SECONDARY CLARIFIER OPTIMIZATION

USING STATE POINT ANALYSIS

Oregon Operators Conference

August 14, 2018

Presented by Mark Walter, Waterdude Solutions, LLC

Introductions

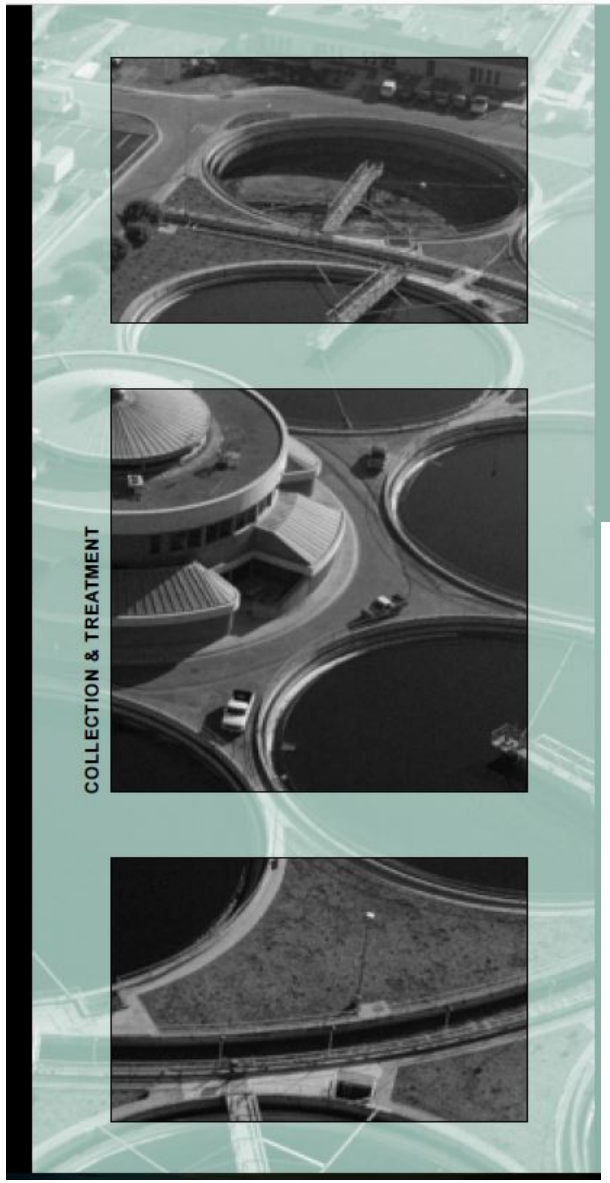
- How many operate secondary clarifiers?
- Do you have more than one clarifier?
- Do you ever have to adjust RAS?

Thank you for your service to the Water Environment!

Presenter's experience

- Wastewater Plant Operator
- Manufacturer's Representative
- O&M Manager Water/Wastewater Facilities
- Consulting and Support as Waterdude

Discovered the benefits of using SPA in 2013



5.5.2 State Point Analysis

The next problem to investigate in the troubleshooting table (Table 5-4) is high sludge blankets. Blanket levels can be measured easily with any of a number of blanket measuring devices, the simplest of which is the Sludge Judge™. If high sludge blankets are detected, a state point analysis is performed to analyze the problem. A state point analysis is performed regardless to plan the stress tests.

For solids inventory control, a state point analysis is an operator's most powerful tool, to be used even with bulky sludges. Despite its usefulness in day-to-day operations and optimization, state point analyses are used primarily by design engineers and engineers performing capacity analyses. Many engineers and operators don't appreciate the power of this relatively straightforward analysis. However, operations training courses are increasingly including instruction in this useful procedure, so with time, this trend should be reversed.

The importance of the state point analysis in the revised protocol cannot be overemphasized; it is both a troubleshooting tool for situations where high blankets are found to exist and a tool for planning the stress tests.

What every operator needs to know about secondary clarification

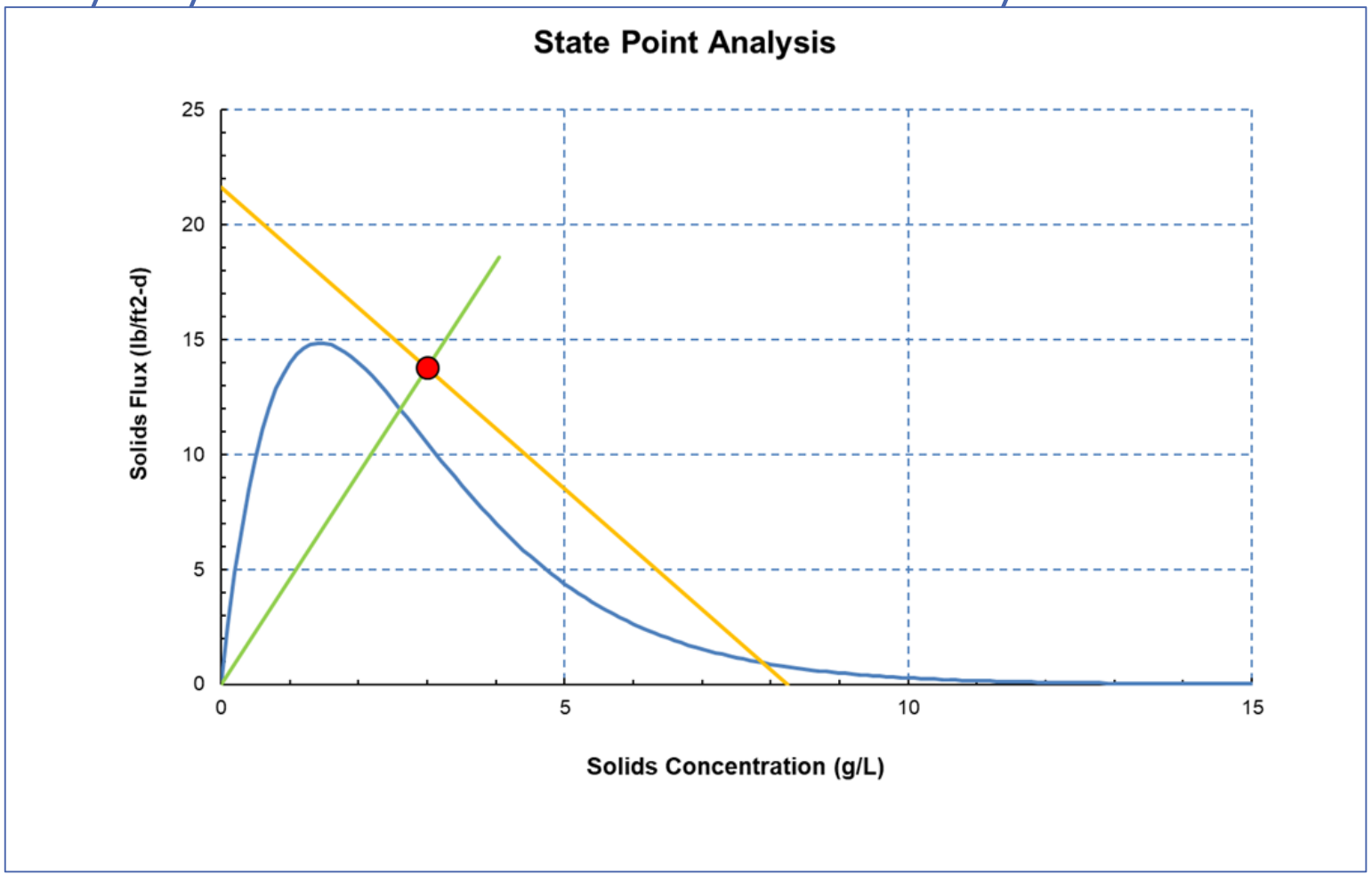
Adam Rogensues

48 WE&T | OCTOBER 2016 | WWW.WEF.ORG/MAGAZINE

Knowledge	Principle	Practical consideration
Advanced performance monitoring	State point analysis (SPA) is a robust analytical procedure that historically has been used by facility designers, but is gaining popularity among operators.	An advantage of the SPA procedure is that it illustrates visually the interrelationship among sludge settleability, SOR, RAS, and SLR to evaluate clarifier performance. For more info on the fundamentals of SPA, download a PDF from the Maine Department of Environment Protection at bit.ly/Maine-SPA.

Check in…

How many of you have used the State Point Analysis ?



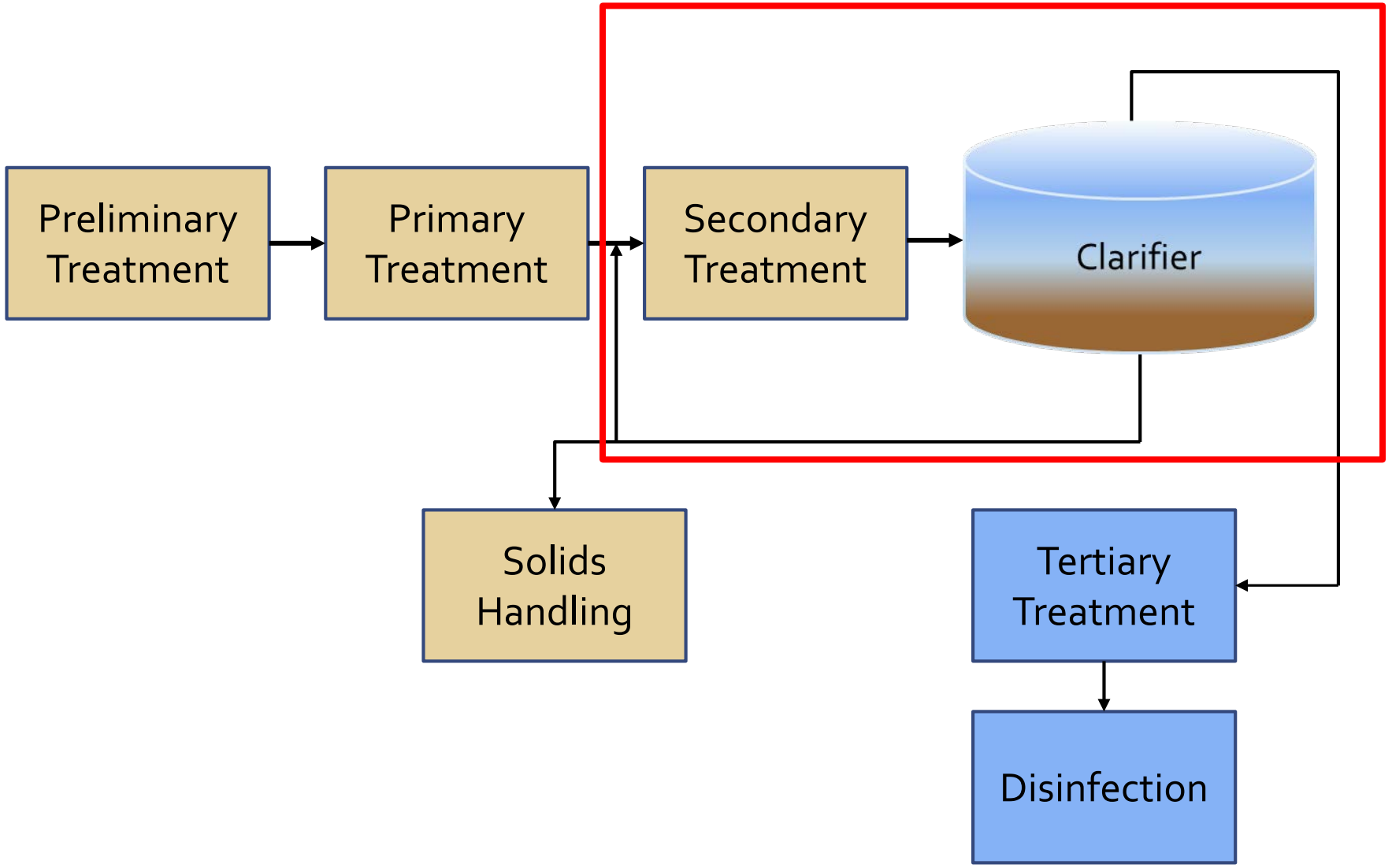
Learning Objectives

- Understand secondary clarifier operation.
- Understand clarifier mass balance
- Acknowledge the State Point Analysis as an operational tool.
- Know where to get to more information.

Agenda for today's training

- Clarifier Components
- Clarifier Operation
- Return Activated Sludge Controls
- State Point Analysis (SPA) as an Operational Tool
- Where to find more information
- Questions

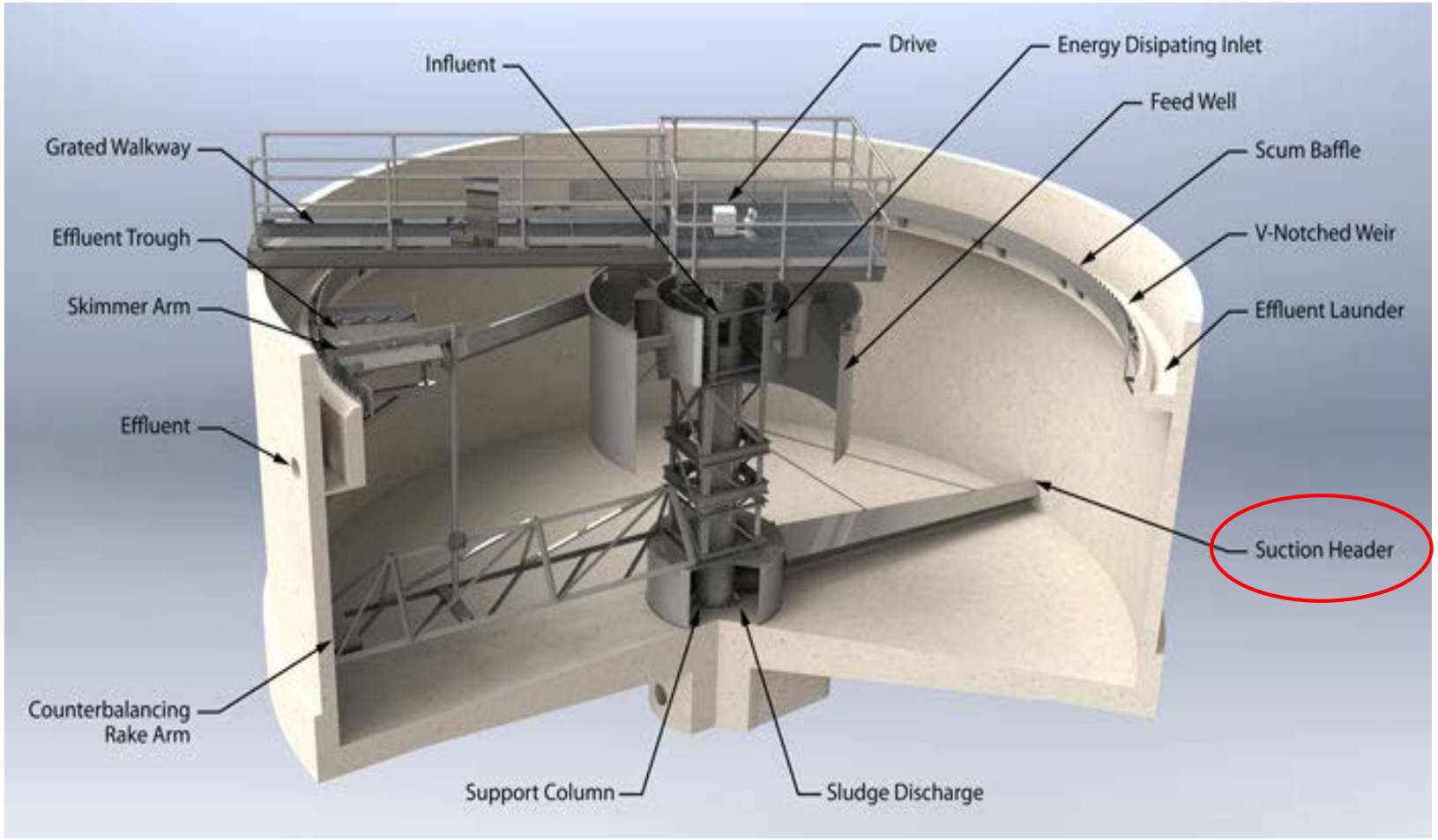
Wastewater Treatment Plant- Overview



Clarifier Components

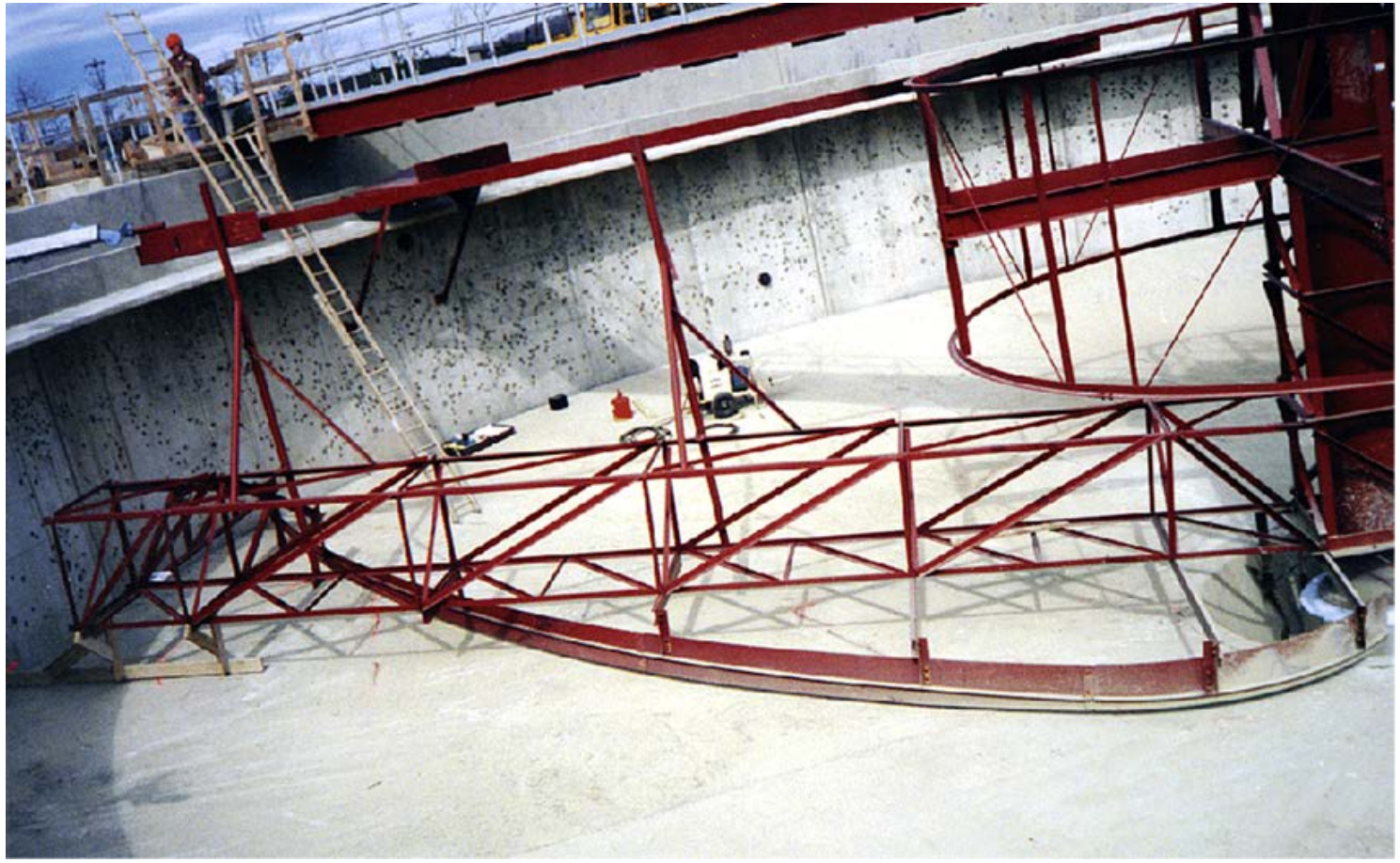
- Focus on circular clarifiers
- Common components
- Sludge removal systems
- Optimization components

Clarifier – Suction Header



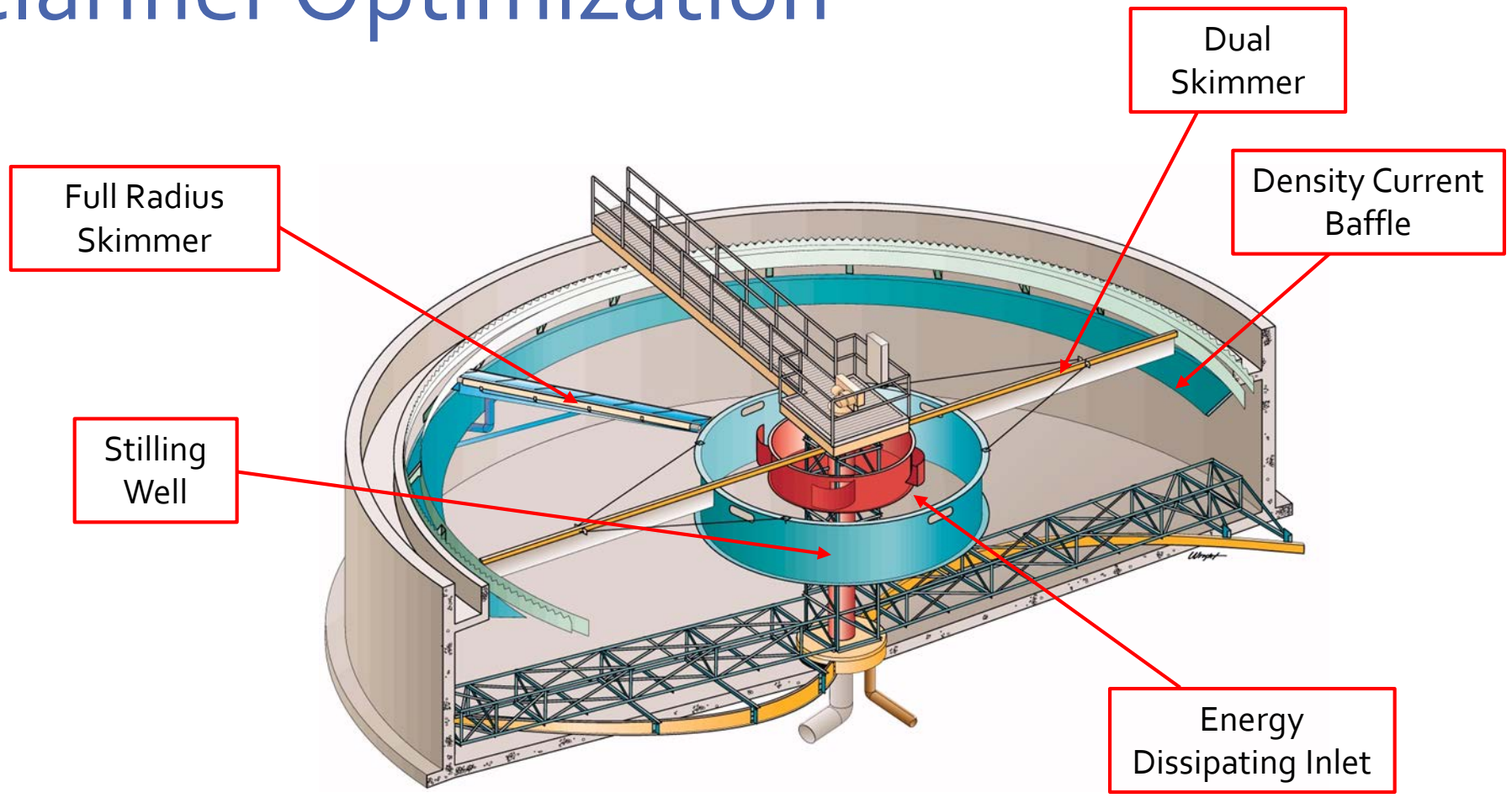
Clarifier – Scraper Blade

Clarifier – Spiral Blade

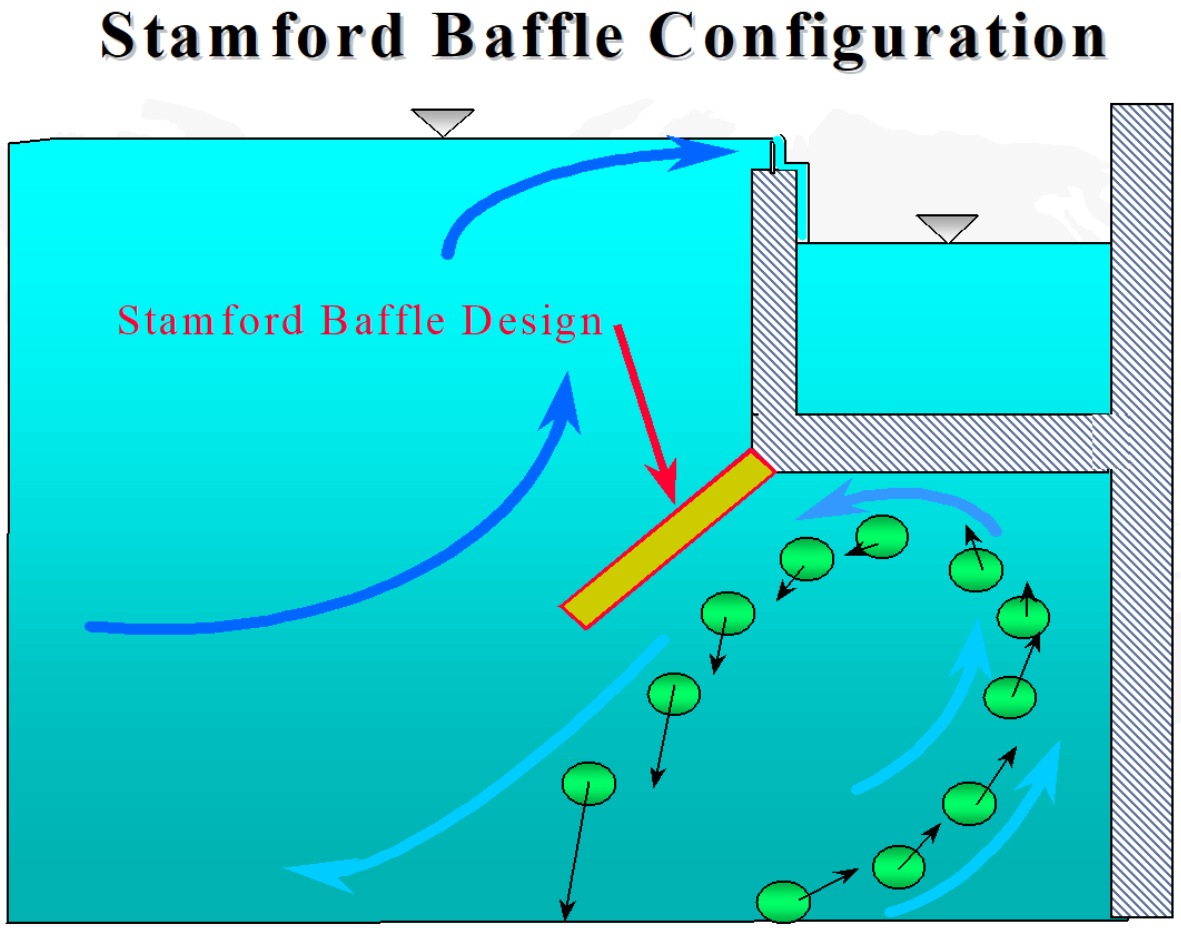


Clarifier – Draft Tube

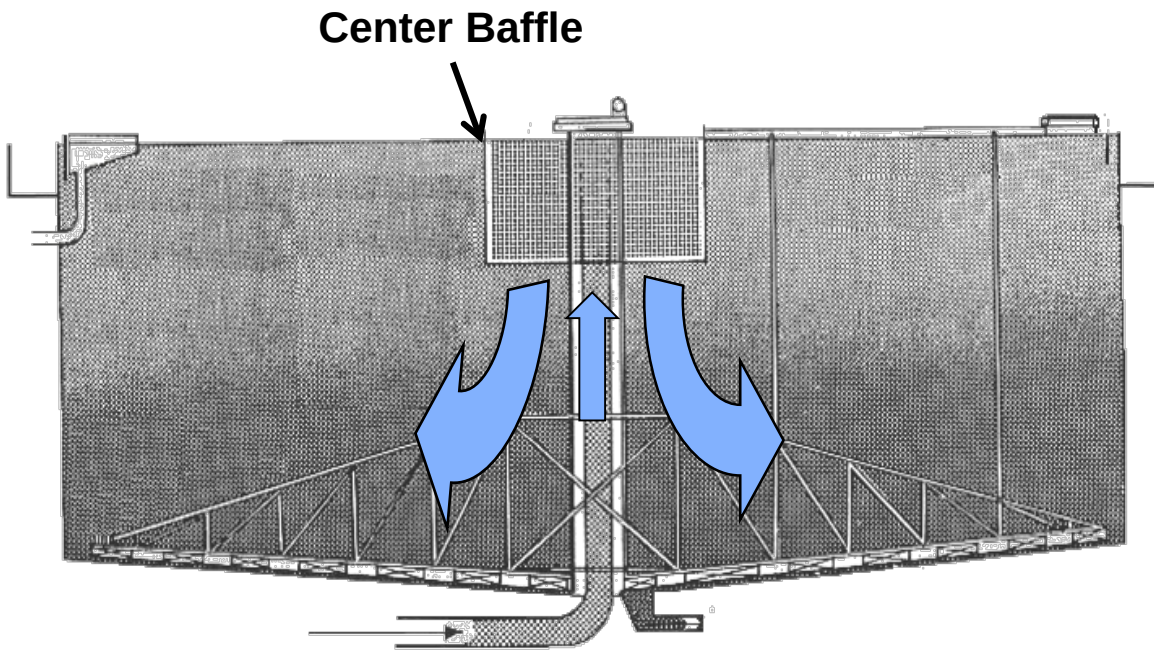
Clarifier Optimization



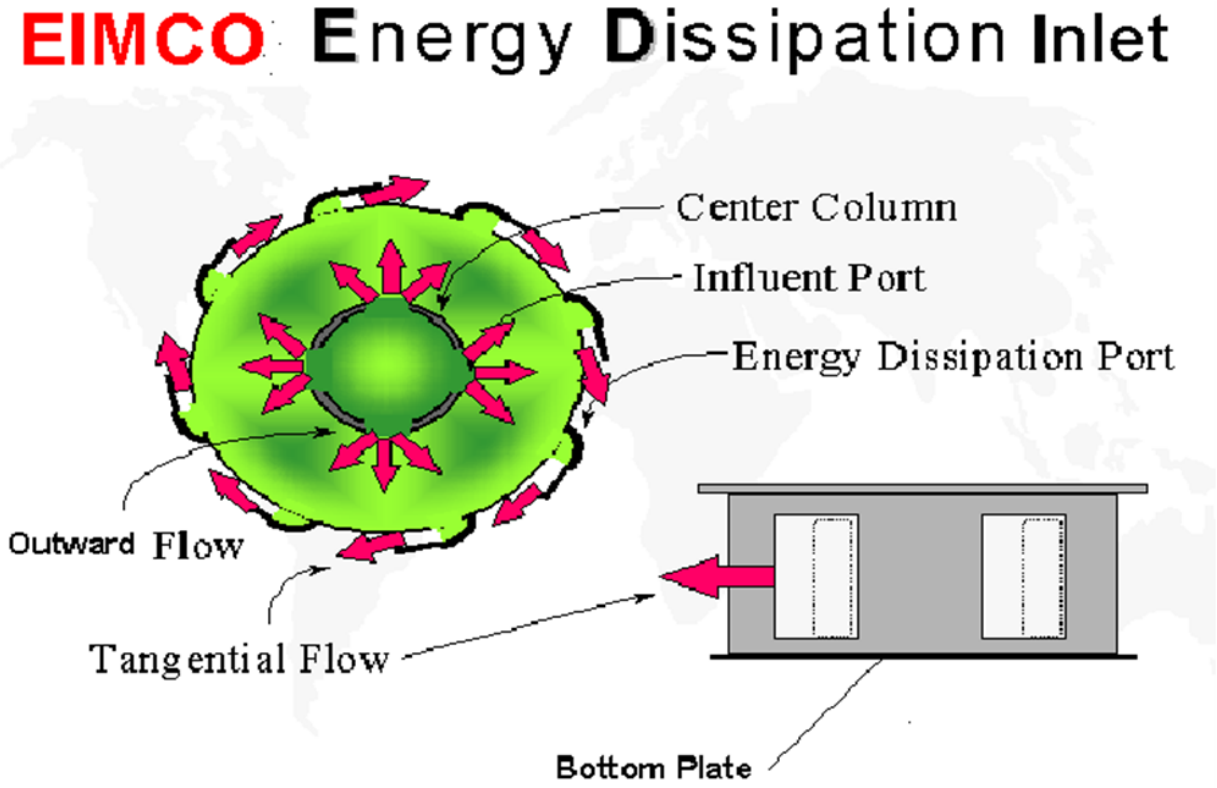
Density Current Baffle



Energy Dispersing inlets and feed wells

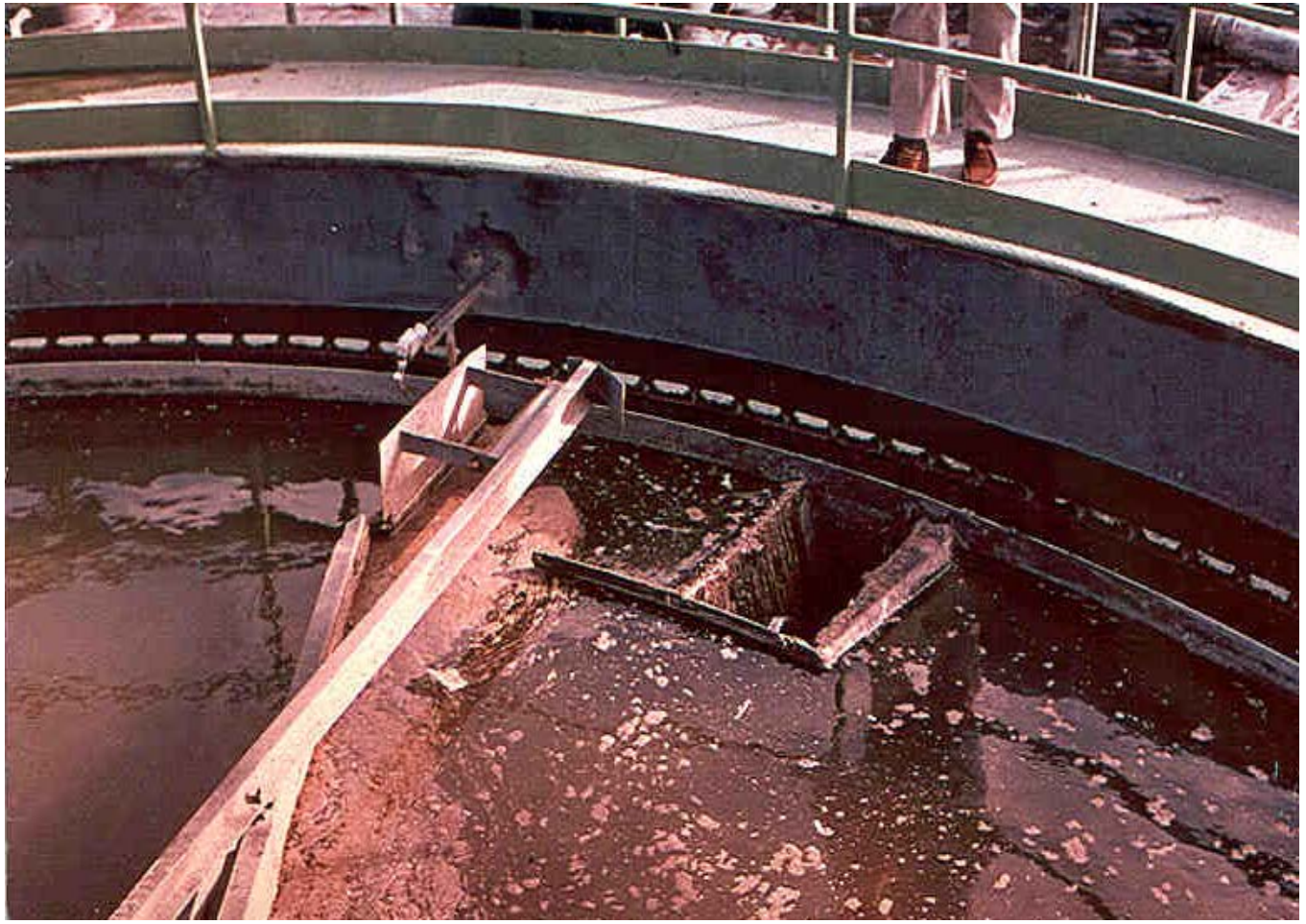


A Circular Baffle Directs Flow

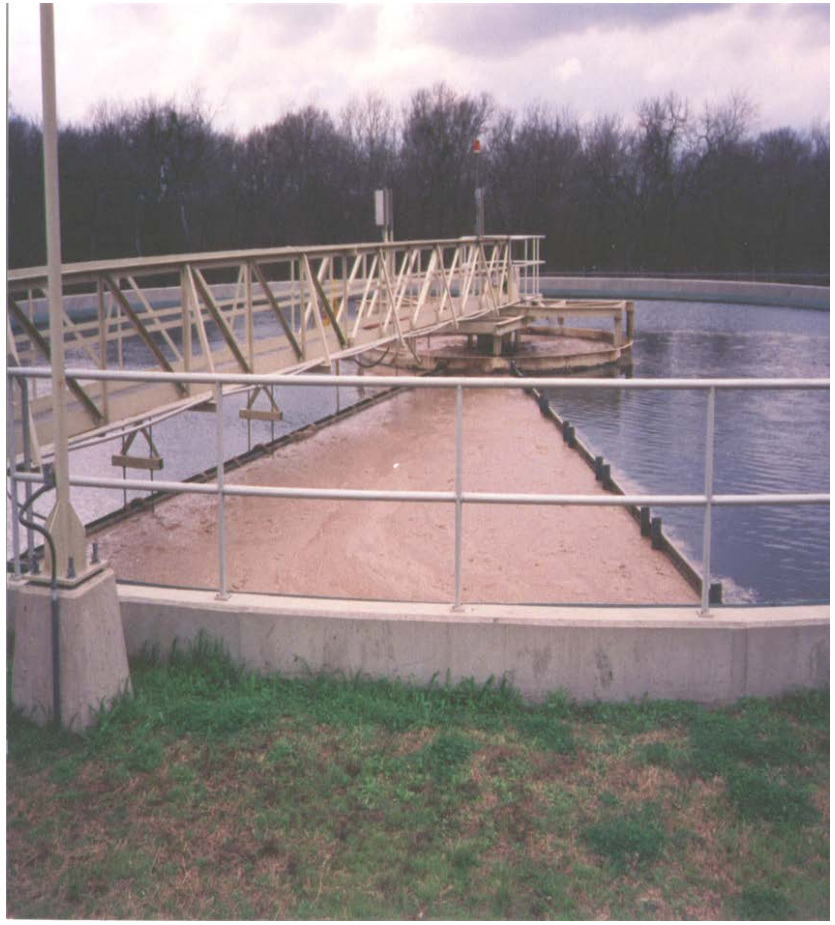


Energy Dispersing Inlets and feed wells

Typical Scum Removal



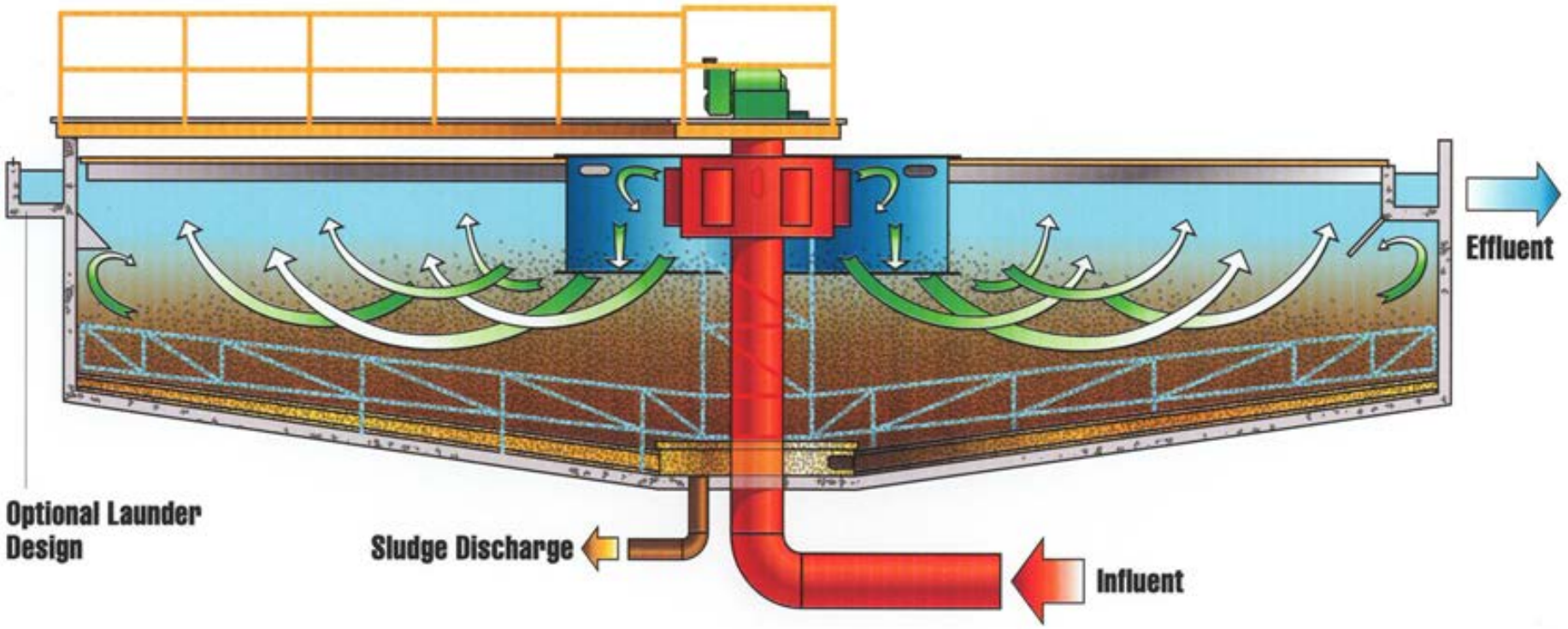
Automated Ducking Skimmer with Automated scum trough



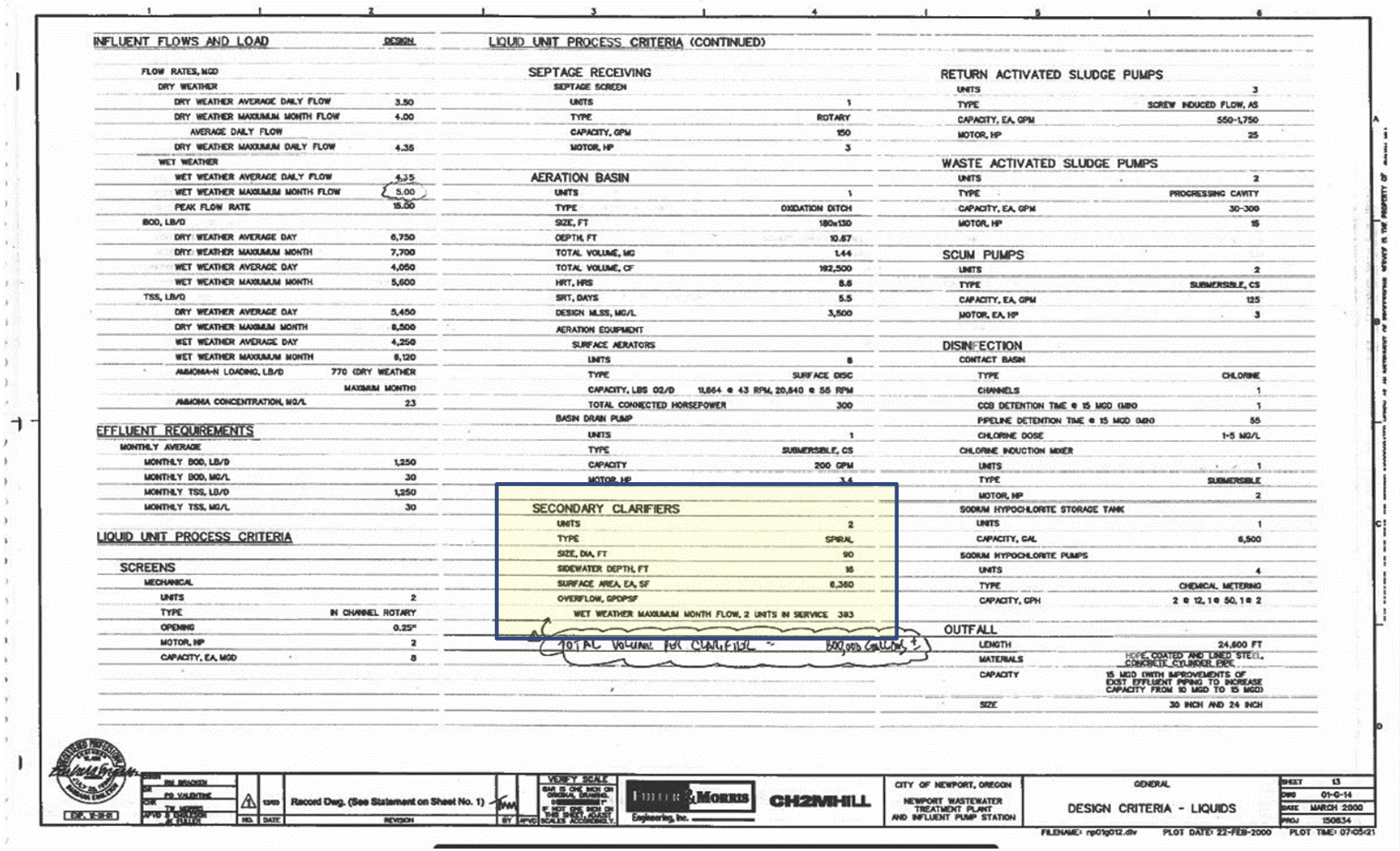
Clarifier Operation – Success Factors

- The secondary or final clarifier is one of the most important unit processes and often determines the capacity of a WWTP.
- Clarification is a solids separation process, which results in the removal of 99 percent or more of the suspended solids (biological floc) received from the activated sludge system.
- Unless the biological material in the mixed liquor can be separated from the clean water, it is likely that both the BOD and TSS limits will be violated.
- The separated solids are transported to the bottom of the clarifier and removed as return activated sludge (RAS).

Clarifier Flow



Clarifier Operation – Know your design parameters.



INFLUENT FLOWS AND LOAD

	DESIGN
FLOW RATES, MGD	
DRY WEATHER	
DRY WEATHER AVERAGE DAILY FLOW	3.50
DRY WEATHER MAXIMUM MONTH FLOW	4.00
AVERAGE DAILY FLOW	
DRY WEATHER MAXIMUM DAILY FLOW	4.35
WET WEATHER	
WET WEATHER AVERAGE DAILY FLOW	4.35
WET WEATHER MAXIMUM MONTH FLOW	5.00
PEAK FLOW RATE	15.00
BOD, LB/D	
DRY WEATHER AVERAGE DAY	6,750
DRY WEATHER MAXIMUM MONTH	7,700
WET WEATHER AVERAGE DAY	4,050
WET WEATHER MAXIMUM MONTH	5,600
TSS, LB/D	
DRY WEATHER AVERAGE DAY	5,450
DRY WEATHER MAXIMUM MONTH	8,500
WET WEATHER AVERAGE DAY	4,250
WET WEATHER MAXIMUM MONTH	8,120
AMMONIA-N LOADING, LB/D	770 (DRY WEATHER MAXIMUM MONTH)
AMMONIA CONCENTRATION, MG/L	23

EFFLUENT REQUIREMENTS

MONTHLY AVERAGE	
MONTHLY BOD, LB/D	1,250
MONTHLY BOD, MG/L	30
MONTHLY TSS, LB/D	1,250
MONTHLY TSS, MG/L	30

LIQUID UNIT PROCESS CRITERIA

SCREENS

MECHANICAL	
UNITS	2
TYPE	IN CHANNEL ROTARY
OPENING	0.25"
MOTOR, HP	2
CAPACITY, EA, MGD	8

LIQUID UNIT PROCESS CRITERIA (CONTINUED)

SEPTAGE RECEIVING

SEPTAGE SCREEN	
UNITS	1
TYPE	ROTARY
CAPACITY, GPM	150
MOTOR, HP	3

AERATION BASIN

UNITS	1
TYPE	OXIDATION DITCH
SIZE, FT	180x130
DEPTH, FT	10.67
TOTAL VOLUME, MG	1.44
TOTAL VOLUME, CF	192,500
HRT, HRS	8.6
SRT, DAYS	5.5
DESIGN MLSS, MG/L	3,500
AERATION EQUIPMENT	
SURFACE AERATORS	
UNITS	8
TYPE	SURFACE DISC
CAPACITY, LBS O2/D	11,864 @ 43 RPM, 20,840 @ 55 RPM
TOTAL CONNECTED HORSEPOWER	300
BASIN DRAIN PUMP	
UNITS	1
TYPE	SUBMERSIBLE, CS
CAPACITY	200 GPM
MOTOR, HP	3.4

SECONDARY CLARIFIERS

UNITS	2
TYPE	SPIRAL
SIZE, DIA, FT	90
SIDEWATER DEPTH, FT	16
SURFACE AREA, EA, SF	6,360
OVERFLOW, GPD/SF	
WET WEATHER MAXIMUM MONTH FLOW, 2 UNITS IN SERVICE	393

101 AC VOLUME FOR CLARIFIER ~ 500,000 Gallons +

RETURN ACTIVATED SLUDGE PUMPS

UNITS	3
TYPE	SCREW INDUCED FLOW, AS
CAPACITY, EA, GPM	550-1,750
MOTOR, HP	25

WASTE ACTIVATED SLUDGE PUMPS

UNITS	2
TYPE	PROGRESSING CAVITY
CAPACITY, EA, GPM	30-300
MOTOR, HP	15

SCUM PUMPS

UNITS	2
TYPE	SUBMERSIBLE, CS
CAPACITY, EA, GPM	125
MOTOR, EA, HP	3

DISINFECTION

CONTACT BASIN	
TYPE	CHLORINE
CHANNELS	1
CCB DETENTION TIME @ 15 MGD (MIN)	1
PIPELINE DETENTION TIME @ 15 MGD (MIN)	55
CHLORINE DOSE	1-5 MG/L
CHLORINE INDUCTION MIXER	
UNITS	1
TYPE	SUBMERSIBLE
MOTOR, HP	2
SODIUM HYPOCHLORITE STORAGE TANK	
UNITS	1
CAPACITY, GAL	6,500
SODIUM HYPOCHLORITE PUMPS	
UNITS	4
TYPE	CHEMICAL METERING
CAPACITY, GPH	2 @ 12, 1 @ 50, 1 @ 2

OUTFALL

LENGTH	24,600 FT
MATERIALS	HDPE, COATED AND LINED STEEL, CONCRETE CYLINDER PIPE
CAPACITY	15 MGD (WITH IMPROVEMENTS OF EXIST EFFLUENT PIPING TO INCREASE CAPACITY FROM 10 MGD TO 15 MGD)
SIZE	30 INCH AND 24 INCH

Record Dwg. (See Statement on Sheet No. 1)

CITY OF NEWPORT, OREGON
NEWPORT WASTEWATER TREATMENT PLANT AND INFLUENT PUMP STATION

GENERAL
DESIGN CRITERIA - LIQUIDS

FILENAME: np01g012.dlv PLOT DATE: 22-FEB-2000 PLOT TIME: 07:05:21

Clarifier – Factors affecting Performance

- Hydraulic Loading
  - Detention Time
  - Surface Overflow Rate
- Solids Loading
- Nutrient Removal
- Solids Removal Rate
- Sludge Setting Characteristics

Clarifier Monitoring

- **Clarifier Effluent**
  - BOD/TSS
- **Sludge Blanket**
  - Blanket Depth
  - Consider developing a profile
- **Return Activated Sludge (RAS)**
  - Return Rate of Flow
  - Concentration (TSS)
- **Waste Activated Sludge (WAS)**
  - WAS Flow
  - Concentration (TSS)

Always be mindful of sampling locations and practices

Additional Testing:

- Mixed Liquor Suspended Solids (MLSS)
- Settleometer
- Sludge Volume Index
- Chemical Addition
- Nutrients

Return Activated Sludge Control

It's all about "Mass Balance" or "Solids Balance"

Whatever goes in will come out… or Pounds in = Pounds out

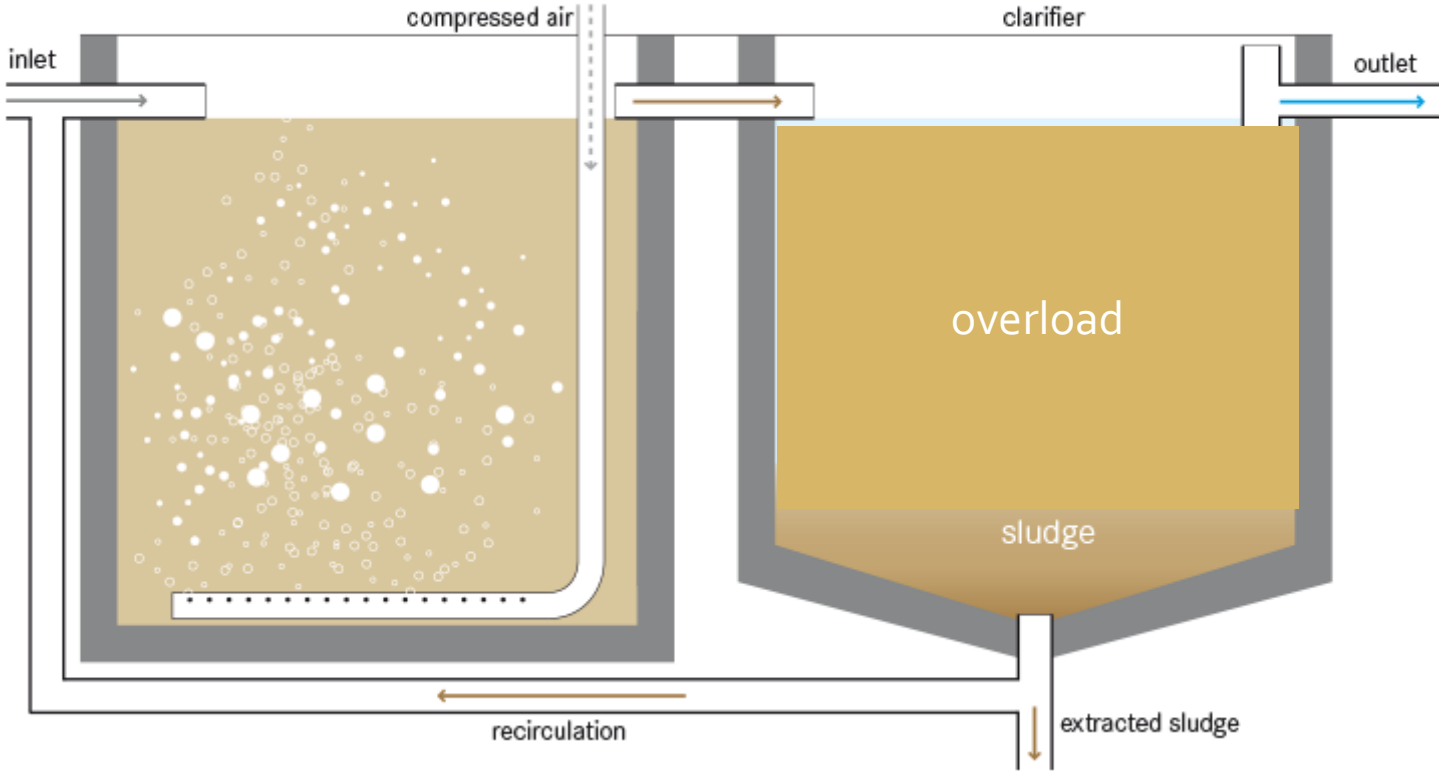
Your trying to maintain solids in the Activated Sludge System while maintaining quality effluent out of the clarifier.

Improper RAS pumping could result in negative process impacts:

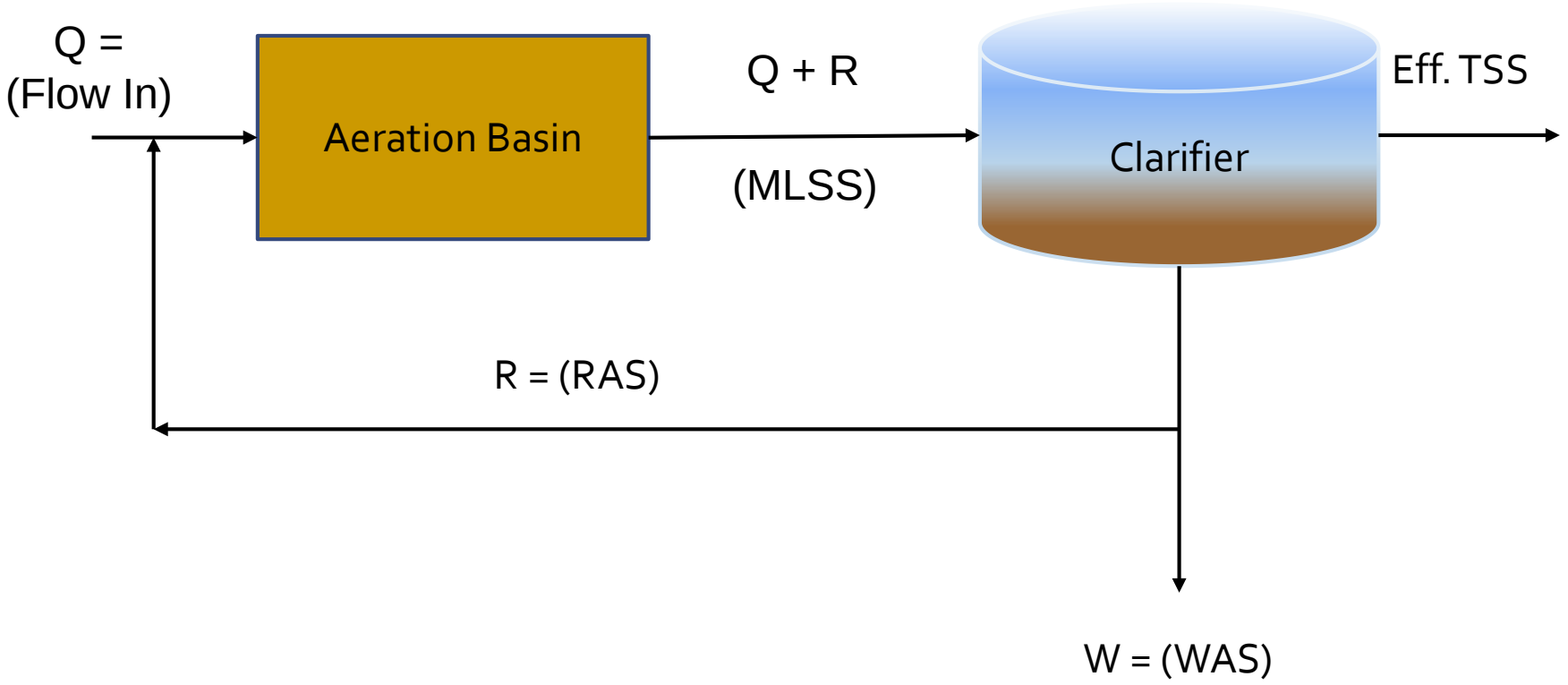
- Insufficient MLSS concentrations in the bioreactor
- Septic Conditions/De-Nitrification
- Solids overload resulting in solids in the effluent

Remember Conditions Change –
Clarifier operation requires consistent monitoring and effective process control strategies

Let's talk about RAS flow



Clarifier Mass Balance



Clarifier Mass Balance

Calculate what is entering the clarifier:

(Influent Q + RAS Q)* MLSS* 8.34 lb./gal

(1.5mgd+ .60mgd)* 2,500 mg/l* 8.34 lb/gal.= 43,795 lbs.

Calculate what is exiting the clarifier: RAS rate 40%

(RAS Q * RASS * 8.34 lb./gal.)+(Effluent Q * Eff. TSS * 8.34 lb./gal.)

(0.60 mgd *8,000 mg/l * 8.34 lb./gal.) +(1.5mgd * 5 mg/l*8.34)=

40,032 lbs.+63 Eff. lbs. + 3,000 WAS lbs. = 43,095

Ratio in vs. out = 1.01

Optimizing Return Sludge Pumping

- Strategies to optimize RAS pumping include:
  - RAS flow control (fixed or ratio)
  - Blanket level control
  - Control based on sludge settling characteristics
  - **Control based on solids flux theory**

STATE POINT ANALYSIS

Introduction

Introduction to SPA

The State Point Analysis (SPA) is a practical tool that can be used to perform a "what if" analysis based on site specific data.

It enables Operators to examine clarifier behavior under various flow and loading scenarios.

Utilizing the SPA Operators can predict impending problems early, implement corrective measures in a timely fashion, and adapt to upstream changes in the biological process.

State point analysis can be used to determine if a secondary clarifier is overloaded, critically loaded, or underloaded with respect to both its clarification and thickening capacities.

So, when is State Point Analysis useful to Operators?

Hydraulic Loading Changes

- Inflow and Infiltration effecting influent flows

Activated Sludge Settling Characteristics Change

- Sludge Volume Index (SVI) increases or decreases

State Point A

These become "Inputs" in the SPA tool

- Evaluates clarifier c balance approach
- Data required:
  - Flow rate
  - Underflow rate
  - Clarifier area
  - Mixed liquor concentration
  - Settling properties
- Is not an "all in one" solution. Does not consider sludge blanket elevation or volume of solids in clarifier.
- As the name implies, this is a measurement of a particular "state".

Solids Flux

Solids Flux describes the movement of solids through a clarifier.

The state point analysis plot requires a settling solids flux curve. The curve shows graphically the relationship between solids flux and suspended solids concentration.

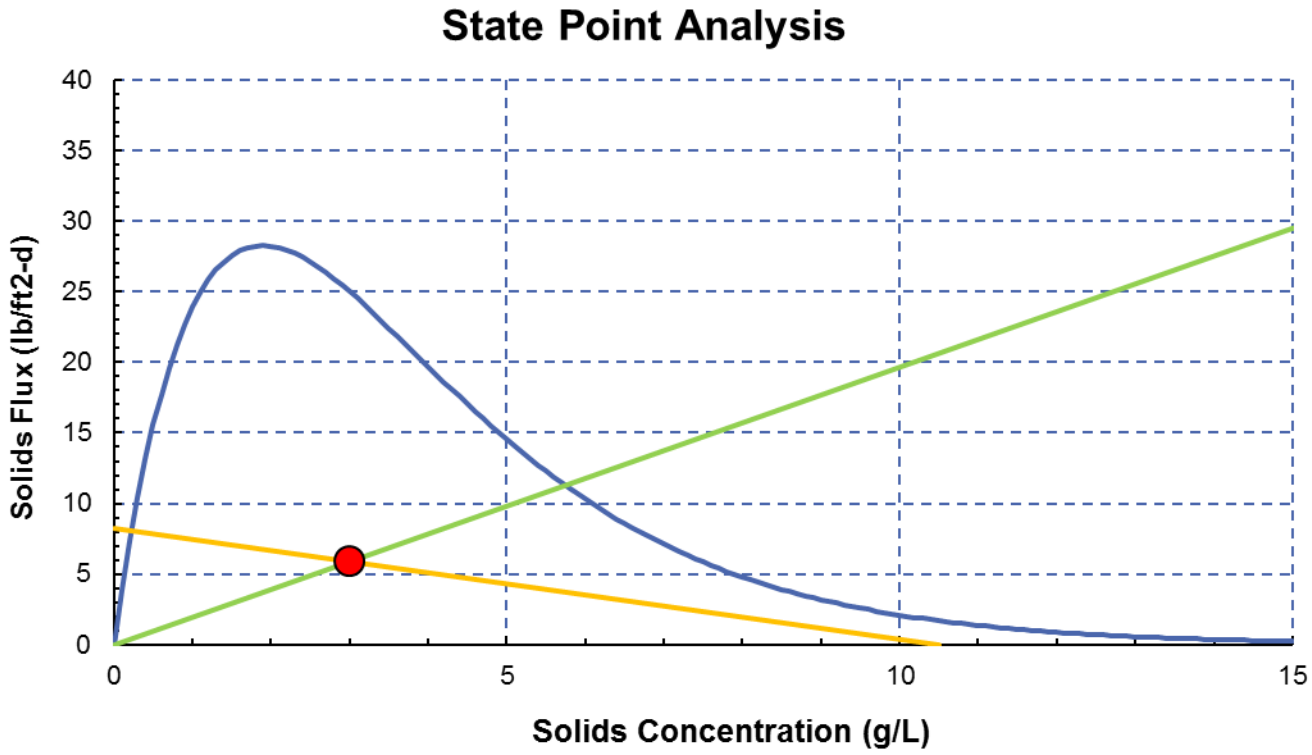
Typical ways to obtain the solids flux curve:

1) Perform site specific settling tests to calculate the flux curve.

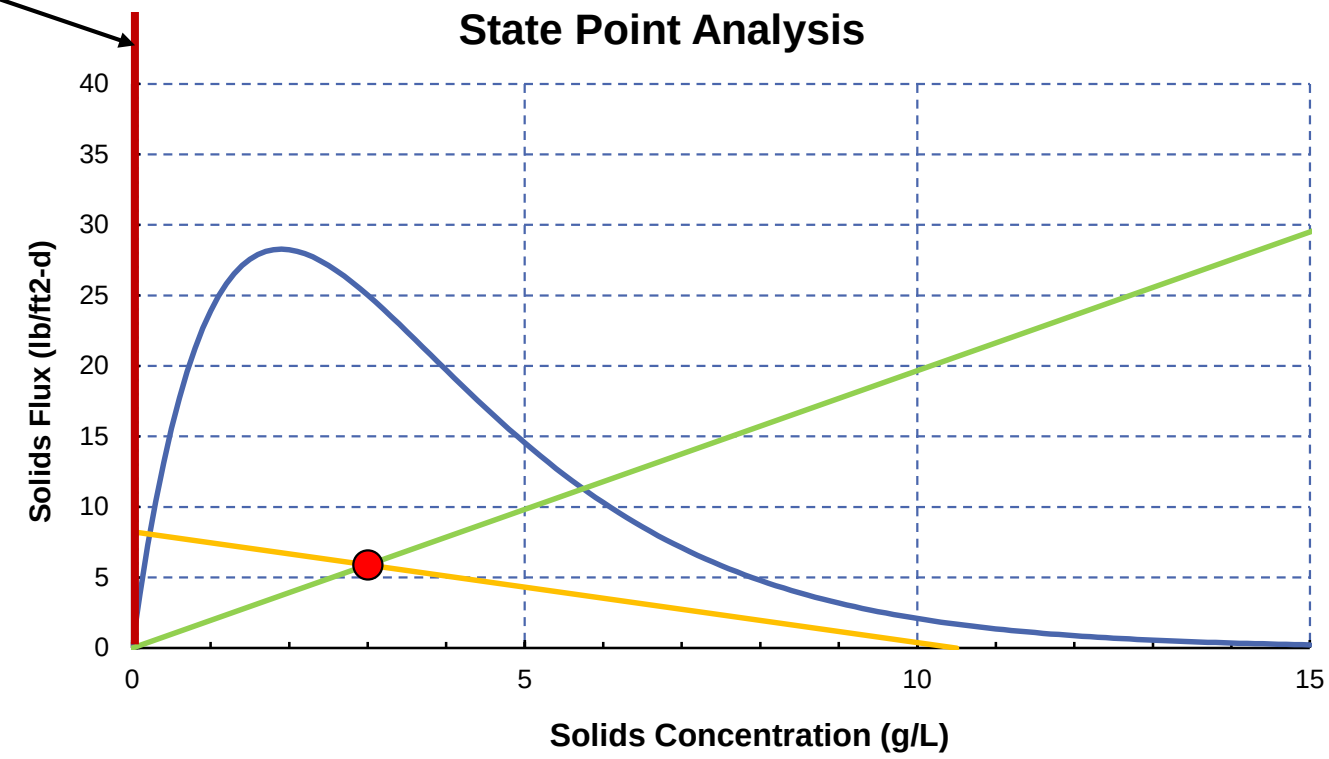
The settling solids flux curve is developed based on the results of settling tests conducted on the mixed liquor. More information regarding the development of settling solids flux curves can be found in WERF (2009) and Metcalf & Eddy(2003).

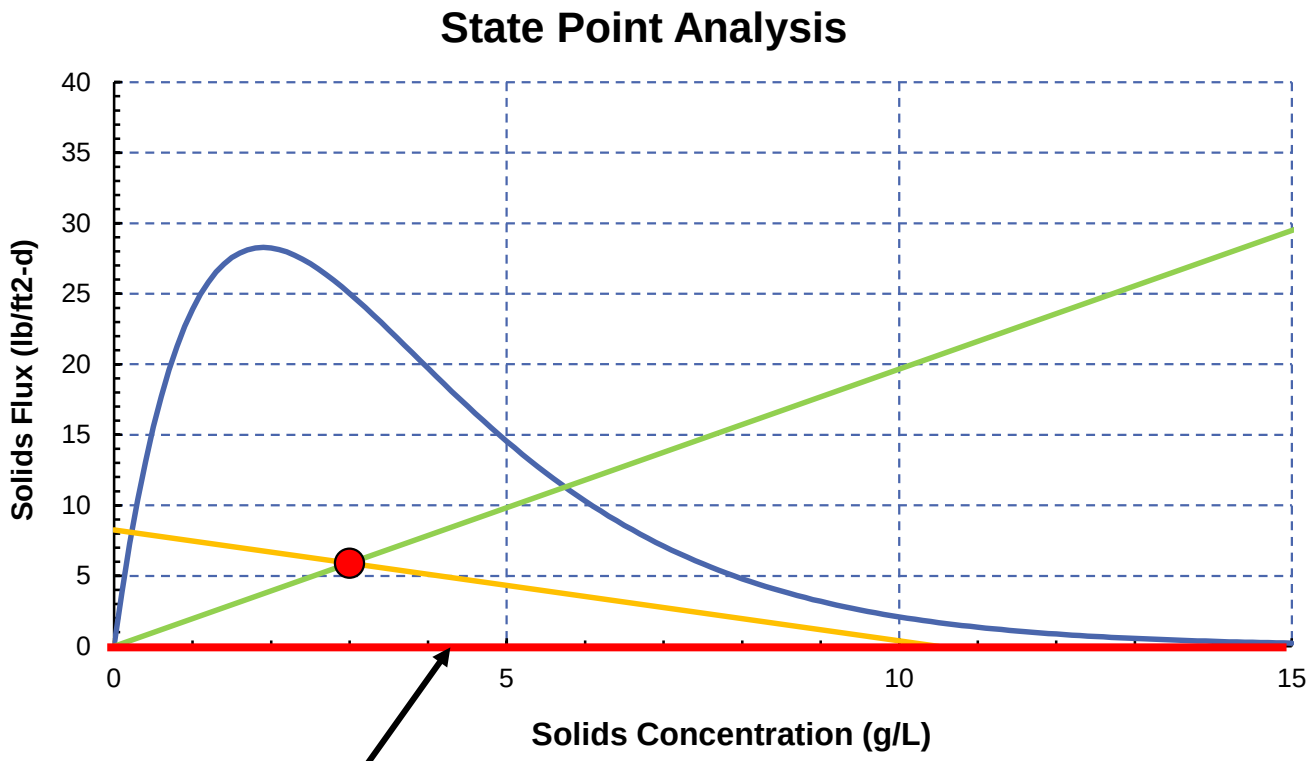
2) Utilize existing solids flux data developed by industry experts.

State Point Analysis - definitions



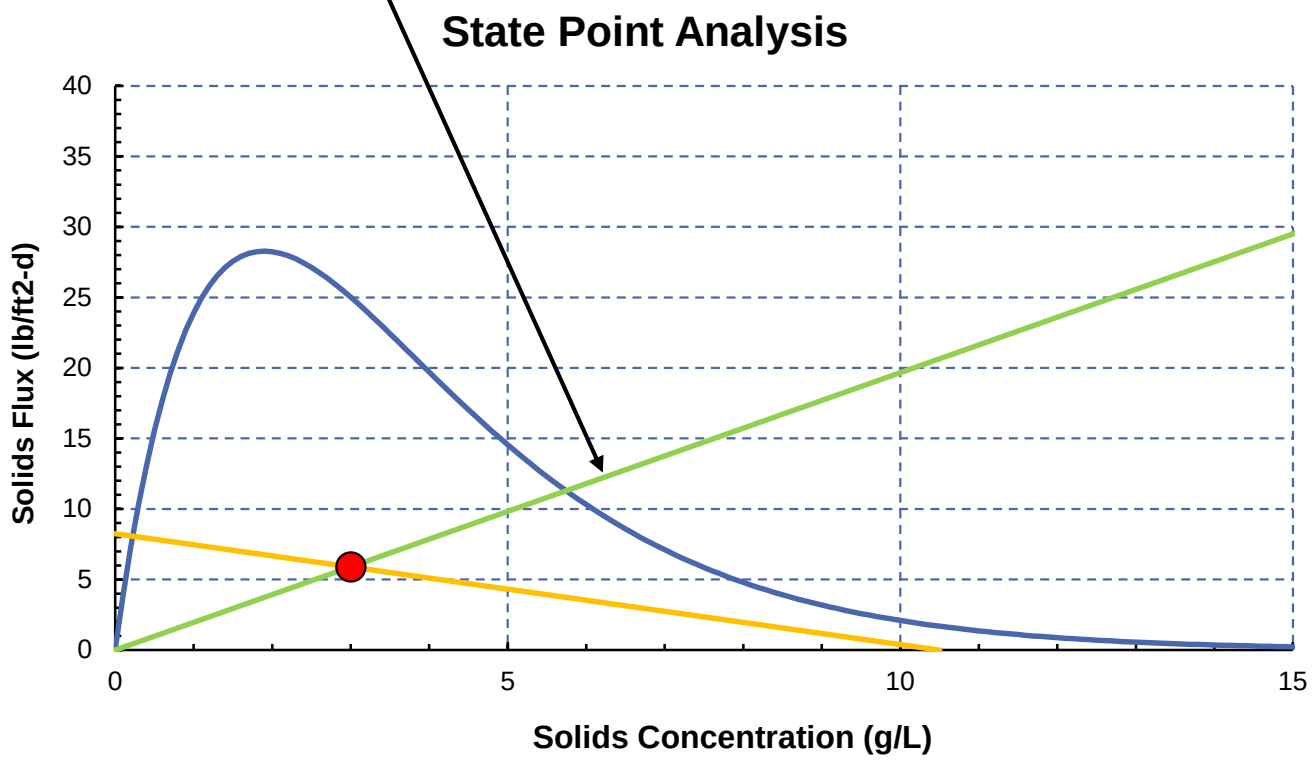
"Y" axis or vertical line reflects the solids flux. How fast solids pass through the volume.

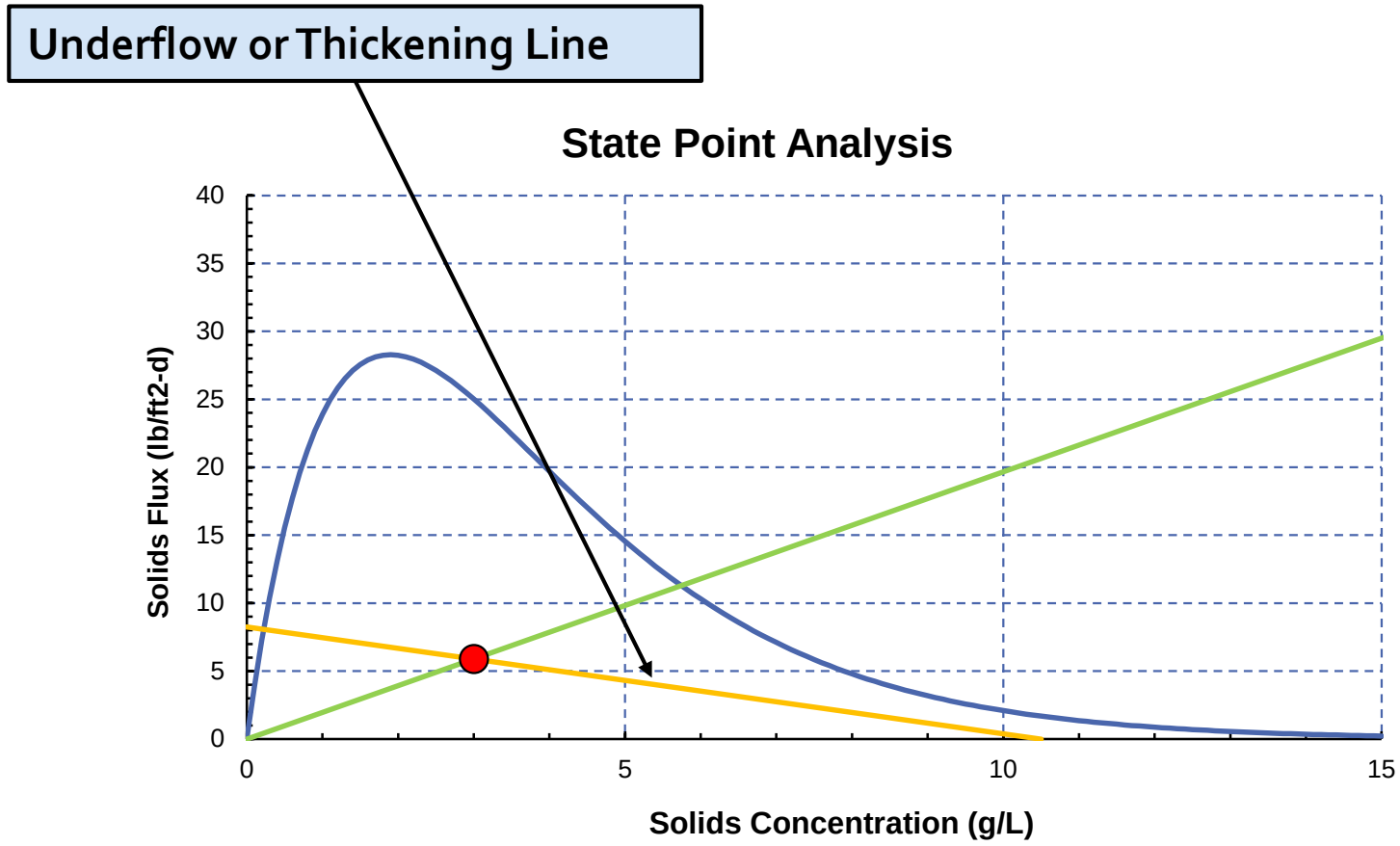


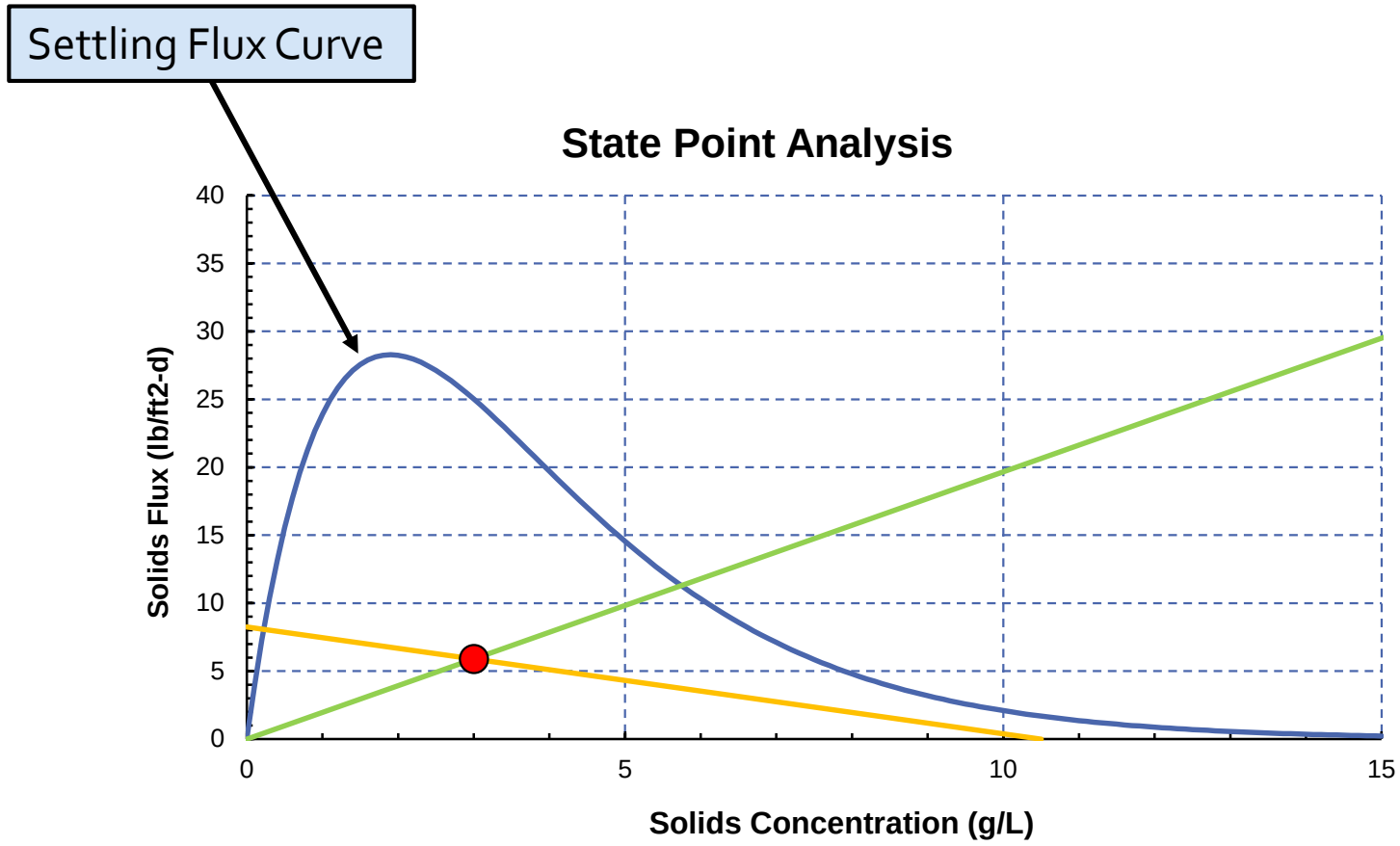


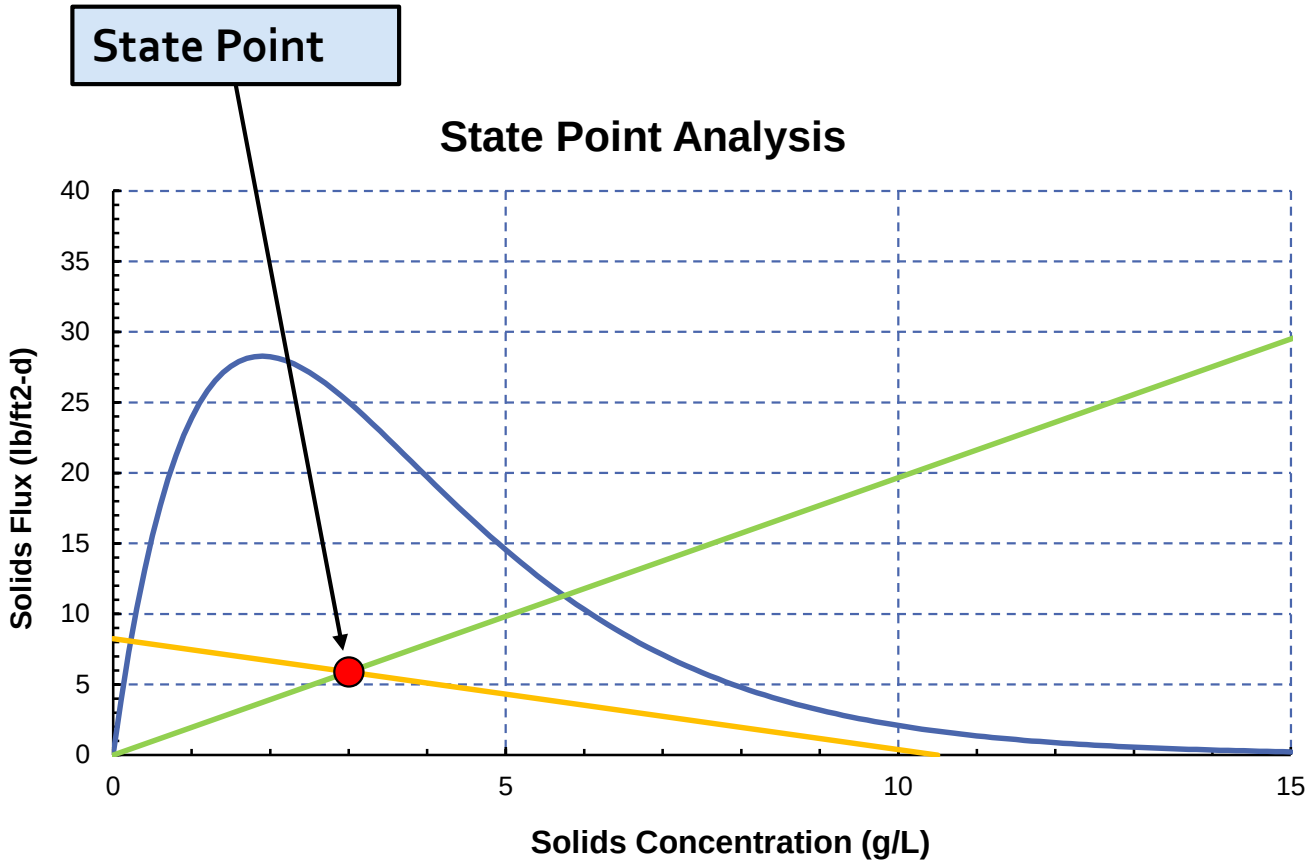
"X" axis or horizontal line is the solids concentration in grams/liter, which is milligrams per liter divided by 1,000.

Overflow Line – Slope equals the overflow rate.

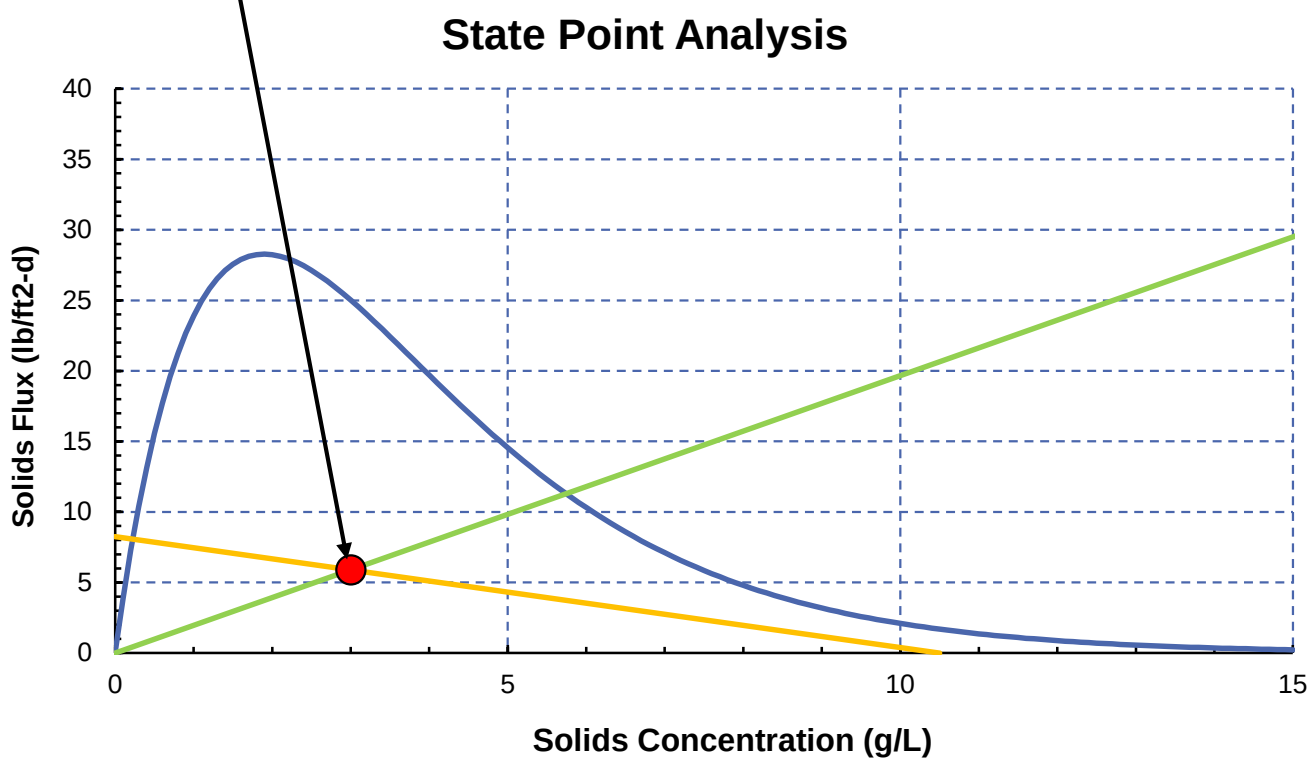



Underflow or Thickening Line
State Point Analysis
Solids Flux (lb/ft2-d)
40
35
30
25
20
15
10
5
0
0
5
10
15
Solids Concentration (g/L)


Settling Flux Curve
State Point Analysis
Solids Flux (lb/ft2-d)
40
35
30
25
20
15
10
5
0
0
5
10
15
Solids Concentration (g/L)


State Point
State Point Analysis
Solids Flux (lb/ft2-d)
40
35
30
25
20
15
10
5
0
0
5
10
15
Solids Concentration (g/L)

State Point – Must be inside of flux curve for clarification to be successful



State Point Analysis for Operations

Dr. Eric Wahlberg, Brown & Caldwell – Internet Version

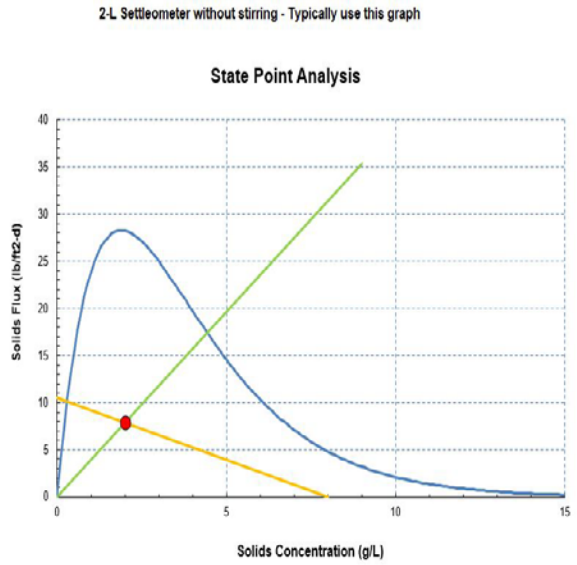
This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

SVISN	160	mL/g
Number of clarifiers	1	
Area of each clarifier	6,361	ft^2
MLSS	2	g/L
Influent flow	3	mgd
RAS flow	1	mgd
Alternate influent flow	0	mgd
Alternate RAS flow	0	mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:

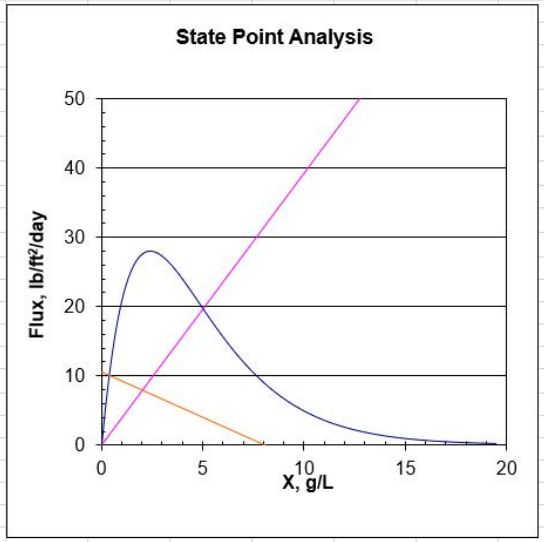
kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

Influent flow	3500	gpm
	5.04	mgd
Combined RAS flow	1500	gpm
	2.16	mgd



CH2M For Oak Loge WWTP

CLARIFIER STATE POINT ANALYSIS		
MLSS, g/L		2
Effluent Flow, MGD		3
RAS Flow, MGD		1
Number of Clarifiers		1
Clarifier Diameter, ft		90
Total clarifier area, ft^2		6361.725
Overflow Rate, $gal/ft^2/day$		471.5702
Underflow Rate, $gal/ft^2/day$		157.1901
Underflow TSS, g/L		8
Surface Loading Rate, $lb/ft^2/day$		10.47515
State Point Flux, $lb/ft^2/day$		7.85636
Vo	511.4	ft/day
SVI	160	ml/gm
Stirred SV	no	(yes/no)
k	0.41836	L/g
increment	0.1	g/L
$G = (Vo)(X)(e^{-kX})$		
sSVI	100	ml/gm
SVI	150.0	ml/gm



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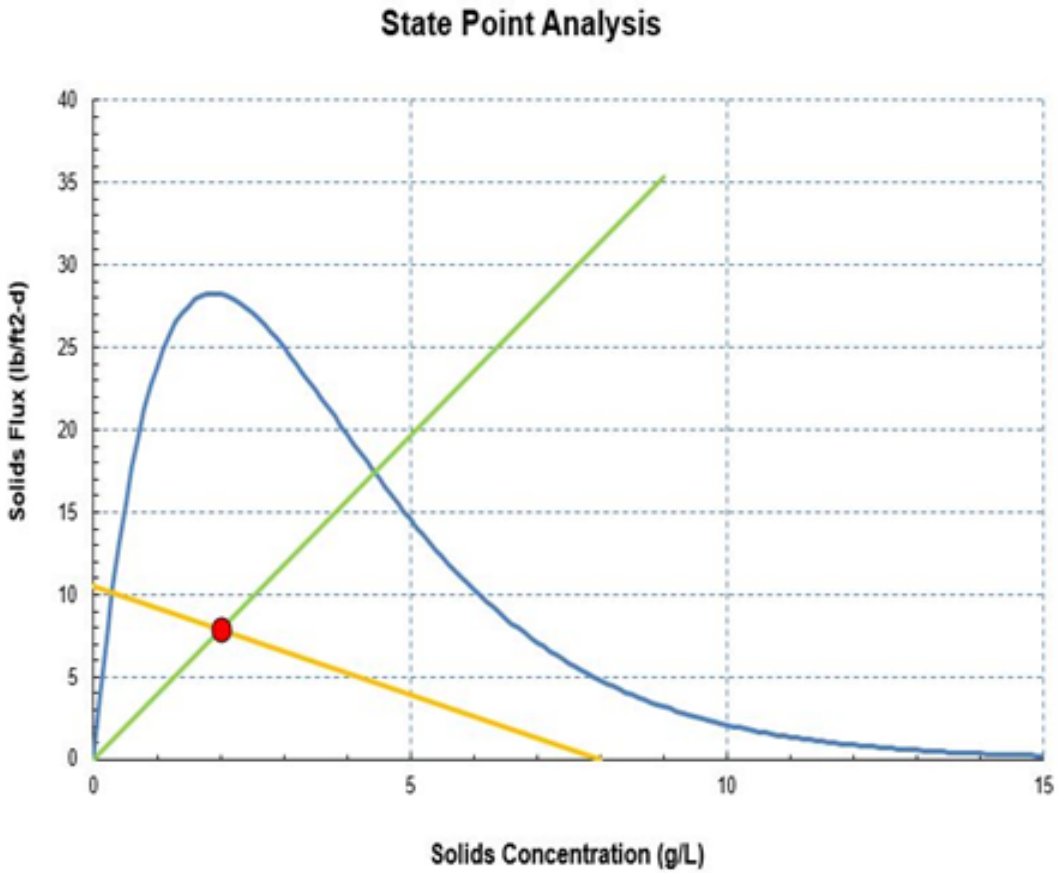
Alternate influent flow	0	mgd
Alternate RAS flow	0	mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:	
kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

Influent flow	3500	gpm
	5.04	mgd
Combined RAS flow	1500	gpm
	2.16	mgd

2-L Settleometer without stirring - Typically use this graph



Plant Data:

Influent Q = 3.0 MGD
RAS = 30%
MLSS = 2,000 mg/l

2 each 90 ft Dia. Clarifiers

SVI = 160 mL/g

Remember, seldom will only one input parameter change.

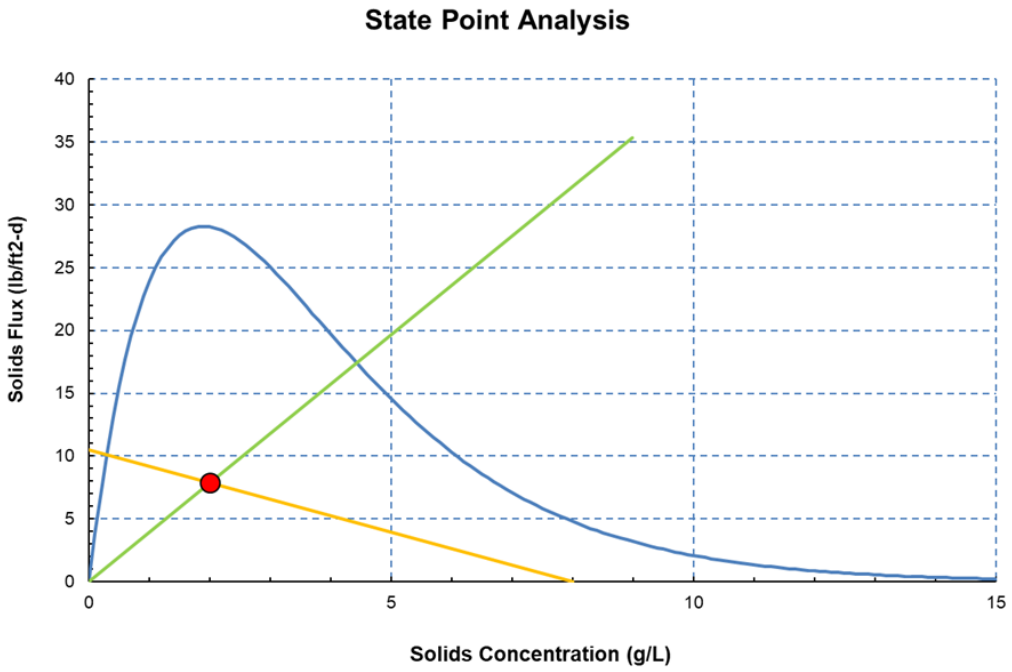
Examples -

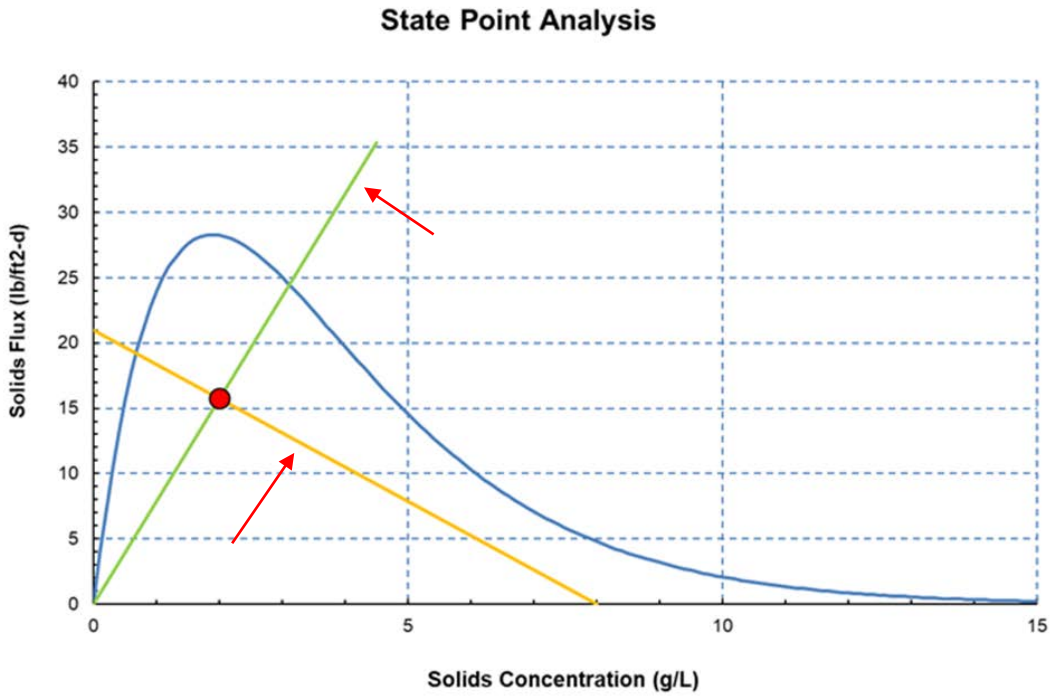
- It is important to practice using the tool BEFORE you need it.
- Examples only change one data point at a time.
- Return Activated Sludge (RAS) is flow paced as a percentage of the influent flow.
- **Three Examples:**
  - Hydraulic
  - Settling Characteristic
  - Solids Loading

Example 1– High Flow Storm Event

Decision Point – Add 2nd Clarifier?

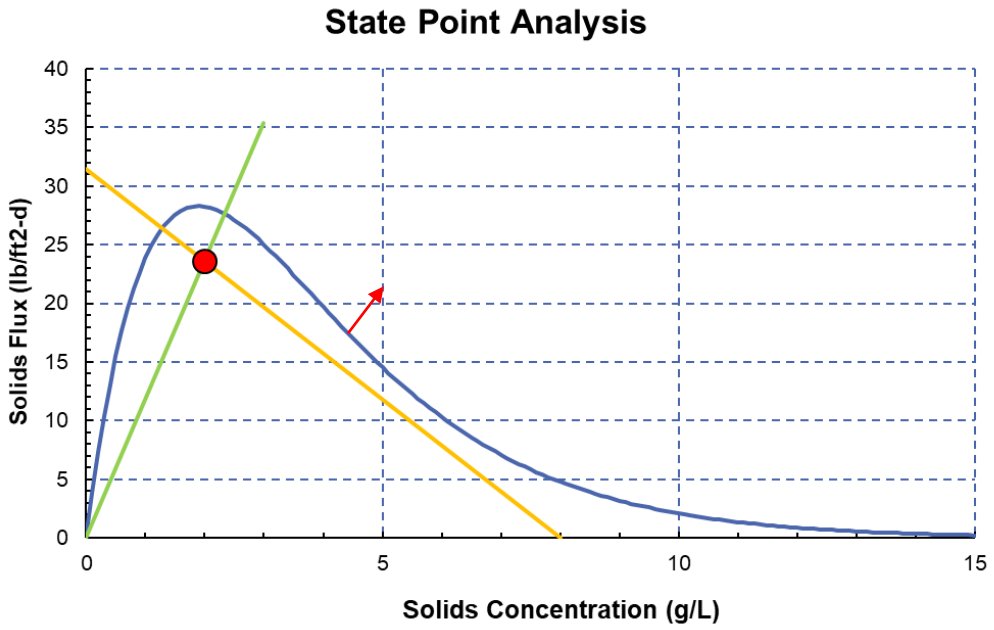
Steady State – 2 MGD ⟶ **Storm event increases flow to 6 MGD**



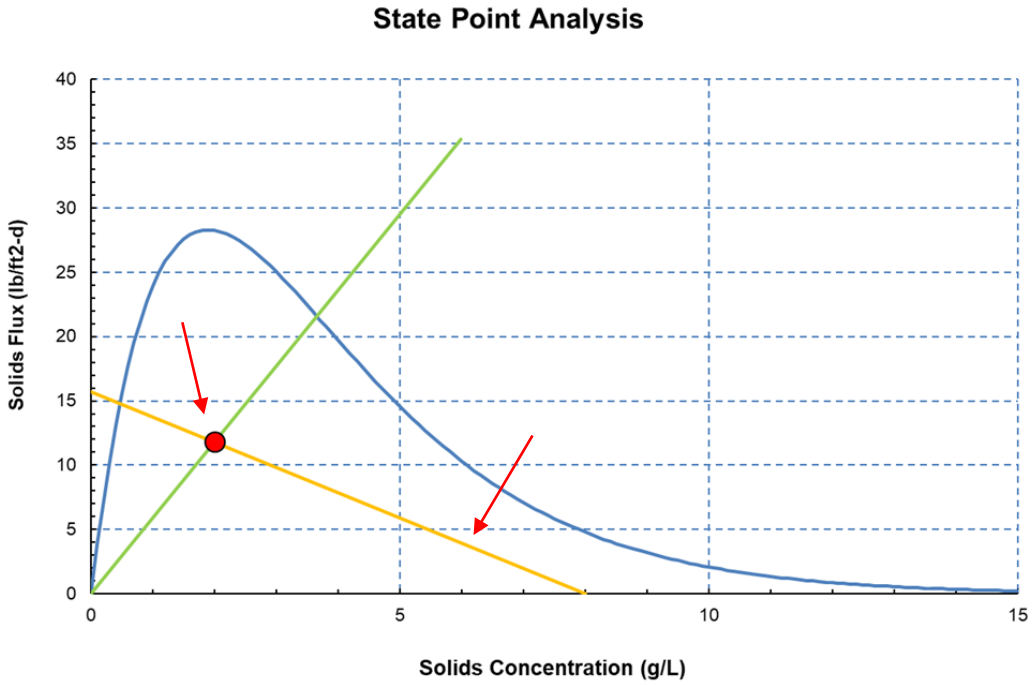


Example – High Flow Storm Event, cont.

Storm Flow increases to 9 MGD

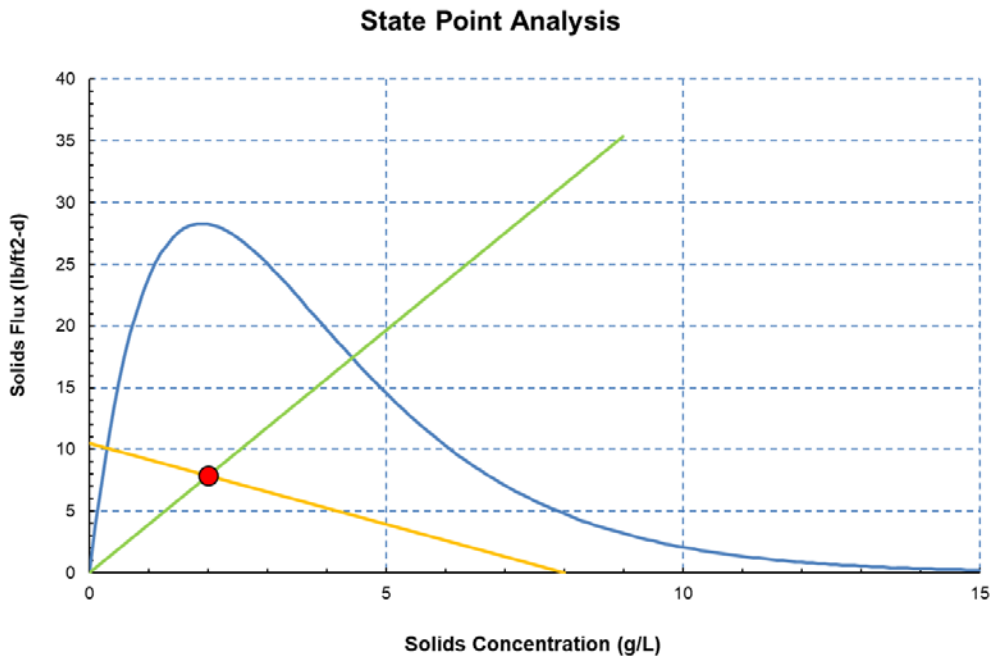


Second Clarifier added at 9 MGD

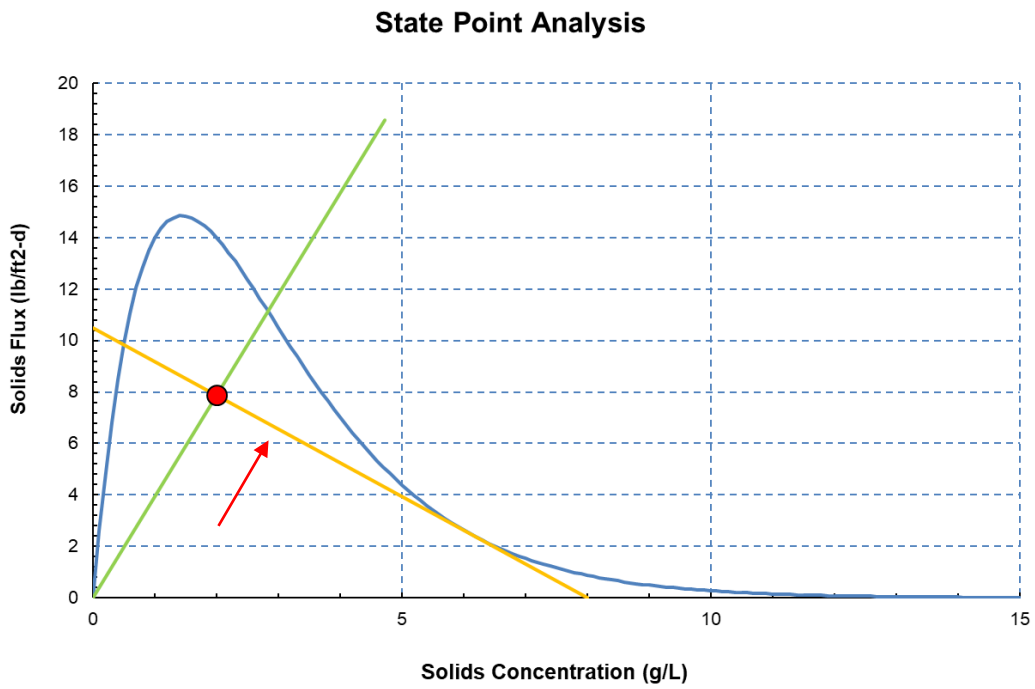


Example 2: High SVI

Steady State SVI 160 mL/g

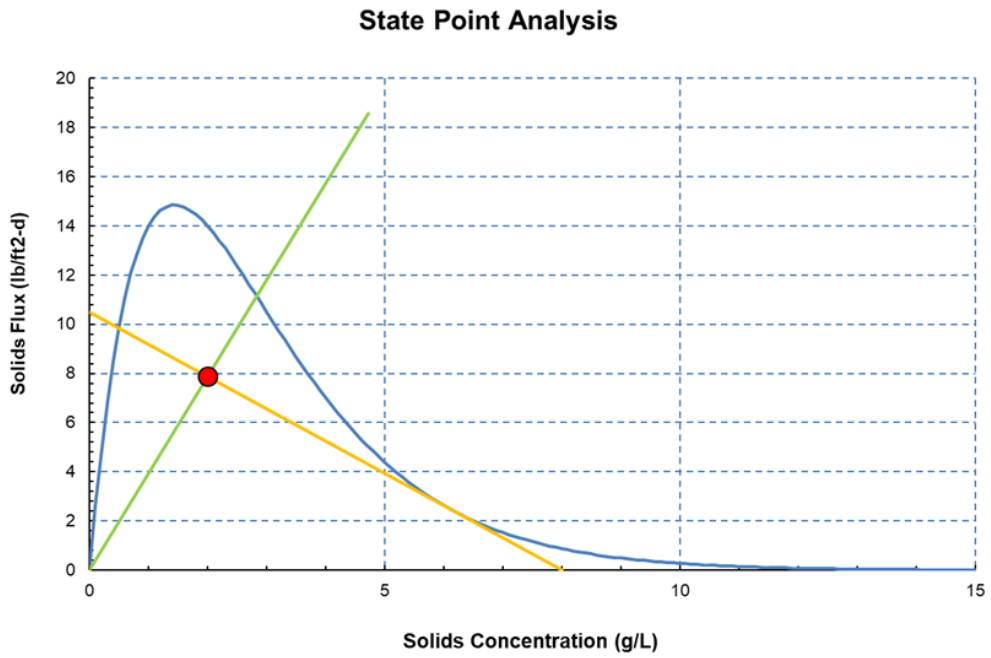


SVI Increases to 260 mL/g

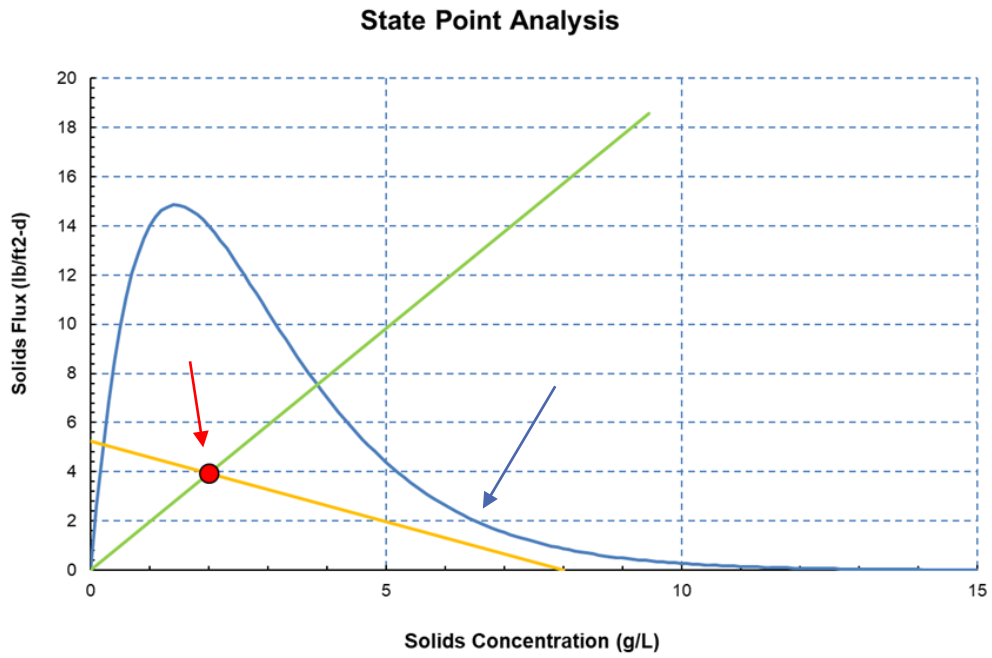


Option 1 – Add Second Clarifier

SVI 260 mL/g

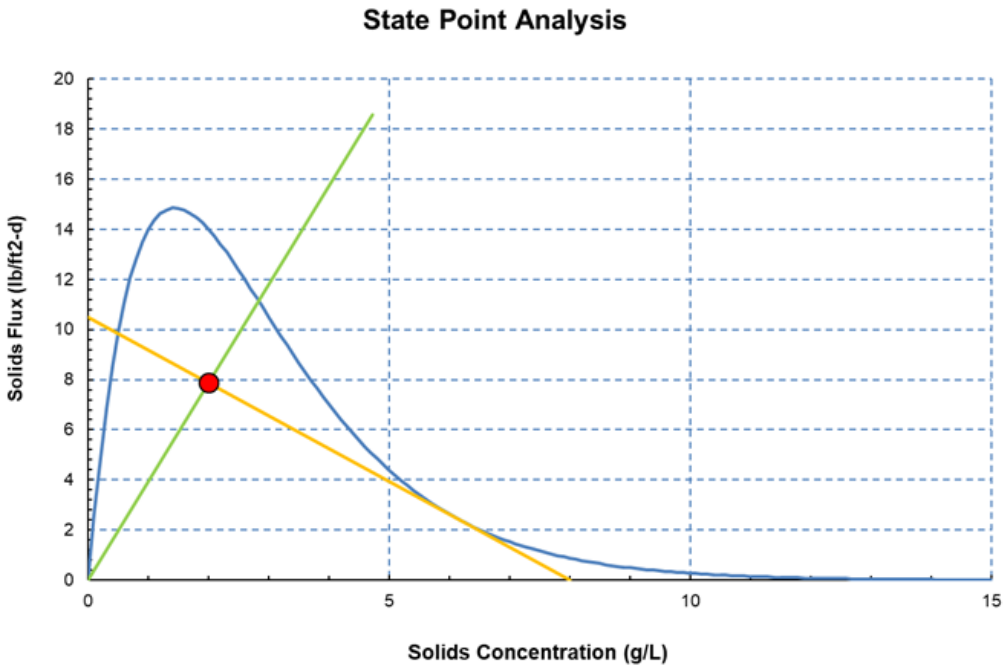


Second Clarifier Added

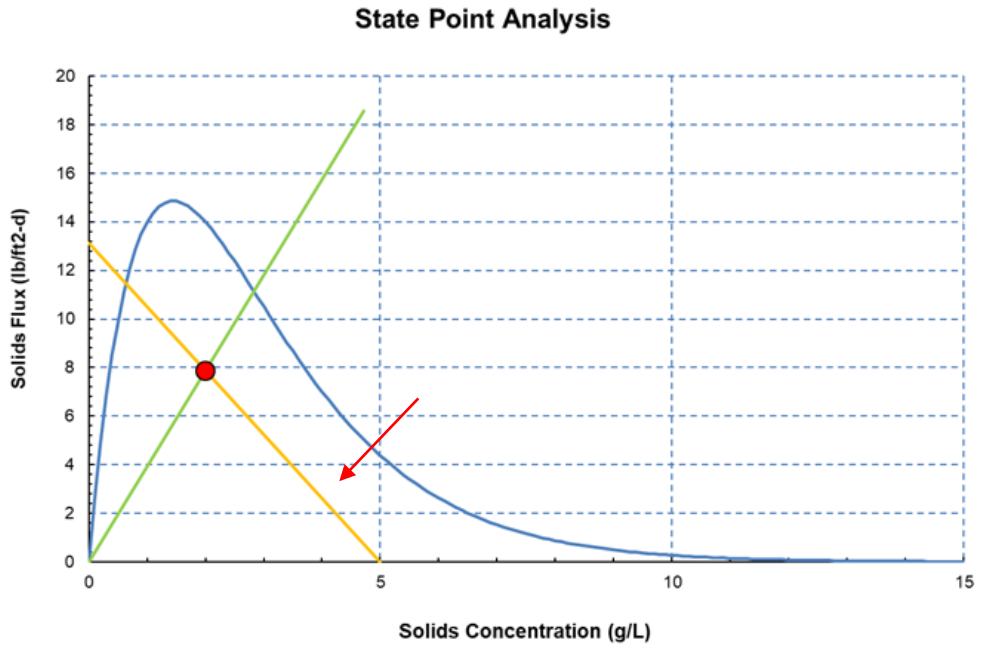


Option 2 - Increase RAS

SVI 260 mL/g

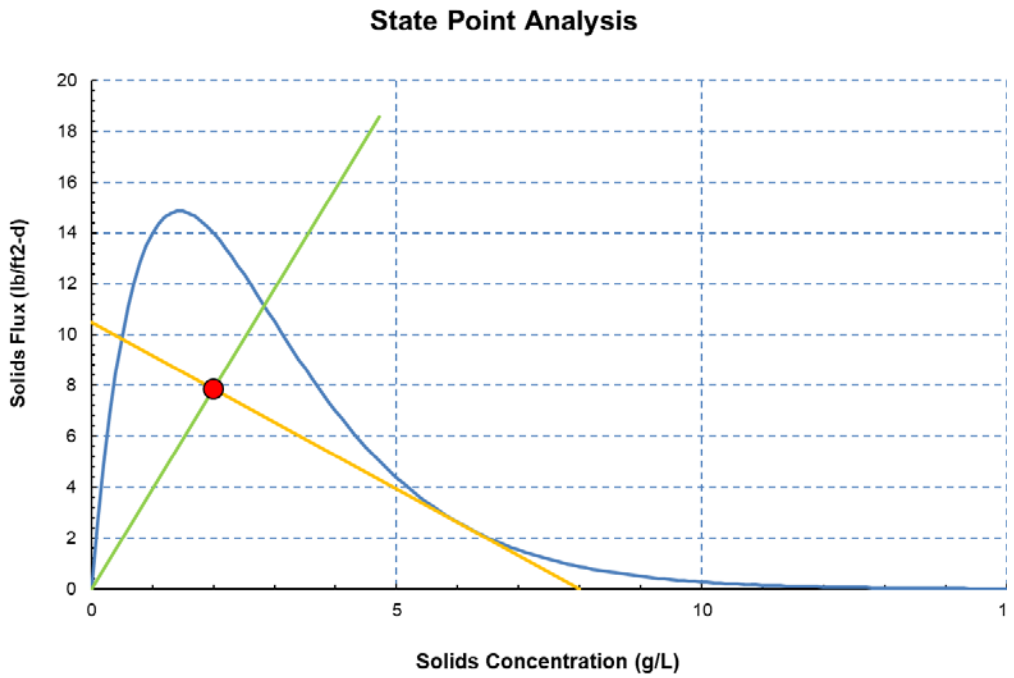


Increased RAS from 30% to 67%

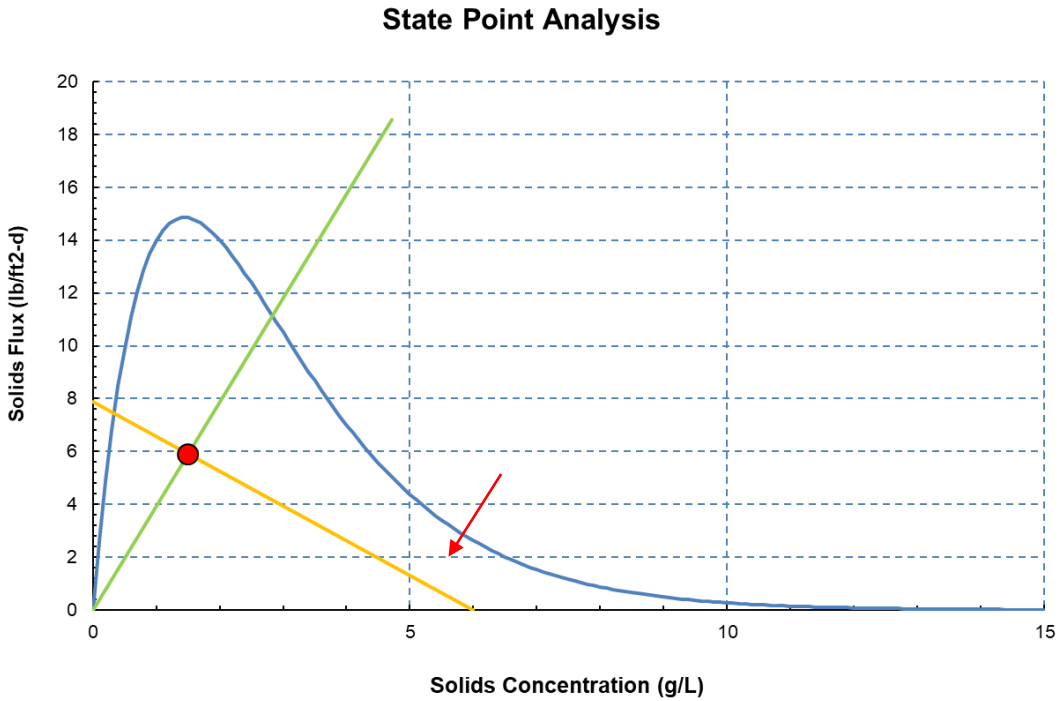


Option 3 – Decrease MLSS

MLSS 2000 mg/l

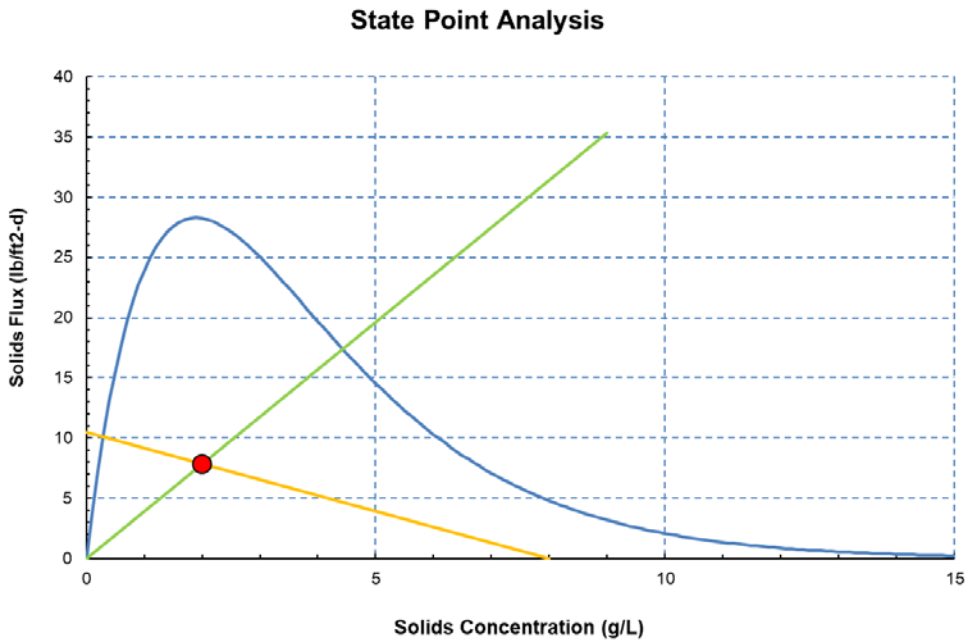


MLSS 1500 mg/l

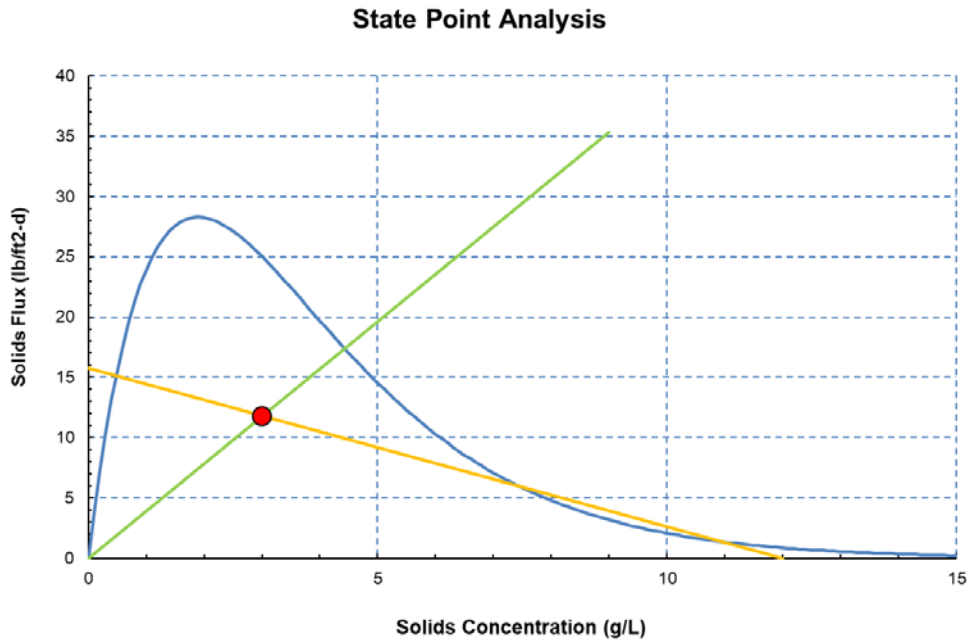


Example 3- Solids Loading Increase

MLSS at 2000 mg/l

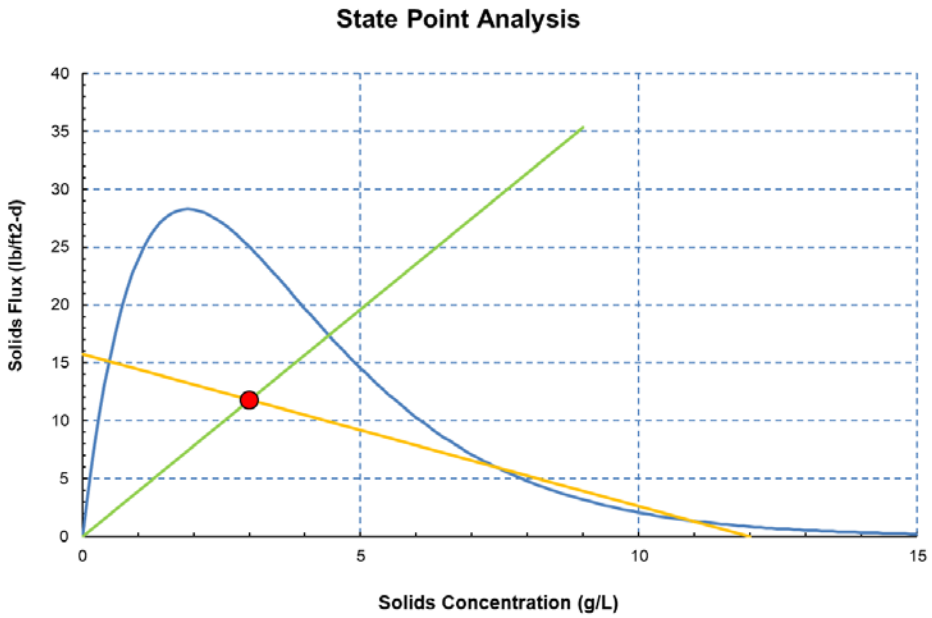


MLSS increases to 3000 mg/l

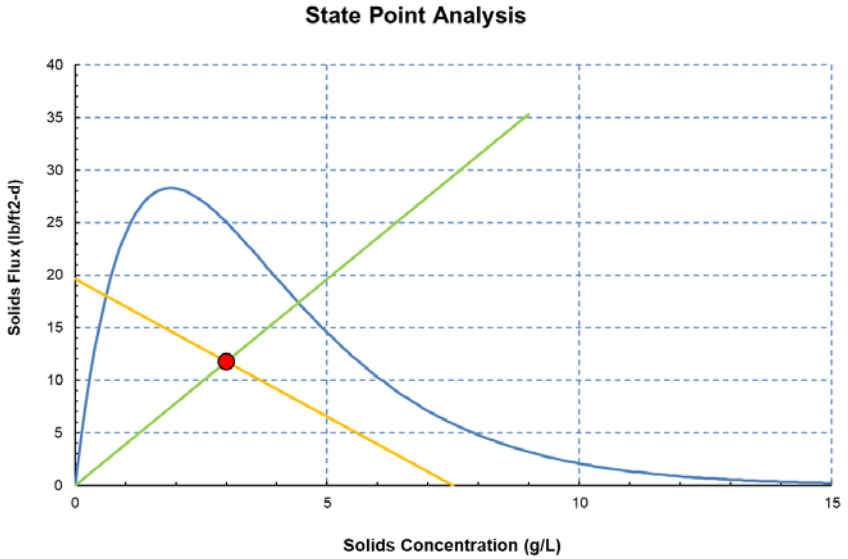


Option 1 – Increase RAS Rate

RAS Rate 30%

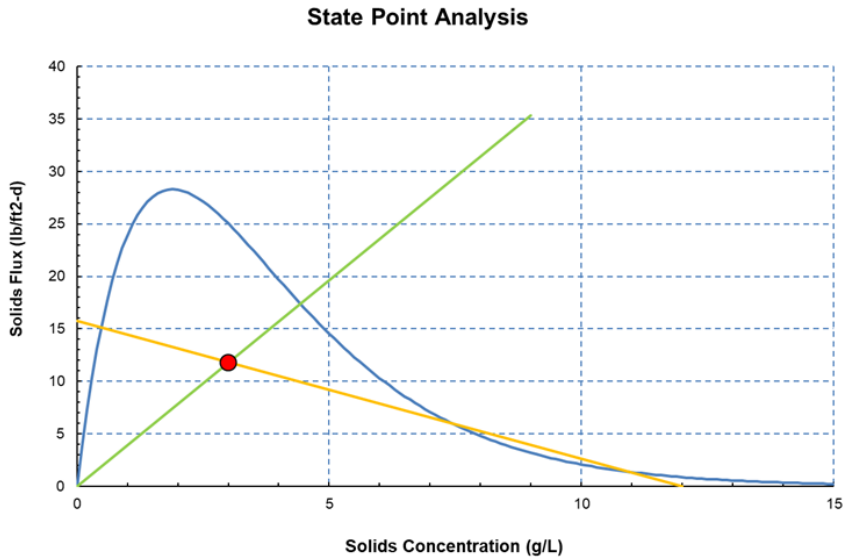


RAS Rate 67%

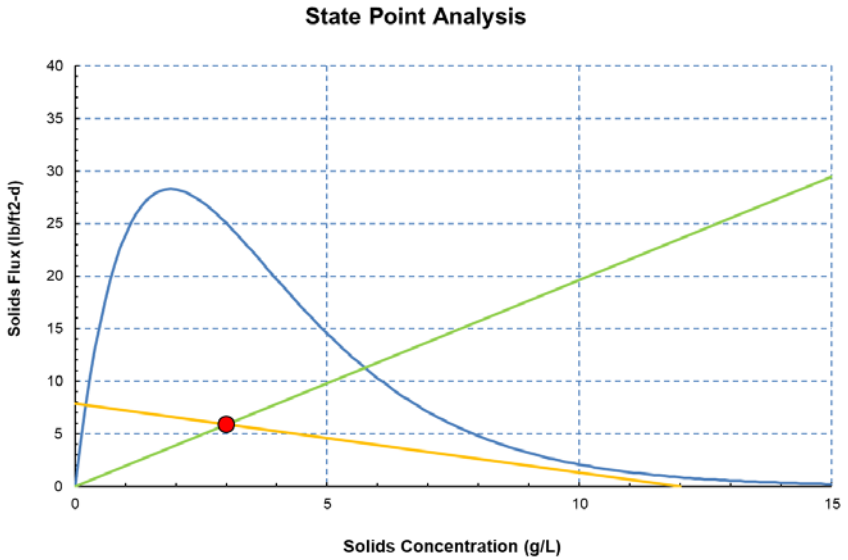


Option 2 – Add Second Clarifier

MLSS at 3000 mg/l

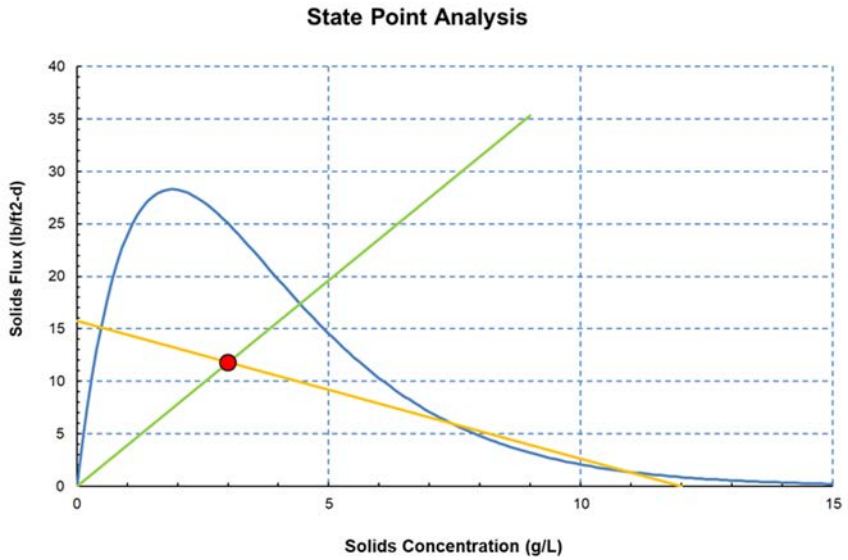


Second Clarifier Added

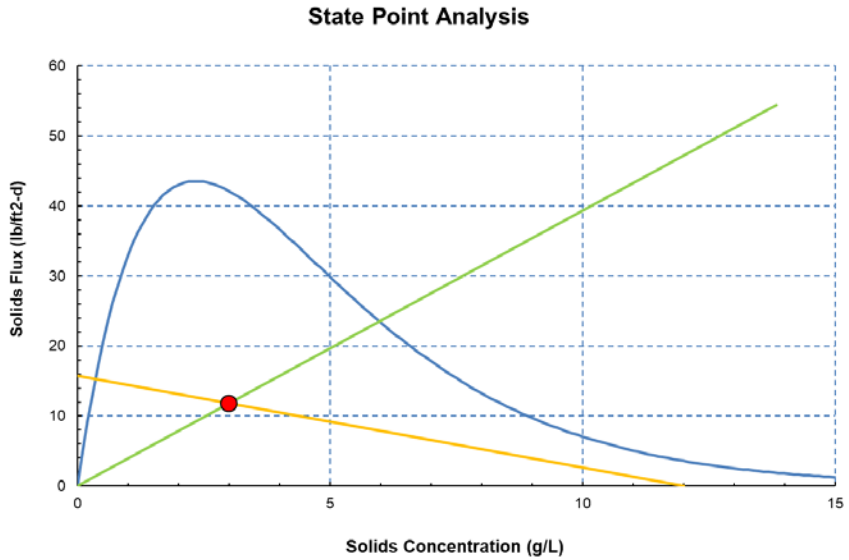


Option 3 – Reduce SVI

SVI at 160 mL/g



SVI Reduced to 100 mL/g



SPA Tool - allows Operator to test outcomes before implementing

This spreadsheet will generate a flux curve given the following inputs (insert value in the appropriate cell between thick lines -- mind your units):

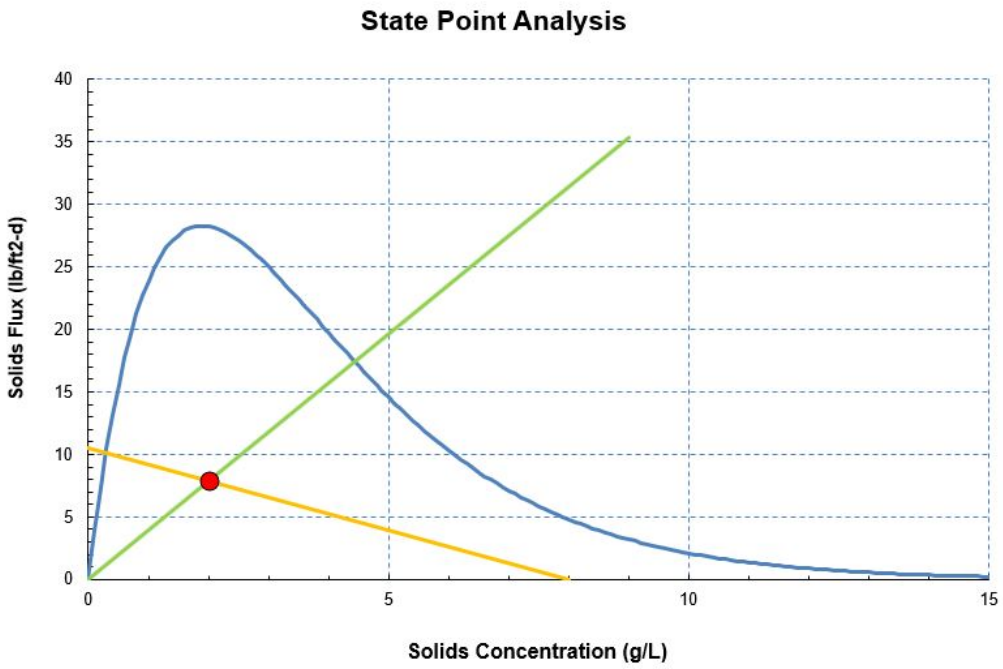
SVISN	160	mL/g
Number of clarifiers	1	
Area of each clarifier	6,361	ft^2
MLSS	2	g/L
Influent flow	3	mgd
RAS flow	1	mgd

Alternate influent flow	0	mgd
Alternate RAS flow	0	mgd

Choose desired flux units by placing a "1" in place of the "0" next to desired units:	
kg/m^2h	0
kg/m^2d	0
lb/ft^2d	1

Influent flow	3500	gpm
	5.04	mgd
Combined RAS flow	1500	gpm
	2.16	mgd

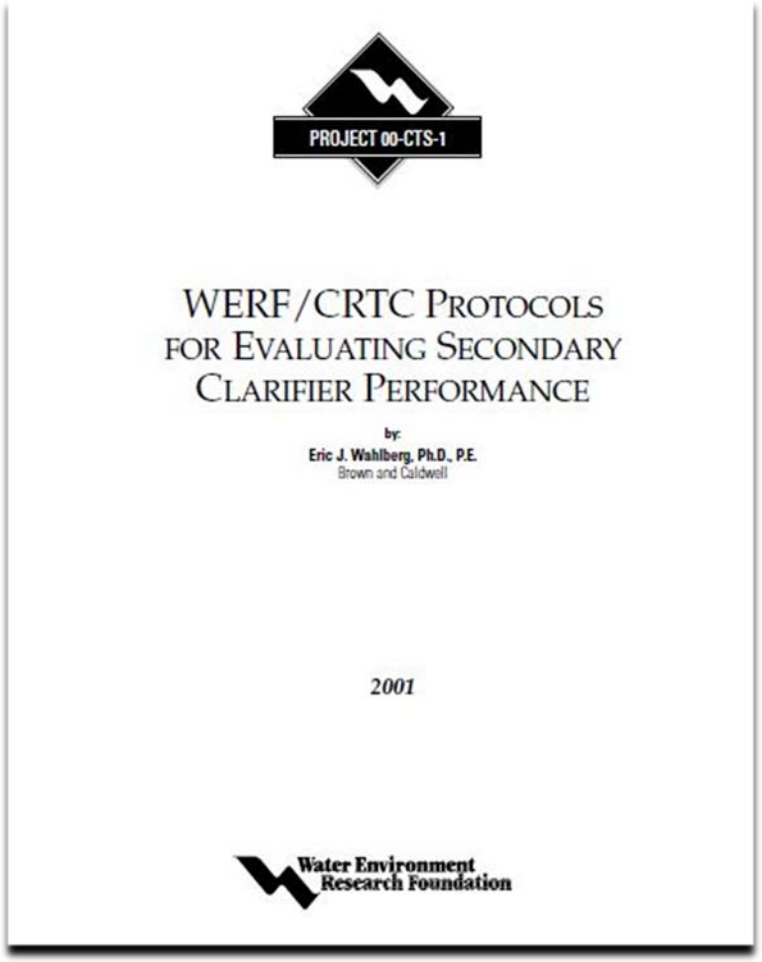
2-L Settleometer without stirring - Typically use this graph



MORE INFORMATION

State Point Analysis Resources

Water Environment Research Foundation



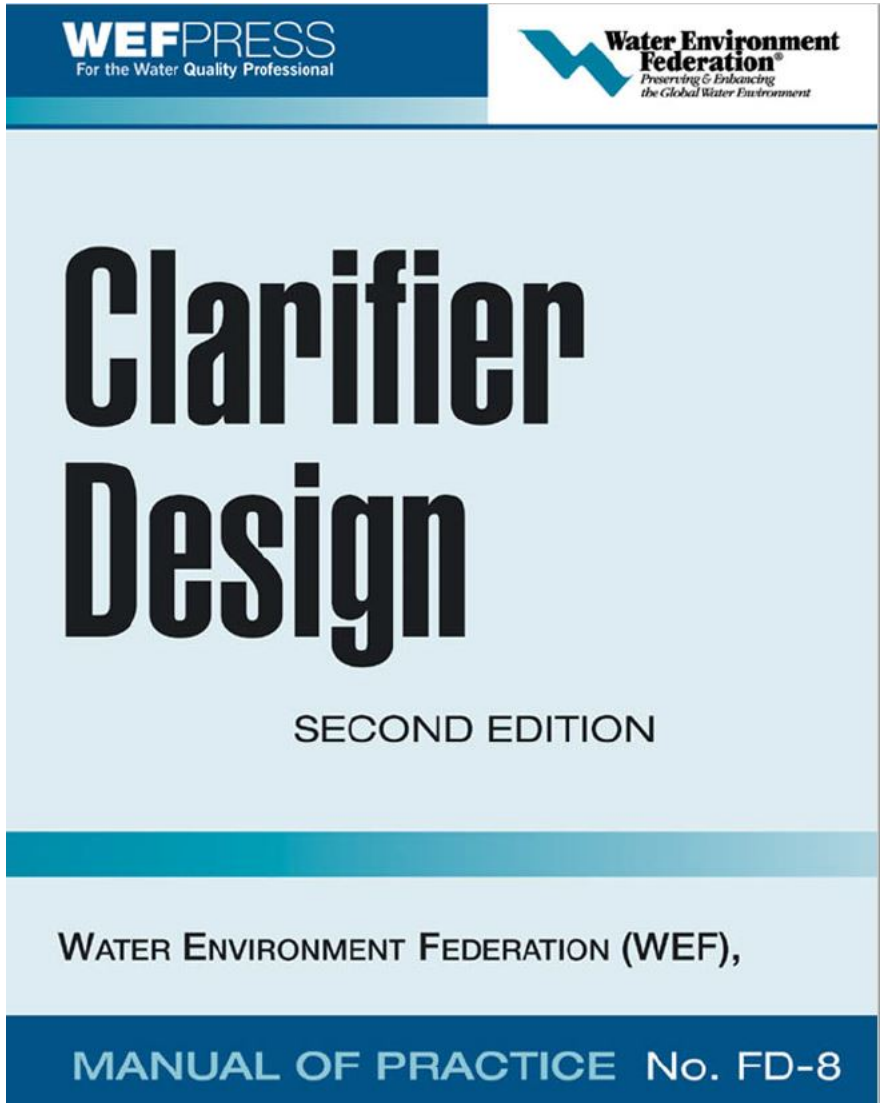


TABLE 4.9 Interpretation of the state point analysis.

Location of state point	Location of underflow line	Condition of clarifier	Potential corrective action
Within the flux curve (Figure 4.14)	Below the descending limb of the flux curve	Underloaded	None
Within the flux curve (Figure 4.15)	Tangential to the descending limb of the flux curve	Critically loaded	Increase RAS rate to become underloaded
Within the flux curve (Figure 4.16)	Above the descending limb of the flux curve	Overloaded	Increase RAS rate to become underloaded
On the flux curve (Figure 4.17)	Below the descending limb of the flux curve	Critically loaded	Reduce clarifier feed solids to become underloaded Convert to step-feed or Lower MLSS (SRT)
On the flux curve (Figure 4.18)	Above the descending limb of the flux curve	Overloaded	Increase RAS rate to become critically loaded
Outside the flux curve (Figure 4.19)		Overloaded	Reduce clarifier feed solids to become underloaded Convert to step-feed or Lower MLSS (SRT)

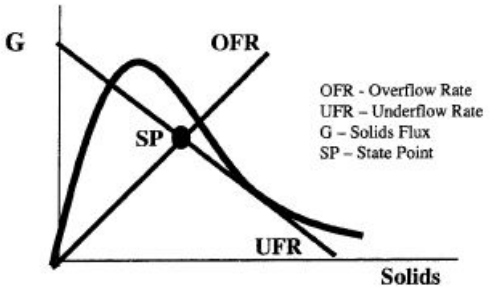
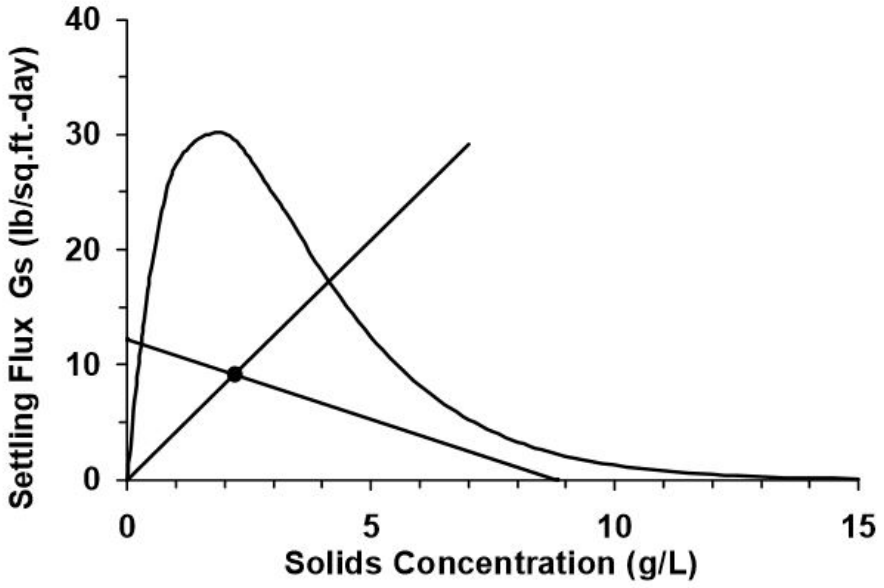
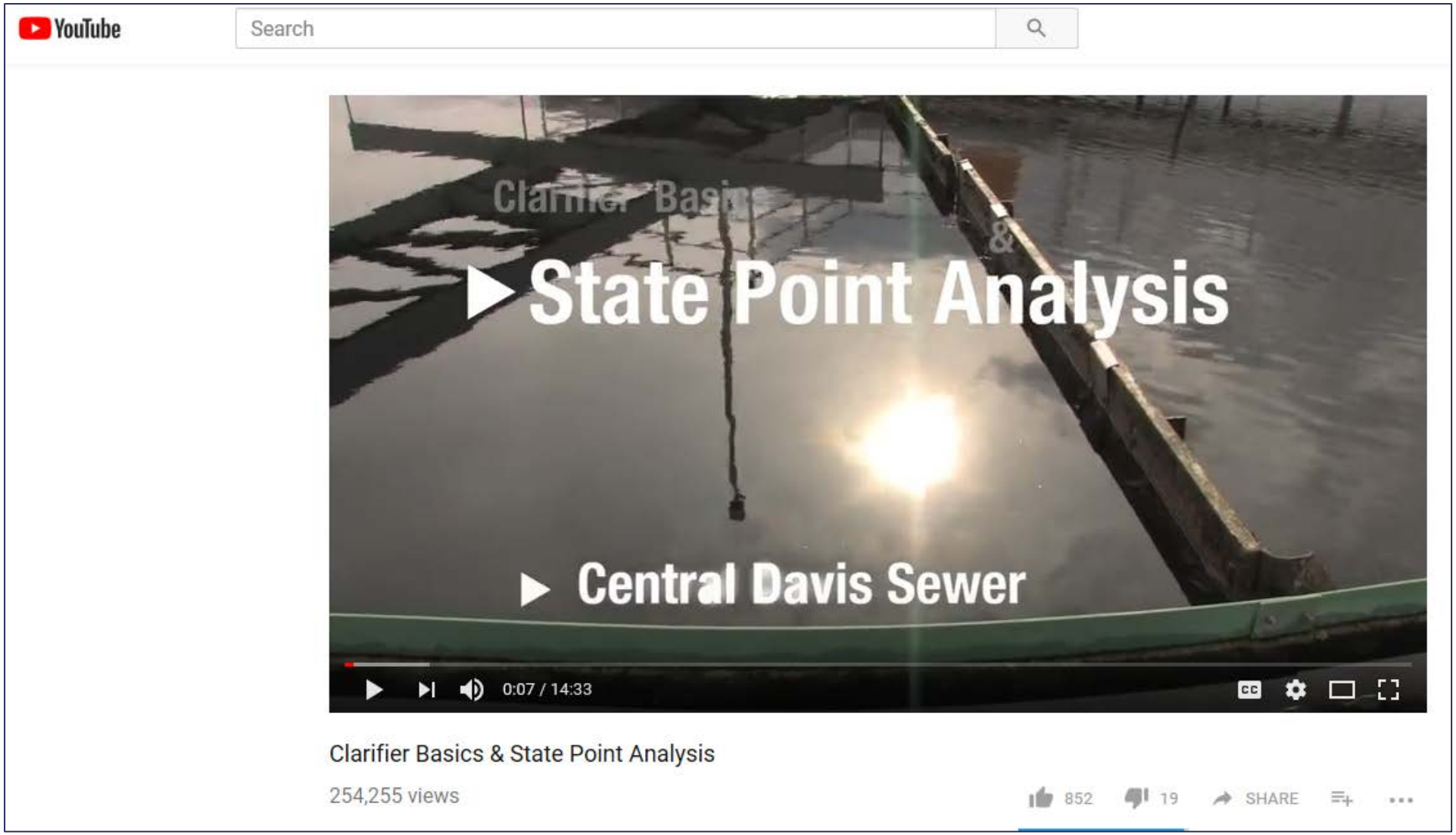


FIGURE 4.15 Critically loaded clarifier.

Using State Point Analysis to Maximize Secondary Clarifier Performance



www.maine.gov/dep/water/wwtreatment/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Clarifier Basics & State Point Analysis
254,255 views
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19
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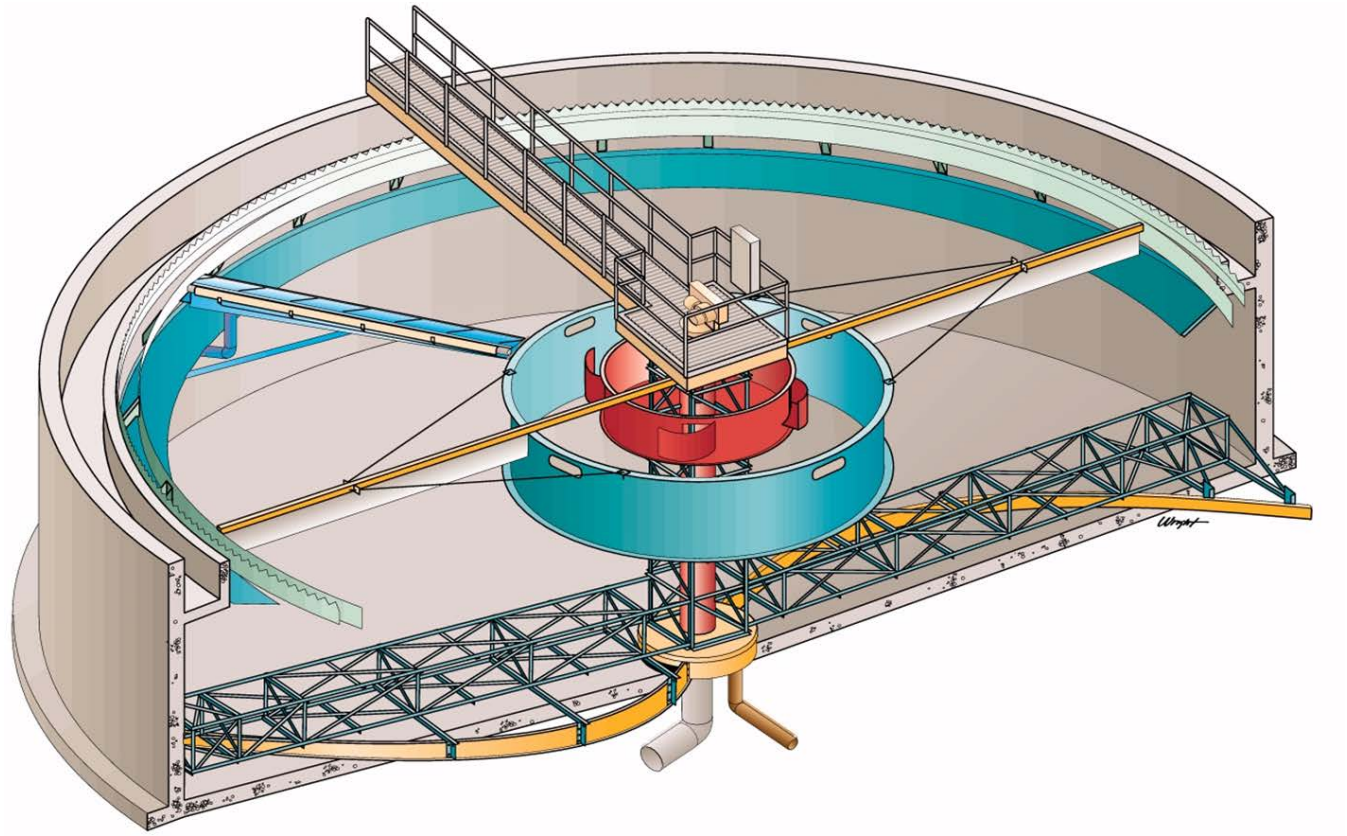
Review

- Clarifier components make a difference
- Maintaining a mass balance in your clarifier is important
- The State Point Analysis is a tool Operators can use
- There is a lot of good State Point Analysis information available.

Questions?



WATERDUDE SOLUTIONS

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