AWT & Conventional Mixed Liquor Settling Velocities

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Objectives

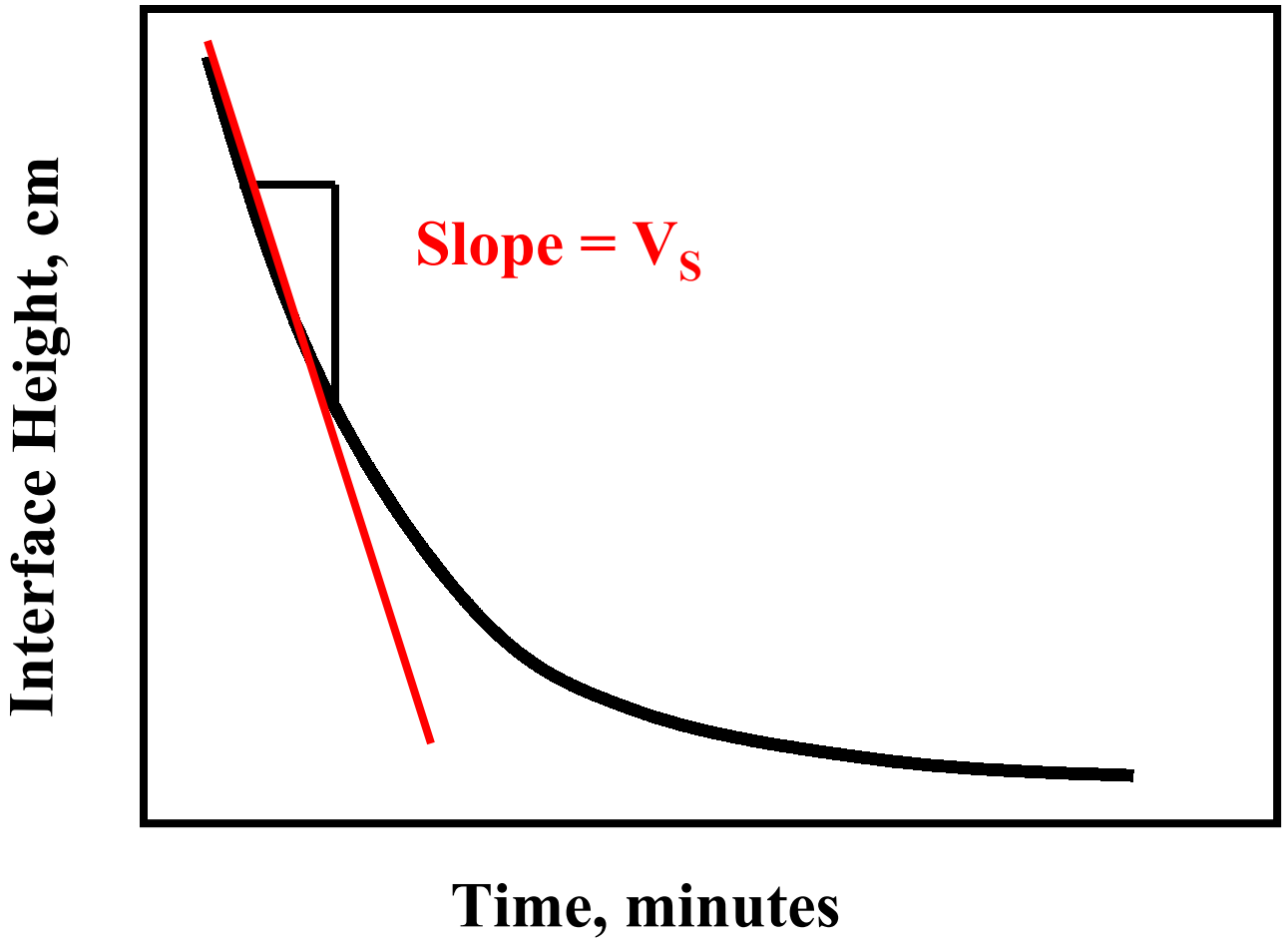
1. Evaluate mixed liquor settling characteristics from AWT & conventional WWTPs.

2. Develop an algorithm relating ZSV to MLSS and SVI.

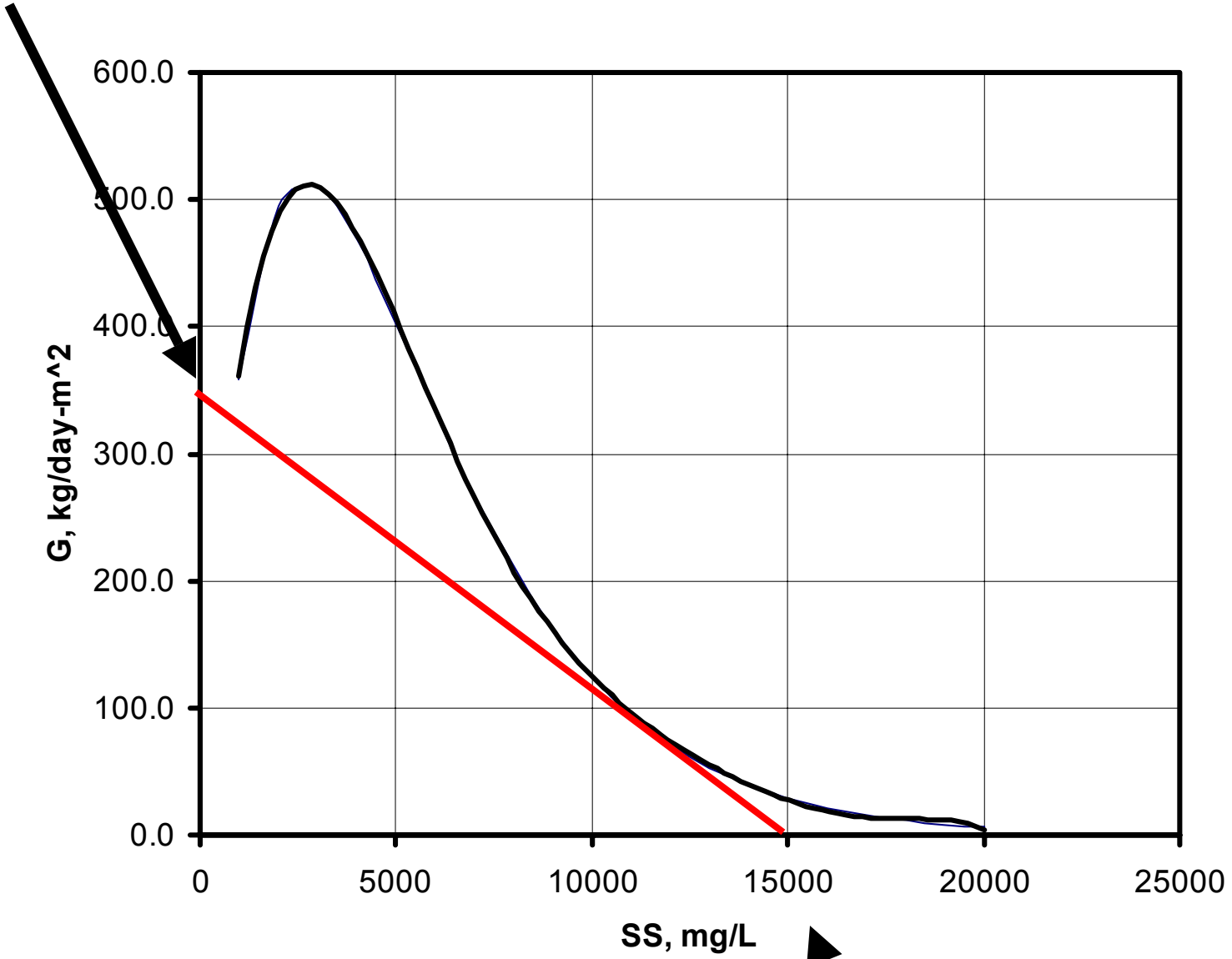
3. Develop a secondary clarifier operating diagram.

Background

- Dick and Ewing, 1967
- Vesilind, 1968
- Daigger and Roper, 1985
- Wahlberg and Keinath, 1988
- Keinath, 1990
- Daigger, 1995
- Hermanowicz, 1998


Slope = V_S
Interface Height, cm
Time, minutes

G_L = Limiting Flux



X_u = Underflow Concentraion

Daigger and Roper

$$V_S = 7.80\, e^{-[(0.148+0.00210(sSVI))X]}$$

$V_S = zone\ settling\ velocity, m/h$

$sSVI = stirred\ sludge\ volume\ index, mL/g$

$X = initial\ mixed\ liquor\ suspended\ solids, g/L$

Wahlberg and Keinath

$$V_S = \left[15.3 - 0.0615\left(sSVI\right)\right] e^{\left[-0.426 + 0.00384\left(sSVI\right) - 0.0000543\left(sSVI\right)^2\right] X}$$

Daigger

$$\ln(V_S) = 1.871 - (0.1646 + 0.001586\,sSVI)\,X$$

Materials and Methods

- Two, 1.87-m high with 14.5-cm inside diameter Plexiglas columns utilized.
- uSVIs and sSVIs determined on mixed liquor from 7 AWT facilities and two conventional facilities.
- Regression analysis and paired comparisons performed on data at the 95 % confidence level.

TABLE 1. Summary of Sludge Settling Characteristics

WWTPs	Process	V_S (m/h)	uSVI (mL/g)	sSVI (mL/g)	MLSS (mg/L)	C_u (mg/L)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Clearwater #1	5-Stage Bardenpho	1.28	212	n.a.	3957	13615
Clearwater #2	5-Stage Bardenpho	1.26	153	152	3599	13120
Dunedin #1	A^2/O	4.18	69	62	3335	24427
Dunedin #2	A^2/O	3.93	50	n.a.	4502	21357
Dale Mabry #1	Oxidation Ditch	0.53	161	147	6025	13447
Dale Mabry #2	Oxidation Ditch	0.66	161	148	5722	13540
NW Regional #1	5-Stage Bardenpho	3.05	126	114	3085	19600
NW Regional #2	5-Stage Bardenpho	1.39	130	135	4550	16027
River Oaks #1	2-Stage Nitr./Denite	2.98	64	78	4672	24793
River Oaks #2	2-Stage Nitr./Denite	5.99	61	63	3598	26770
Largo #1	A^2/O	3.08	107	n.a.	2802	18052
Largo #2	A^2/O	5.50	99	85	1917	21920
St. Pete NW #1	Conventional	4.08	185	120	1728	18479
St. Pete NW #2	Conventional	1.36	176	139	1760	17350
St. Pete SW #1	Conventional	2.60	195	232	2103	12440
St. Pete SW #2	Conventional	1.36	236	177	3605	12563
Tampa	2-Stage Pure O_2	13.72	27	21	4050	25784

Rank of Settling Velocities

MLSS	*Plant*	*ZSV (m/h)*
1.7-2.1	A^2/O > Conventional	5.5 > 1.36
2.8-3.3	A^2/O > Bardenpho	4.18 > 3.05
3.6	Nit/Den> Conv > Bardenpho	5.99 >1.36> 1.26
3.9-4	Oxygen > Bardenpho	13.72 > 1.28
4.5-4.7	A^2/O > Nit/Den>Bard	3.93 > 2.98 > 1.39
5.7-6	Selector Oxidation Ditch	0.53-0.60

Rank of Unstirred SVIs

MLSS	*Plant*	*uSVI (mL/g)*
1.7-2.1	A^2/O < Conventional	99 < 185
2.8-3.3	A^2/O < Bardenpho	69 < 126
3.6	Nit/Den < Conv < Bardenpho	61 < 153< 236
3.9-4	Oxygen < Bardenpho	27 < 212
4.5-4.7	A^2/O < Nit/Den<Bard	50< 64 < 130
5.7-6	Selector Oxidation Ditch	161

Rank of Stirred SVIs

MLSS	*Plant*	*sSVI (mL/g)*
1.7-2.1	A^2/O < Conventional	85 < 232
2.8-3.3	A^2/O < Bardenpho	692< 114
3.6	Nit/Den < Conv < Bardenpho	63 < 152< 177
3.9-4	Oxygen < Bardenpho	21 < 152
4.5-4.7	A^2/O < Bardenpho	78 < 135
5.7-6	Selector Oxidation Ditch	147-148

Rank of Settling Velocities

Rank	*Plant*	*ZSV (m/h)*
1	2-Stage Pure Oxygen	13.72
2	2-Stage Nitrification Denitrification	4.49
3	A^2/O	2.80
4	Conventional	2.35
5	5-Stage Bardenpho	1.75
6	Selector Oxidation Ditch	0.60

Rank of Unstirred SVIs

Rank	*Plant*	*uSVI (mL/g)*
1	2-Stage Pure Oxygen	27
2	2-Stage Nitrification Denitrification	63
3	A^2/O	81
4	5-Stage Bardenpho	155
5	Selector Oxidation Ditch	161
6	Conventional	198

Rank of Stirred sSVIs

Rank	*Plant*	*sSVI (mL/g)*
1	2-Stage Pure Oxygen	21
2	2-Stage Nitrification Denitrification	71
3	A^2/O	74
4	5-Stage Bardenpho	134
5	Selector Oxidation Ditch	148
6	Conventional	148

ANOVA of Settling Characteristics

Category	F	$F_{critical}$	df	α
(1)	(2)	(3)	(4)	(5)
Zone Settling Velocity	41.7	2.57	5,27	0.05
uSVIs	12.9	3.20	5,11	0.05
sSVIs	10.3	2.71	5,20	0.05

Paired Comparison of uSVIs and sSVIs

Calculated t value = 1.855

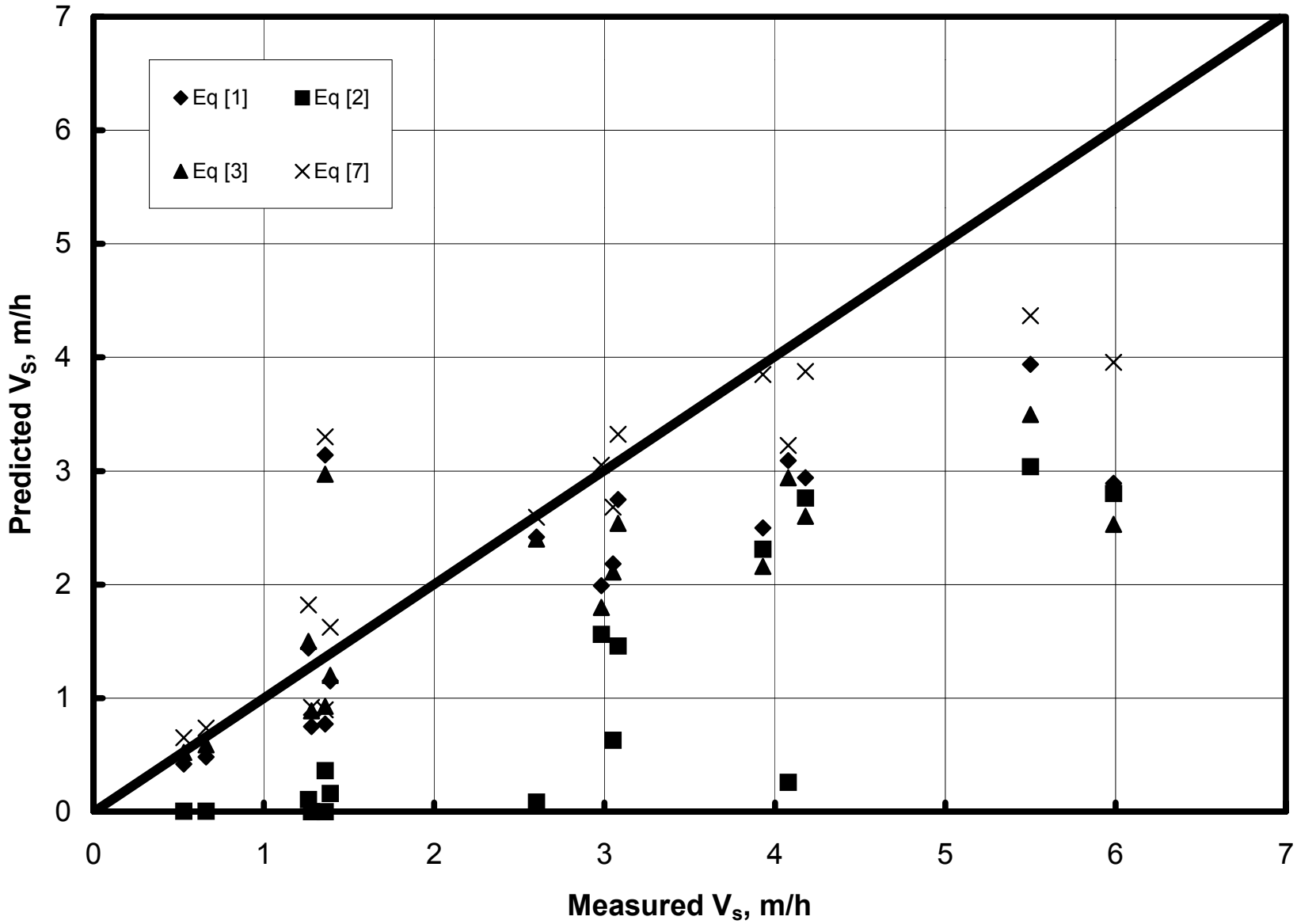
$t_{(0.05)}$ = 2.052 for 27 degrees of freedom

at the 95 % confidence level indicating there was no significant difference between uSVIs and sSVIs.

Regression Analyses

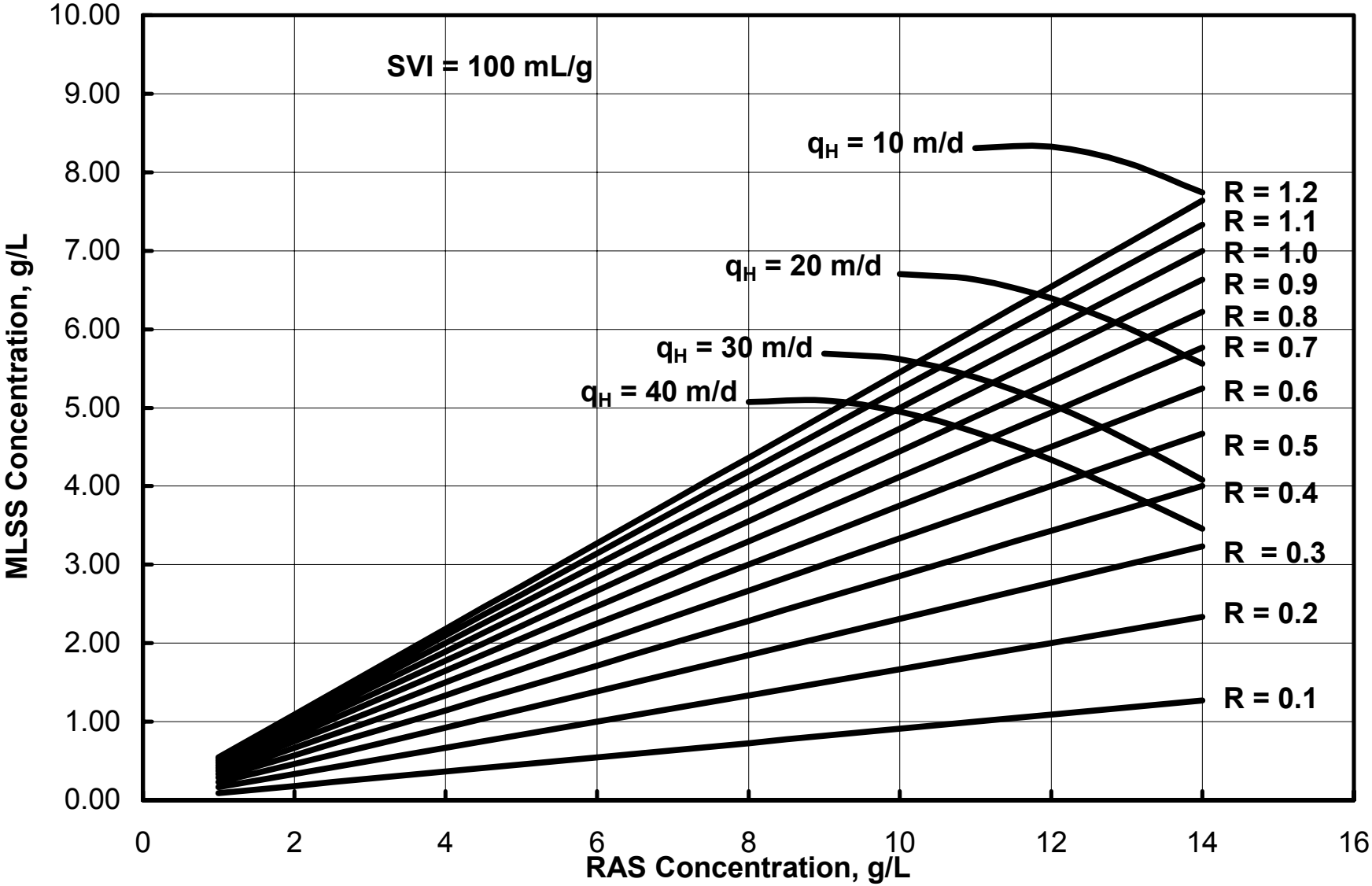
Category	r_1^2	r_2^2
(1)	(2)	(3)
Daigger and Roper	0.65	0.43
Wahlberg and Keinath	0.58	0.54
Daigger	0.68	0.34

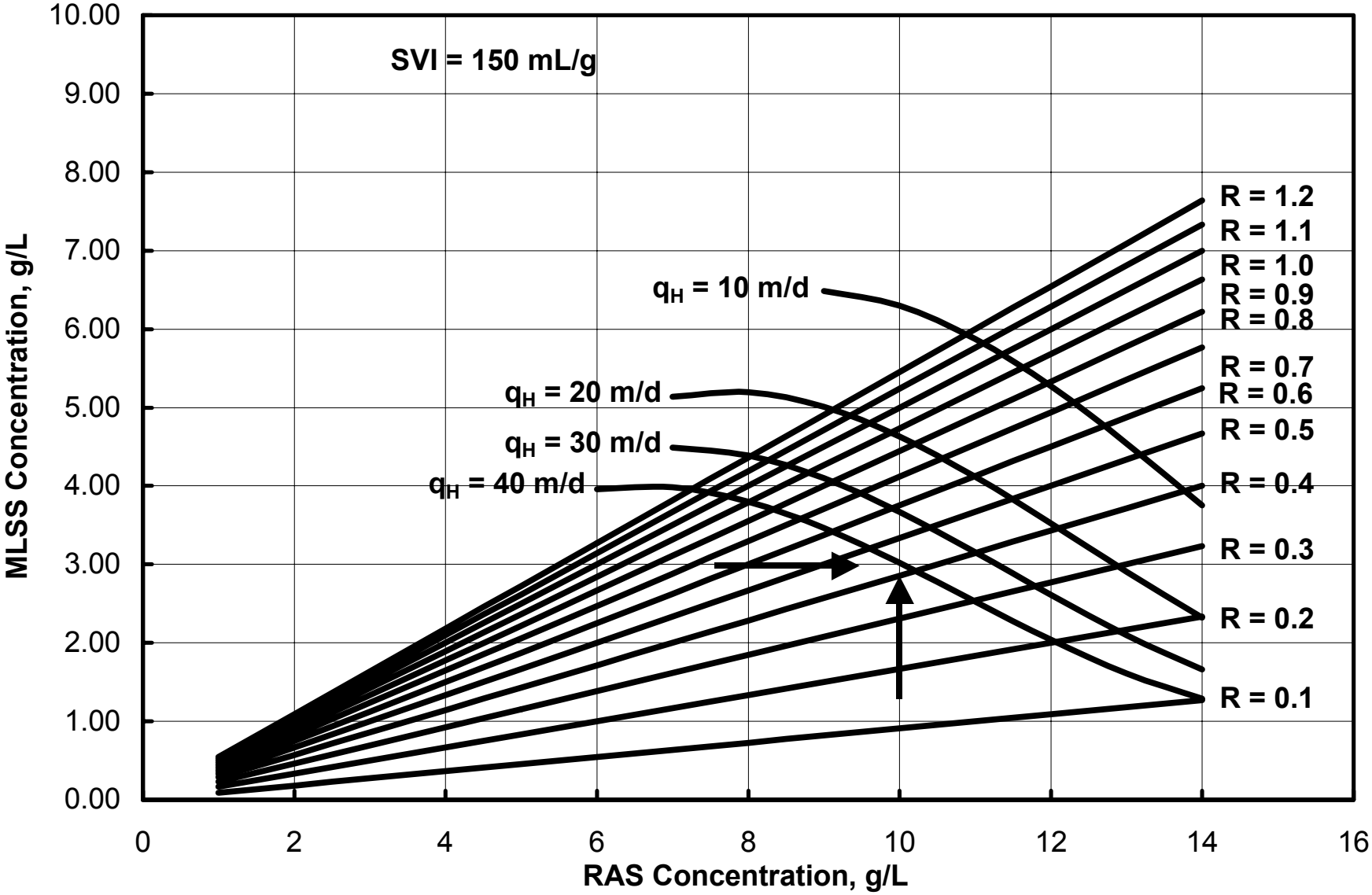
r_1^2= Coefficient of Determination for log transformed data
r_2^2= Coefficient of Determination for non-transformed data

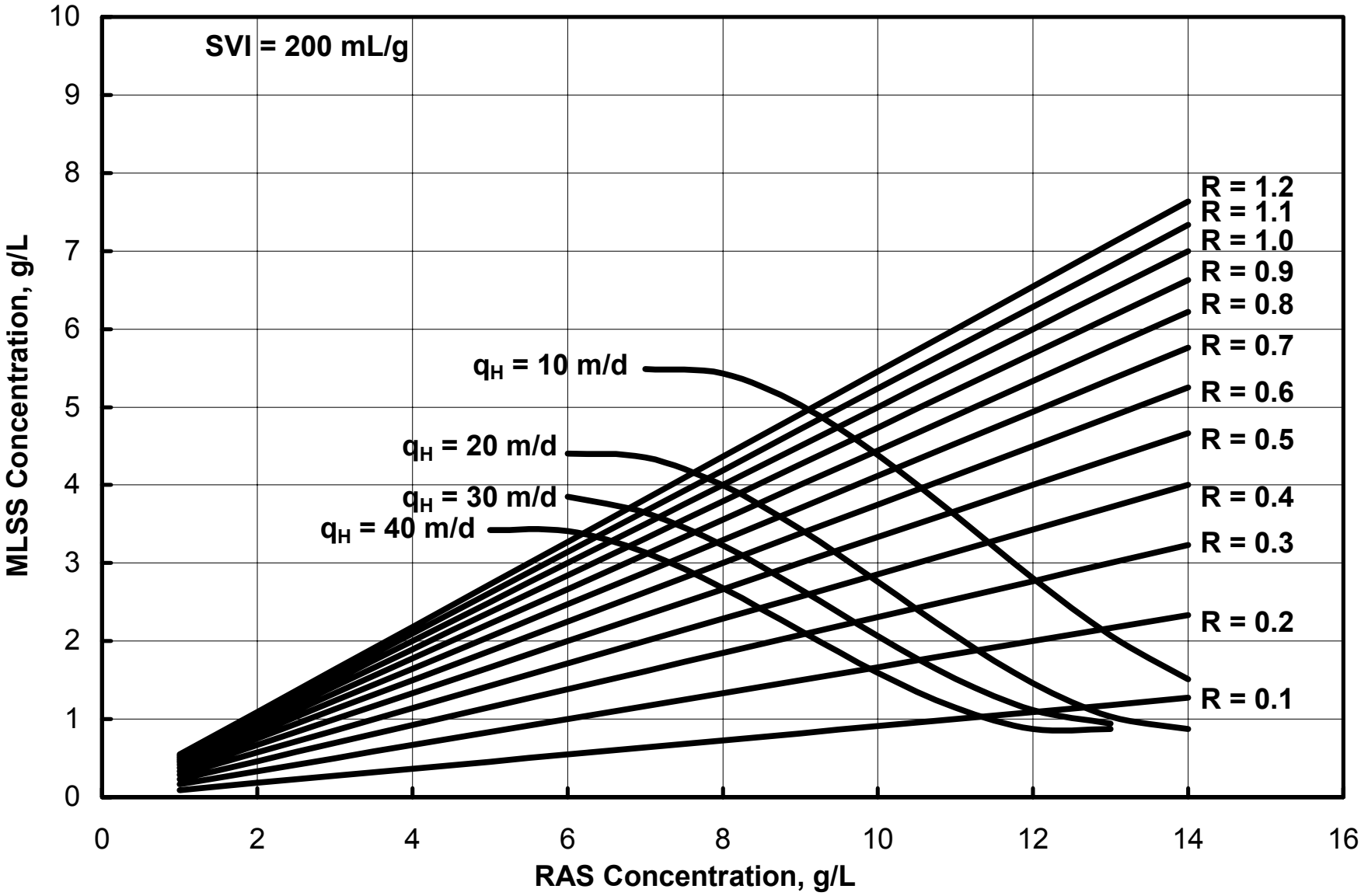

Eq [1]
Eq [2]
Eq [3]
Eq [7]
Predicted V_S, m/h
Measured V_s, m/h
0
1
2
3
4
5
6
7

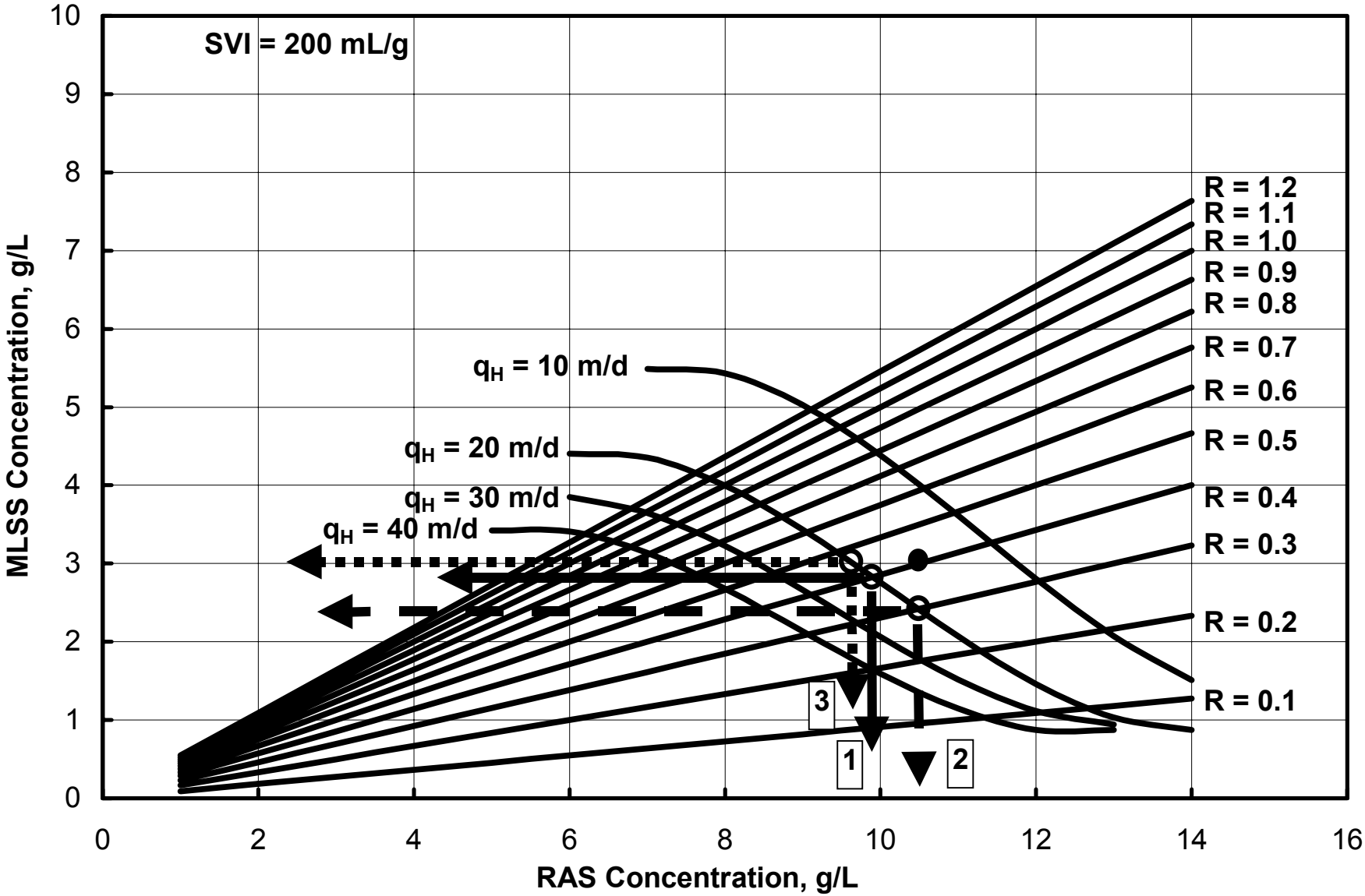
Regression Analysis of Data

$$V_S = 7.042\, e^{\left[-\left(0.0167 + 0.00235\, uSVI\right)X\right]}$$


SVI = 100 mL/g
q_H = 10 m/d
q_H = 20 m/d
q_H = 30 m/d
q_H = 40 m/d
R = 1.2
R = 1.1
R = 1.0
R = 0.9
R = 0.8
R = 0.7
R = 0.6
R = 0.5
R = 0.4
R = 0.3
R = 0.2
R = 0.1
MLSS Concentration, g/L
RAS Concentration, g/L
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
8
10
12
14
16


SVI = 150 mL/g
MLSS Concentration, g/L
RAS Concentration, g/L
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
8
10
12
14
16
R = 1.2
R = 1.1
R = 1.0
R = 0.9
R = 0.8
R = 0.7
R = 0.6
R = 0.5
R = 0.4
R = 0.3
R = 0.2
R = 0.1
qH = 10 m/d
qH = 20 m/d
qH = 30 m/d
qH = 40 m/d


SVI = 200 mL/g
MLSS Concentration, g/L
RAS Concentration, g/L
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
R = 1.2
R = 1.1
R = 1.0
R = 0.9
R = 0.8
R = 0.7
R = 0.6
R = 0.5
R = 0.4
R = 0.3
R = 0.2
R = 0.1
qH = 10 m/d
qH = 20 m/d
qH = 30 m/d
qH = 40 m/d


SVI = 200 mL/g
MLSS Concentration, g/L
RAS Concentration, g/L
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
R = 1.2
R = 1.1
R = 1.0
R = 0.9
R = 0.8
R = 0.7
R = 0.6
R = 0.5
R = 0.4
R = 0.3
R = 0.2
R = 0.1
qH = 10 m/d
qH = 20 m/d
qH = 30 m/d
qH = 40 m/d
1
2
3

Conclusions

- Zone settling velocity from different types of biological treatment facilities can be described by a single, empirical equation
- Two-tailed paired comparison analyses indicated there was no significant difference between unstirred and stirred SVIs.
- A secondary clarifier operating diagram was developed that can be used by operators and engineers in the operation and design of secondary clarifiers.