Homework 4, Problem 1

Initial concentration	C_{in}	5	25	125	mg/L
Particle size	d_P	0.1	1	10	μm
Particle size	d_P	1.00E-07	1.00E-06	1.00E-05	meters
Collector size	d_C	0.5	0.5	0.5	mm
Collector size	d_C	5.00E-04	5.00E-04	5.00E-04	meters
Temperature	T	25	25	25	degrees C
Temperature	T	298	298	298	degrees K
Particle density	ρ_P	1.05	1.05	1.05	g/cm^3
Particle density	ρ_P	1050	1050	1050	kg/m^3
Water density	ρ_W	0.978	0.978	0.978	g/cm^3 from Viessman and Hammer, Table A.8, p. 852
Water density	ρ_W	978	978	978	kg/m^3
Bed depth	L	6.00E-01	6.00E-01	6.00E-01	meter
Bed porosity	n	0.4	0.4	0.4	
Overflow rate	V_f	15	15	15	m/hr
Overflow rate	V_f	0.004166667	0.004166667	0.004166667	m/sec
Dynamic viscosity of water	μ□	8.90E-04	8.90E-04	8.90E-04	kg/(m-s) from Viessman and Hammer, Table A.8, p. 852
Boltzmann constant	κ	1.38E-23	1.38E-23	1.38E-23	m^2 kg / (s K)
Interception efficiency	$\eta_I = 3/2\ (d_P/d_C)^2$	6.00E-08	6.00E-06	6.00E-04	
Sedimentation efficiency	$\eta_G = (\rho_P-\rho_W)\ g\ d_P^2 / (18\ \mu\ V_f)$	1.06E-07	1.06E-05	1.06E-03	
Diffusion efficiency	$\eta_D = 0.9\ (\kappa T/(\mu\ d_P\ d_C\ V_f))^{2/3}$	7.11E-04	1.53E-04	3.30E-05	
Overall efficiency	$\eta = \eta_I + \eta_G + \eta_D$	7.11E-04	1.70E-04	1.69E-03	
Attachment efficiency	α	0.2	0.2	0.2	
Outflow concentration	$C_{out} = C_{in} * \exp(-3\ (1-n)\ \eta\ \alpha\ L/(2\ d_C))$	4.29	24.10	86.77	mg/L
Treatment efficiency	$= 1 - C_{out}/C_{in}$	14%	4%	31%	
Attachment efficiency	α	1	1	1	
Outflow concentration	$C_{out} = C_{in} * \exp(-3\ (1-n)\ \eta\ \alpha\ L/(2\ d_C))$	2.32	20.81	20.15	mg/L
Treatment efficiency	$= 1 - C_{out}/C_{in}$	99%	93%	93%	

Homework 4, Question 2

Step 1: Determine number of tanks

Two is minimum, but entire flow will go through one tank if the other is taken out of service. Three tanks is safer.

Step 2: Determine size of basins

Tank overflow rate fixes total area.

$$A_p = \frac{Q}{V_s} = \frac{4 \ m^3/s}{3.2 \ m/hr} \cdot 60 \cdot 60 \frac{s}{hr}$$

$$= 4500 \ m^2 \ \text{total}$$

$$= 1500 \ m^2 \ \text{per basin}$$

Length to width ratio should be at least 4 or 5 to 1

Assume $L = 4.5W$

$$A_p = L \cdot W = 4.5 W^2 = 1500 \ m^2$$

$$\therefore W = \sqrt{\frac{1500}{4.5}} = 18.3 \ m$$

$$= 18 \ m$$ (to be multiple of 6-m scraper width)

$$L = A_p/W = 1500/18 = 83.3 \ m$$

$$L:W = 83.3/18 = 4.6 \checkmark$$

Basin depth should be 3 to 5 m.

Use $D = 4$ m

Step 3: Check design against guidelines

$L = 83.3$ m $W = 18$ m $D = 4$ m

$L:D = 83.3:4 = 21:1 > 15:1 \checkmark$

$W:D = 18:4 = 4.5:1 \checkmark$

$L:W = 4.6:1 \checkmark$

Compute detention time, horizontal velocity, and outlet weir loading rate for max and average flow for 2 and 3 tank configurations:

$$T_R = \frac{L \cdot W \cdot D \cdot N}{Q}$$

N = number of tanks
Q = total flow

$$V_H = \frac{Q}{W \cdot D \cdot N}$$

$$q = \frac{Q}{W \cdot N}$$

See spreadsheet on page 4 for trial with these values. Design fails residence time and horizontal flow criteria.

Getting to a workable design requires multiple iterations. I made this process more efficient by writing an Excel worksheet that allowed me to vary N, L, W, and D and automatically compute the various design criteria. I also used Excel's conditional formatting to automatically flag out-of-range values. It then was pretty simple to vary the design so as to meet all criteria. Pages 5 and 6 show two designs that work. With only 4 tanks, the last design is the least expensive.

Getting the weir parameter was not required of the class. It would entail multiple troughs across the tank.
At 0.75 m^3/s per each of four tanks, $\frac{Q}{W} = 150 \ \frac{m^3}{m\text{-}hr}$

This would entail 6 2-sided troughs across the width of the tank plus the end of the tank itself to get an outlet weir loading rate of 11.5 $m^3/m\text{-}hr$

First try

Check on basin dimensions:

L = 83.3 m
W = 18 m
D = 4 m
N = 3

Case		All tanks, Q_{ave}	All tanks, Q_{max}	1 tank off, Q_{ave}	1 tank off, Q_{max}	Design guideline Minimum	Design guideline Maximum
N		3	3	2	2		
Q	m^3/s	3	4	3	4		
L:D		21	21	21	21	15	
W:D		5	5	5	5	3	6
L:W		4.6	4.6	4.6	4.6	4	5
T_R	h	1.7	**1.2**	**1.1**	**0.8**	1.5	4
V_f	m/min	0.83	**1.11**	**1.25**	**1.67**	0.3	1.1
q	m^2/h	200	267	300	400		
R_h	m	2.8	2.8	2.8	2.8		

Second try

Check on basin dimensions:

L = 75 m
W = 18 m
D = 5 m
N = 5

Case		All tanks, Q_{ave}	All tanks, Q_{max}	1 tank off, Q_{ave}	1 tank off, Q_{max}	Design guideline Minimum	Design guideline Maximum
N		5	5	4	4		
Q	m^3/s	3	4	3	4		
L:D		15	15	15	15	15	
W:D		4	4	4	4	3	6
L:W		4.2	4.2	4.2	4.2	4	5
T_R	h	3.1	2.3	2.5	1.9	1.5	4
V_f	m/min	0.40	0.53	0.50	0.67	0.3	1.1
q	m^2/h	120	160	150	200		
R_h	m	3.2	3.2	3.2	3.2		

Final

Check on basin dimensions:

L = 83.3 m
W = 18 m
D = 5 m
N = 4

Case		All tanks, Q_{ave}	All tanks, Q_{max}	1 tank off, Q_{ave}	1 tank off, Q_{max}	Design guideline Minimum	Design guideline Maximum
N		4	4	3	3		
Q	m^3/s	3	4	3	4		
L:D		17	17	17	17	15	
W:D		4	4	4	4	3	6
L:W		4.6	4.6	4.6	4.6	4	5
T_R	h	2.8	2.1	2.1	1.6	1.5	4
V_f	m/min	0.50	0.67	0.67	0.89	0.3	1.1
q	m^2/h	150	200	200	267		
R_h	m	3.2	3.2	3.2	3.2		