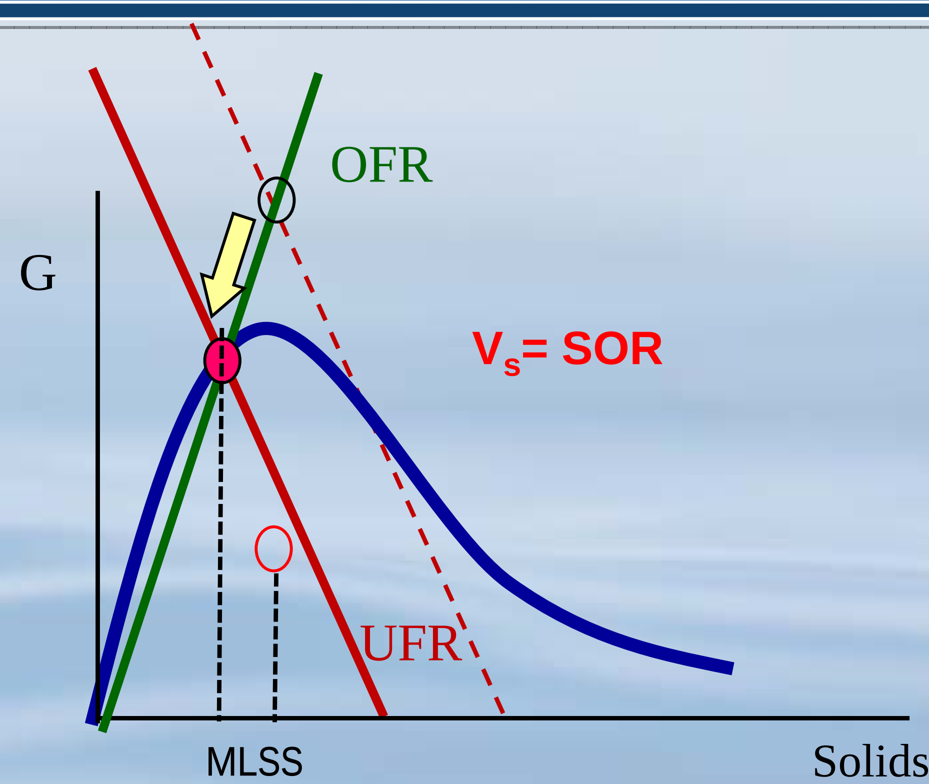


Small flow increase due to normal diurnal variation

- Stable operation
- Reduced safety factor
- No action by operator

Application of SPA
Wet Weather Flows





Large flow increase due to wet weather

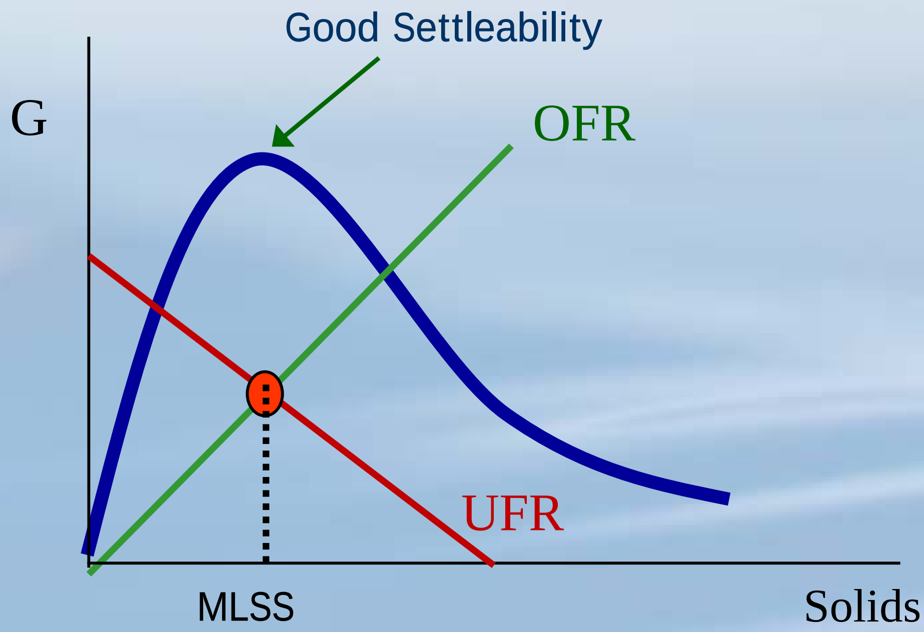
<u>Clarifier response:</u>

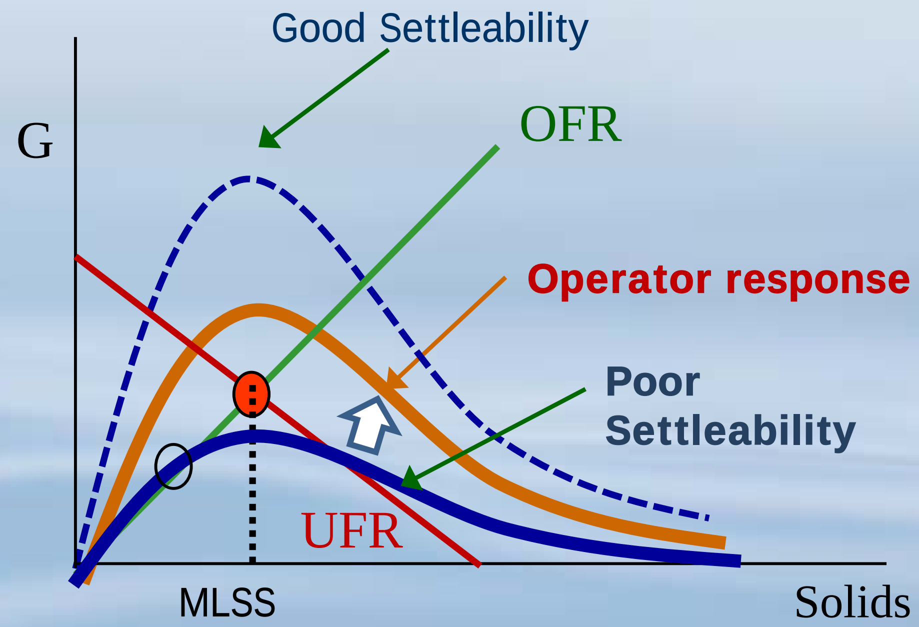
- Solids washout
- Reduced MLSS & SRT
- Nitrification loss

<u>Operator response:</u>

- Convert to step-feed
- Reduced MLSS to clarifier
- SRT not impacted
- Nitrification maintained

Application of SPA
SVI Increase





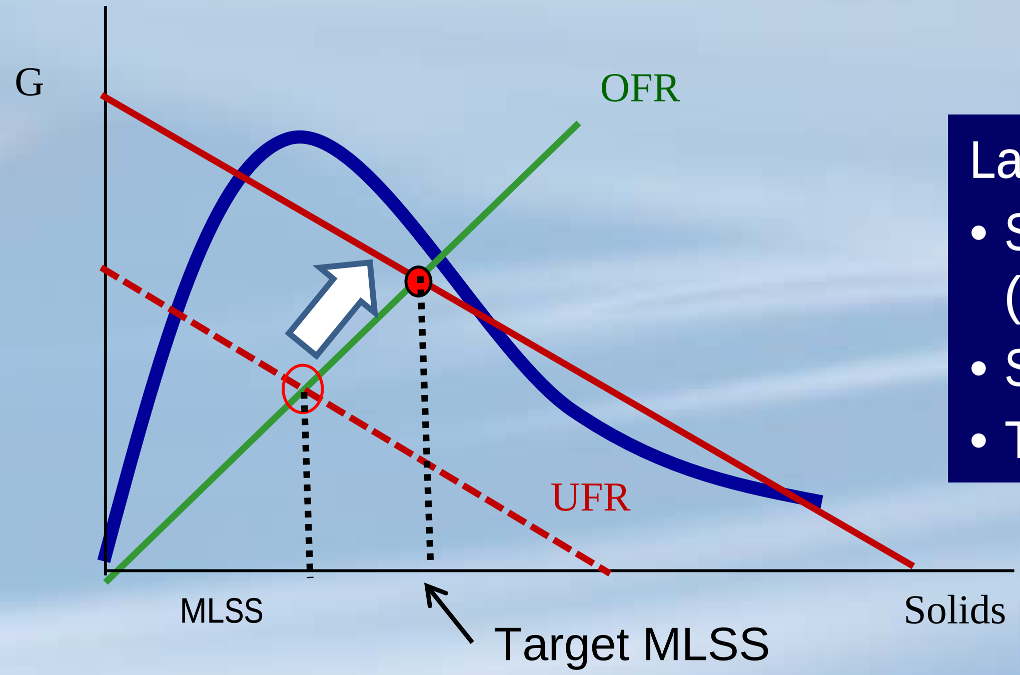
Good settleability (low SVI)
- Stable operation

Poor settleability (High SVI)

<u>Clarifier response</u>
- Clarification failure
- Solids washout
- Lower MLSS
- Nitrification loss

<u>Operator response</u>
- RAS chlorination
- Polymer addition

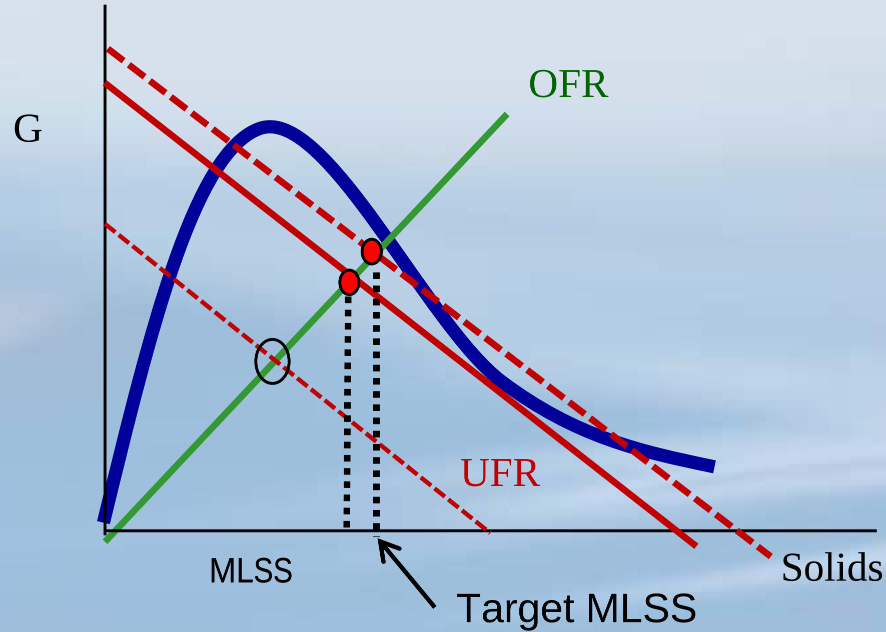
Application of SPA
MLSS Increase

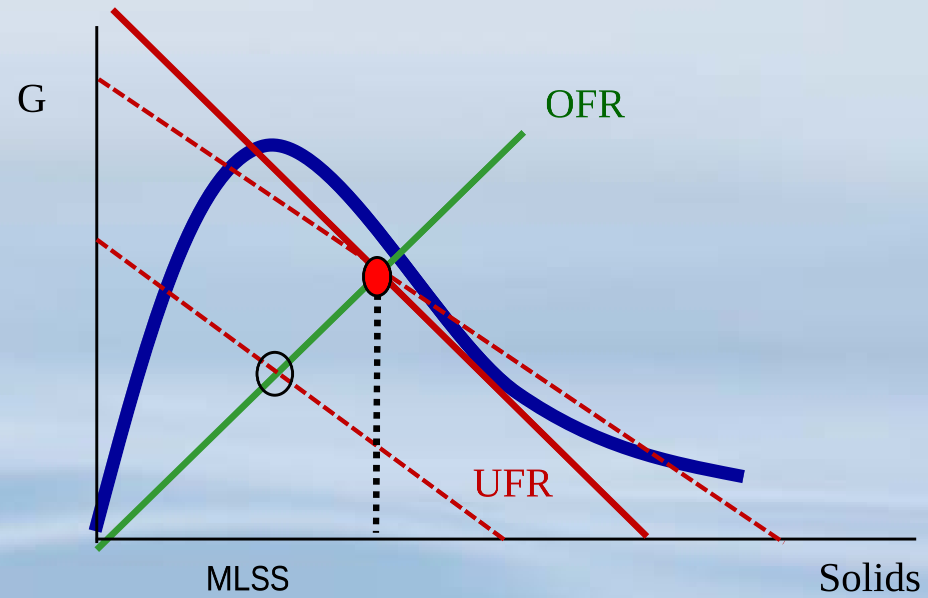


Large MLSS (SRT) Increase to target value:

- Solids in > Solids transport capacity (limiting flux)
- Sludge blanket increase
- Thickening failure

Application of SPA
MLSS Increase





<u>Clarifier Response:</u>

- Solids washout
- MLSS is reduced until limiting flux
- Stable operation with solids in = solids transport capacity
- But MLSS (SRT) < Target value

<u>Operator Action:</u>

- Increase RAS rate until limiting flux
- Maintain target MLSS
- Avoid thickening failure

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Take Home Messages

- Sludge settleability is the single most important factor impacting clarifier performance
- Clarifier design should be based on a systems approach
- SPA and similar tools can be used to improve the design <u>and</u> operation of clarifiers:
  - Use of site-specific sludge settleability data – avoid large safety factors
  - Examine several operating scenarios (flow, SVI, MLSS) – process optimization
  - Size of aeration basin vs. size of clarifier – cost optimization
  - Number of clarifiers in operation
- Clarifiers should not be used for storing sludge
- Minimize sludge blanket depth during normal operation
  - Keep solids in the aeration basin


Questions?