Problem Set 6 | KEY

(1)

(a) COAGULATION

use rapid-mix tank

$\theta = 1-2$ min

select $\theta = 1$ min

$$\forall = Q \times \theta$$

$$= 3.25 \times 10^{6} \frac{\text{gal}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{h}} \times \frac{1 \text{h}}{60 \text{min}} \times 1 \text{ min}$$

$\forall = 2257$ gal, choose $\forall = 2300$

(I picked lowest θ, so round up)

As stated in class, specify fiberglass reinforced plastic, no expectation of failure, so need one tank onsite.

Mixer: $\bar{G} = 600 - 1000 \text{ s}^{-1}$

Select $\bar{G} = 800 \text{ s}^{-1}$

$$P = \bar{G}^2 \times \mu \times \forall$$

$$P = \left(800 \frac{1}{s}\right)^2 \times 1.307 \times 10^{-3} \frac{\text{N} \cdot \text{s}}{\text{m}^2} \times 2300 \text{ gal} \times 3.785 \frac{\text{L}}{\text{gal}} \times \frac{1 \text{ m}^3}{1000 \text{ L}}$$

$$P = 7282 \frac{\text{Nm}}{\text{s}} = 7282 \text{ watts}$$

$P = 7.3$ kW, specify one spare mixer, so two mixers total.

Acceptable range for $P = 3.8 - 22$ kW.

Coagulant Dose:

$$\text{Alum} = 35\ \text{mg/L} \times 3.25 \times 10^6\ \frac{\text{gal}}{\text{day}} \times \frac{1\ \text{tonne}}{10^9\ \text{mg}} \times 365\ \frac{\text{day}}{\text{y}}$$

$$\text{Alum Dose} = 157\ \text{tonne/y}$$

$$\cong 170\ \text{ton/y}\ \text{(short tons)}$$

Alkalinity Required:

$$\text{Alkalinity} = 35\ \frac{\text{mg Alum}}{\text{L}} \times \frac{1\ \text{mole Alum}}{594\ \text{g}} \times \frac{6\ \text{eq alk}}{1\ \text{mole alum}} \times \frac{50\ \text{g}\ CaCO_3}{1\ \text{eq alk}}$$

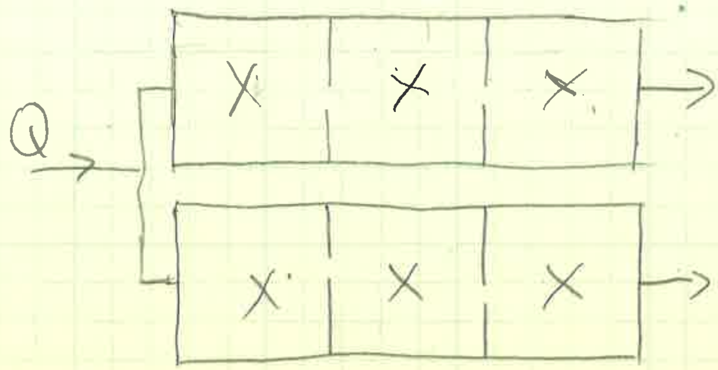
$$\text{Alkalinity Required} = 18\ \text{mg/L as}\ CaCO_3$$

Compare to alkalinity of raw water

$$\text{Alk of raw water} = 50\ \text{mg/L as}\ CaCO_3$$

$18\ \text{mg/L} < 5\ \text{mg/L}$, so don't need to add alkalinity!

(b) Flocculation



$\theta = 10-30$ min, select $\theta = 20$ min (w/ both tanks in service)

$\bar{G} = 20-50\ s^{-1}$, select $\bar{G} = 30\ s^{-1}$

$$V_{tot} = Q \times \theta = 3.25\times10^{6}\ \frac{gal}{d} \times 20\ min \times \frac{1\ day}{24\ h} \times \frac{1\ h}{60\ min}$$

$$\underline{V_{tot} = 45{,}139\ gal}$$

Two tanks, so $\underline{V_{tank}} = \frac{45{,}139}{2} = \underline{22{,}570\ gal}$

Check θ when one tank is out of service:

$$\theta = \frac{V}{Q} = \frac{22{,}570\ gal}{3.25\ \frac{gal}{day} \times \frac{1\ day}{24\ h} \times \frac{1\ h}{60\ min}} = 10\ min\ \checkmark$$

within allowable range!

To calculate power, need volume of each section,

$$V_{section} = \frac{22{,}570}{3} = 7523\ gal$$

$$P = \bar{G}^2 \times \mu \times V = \left(30\ \frac{1}{s}\right)^2 \times 1.307\times10^{-3}\ \frac{N\cdot s}{m^2} \times 7523\ gal \times 3.785\ \frac{L}{gal} \times \frac{1\ m^3}{1000\ L}$$

$$P \cong 34\ \frac{N\cdot m}{s} = \underline{34\ Watt}$$

Need two tanks, each with $V = 22{,}570$ gal, & six mixers each w/ $P = 34$ W.

(c) Sedimentation: To calculate area, need OFR

$OFR = 700\text{-}1400 \ gpd/ft^2$

Choose $OFR = 700 \ \frac{gpd}{ft^2}$ $\qquad OFR = \frac{Q}{A}$

$$A_{tot} = \frac{Q}{OFR} = \frac{3.25 \times 10^6 \ gpd}{700 \ \frac{gpd}{ft^2}} = 4643 \ ft^2$$

Assume two tanks $\quad A_{tank} = \frac{A_{tot}}{2} = \frac{4643}{2} = 2321 \ ft^2$

Check OFR with one tank out of service:

$$OFR = \frac{Q}{A_{tank}} = \frac{3.25 \times 10^6}{2321} = 1400 \ \frac{gpd}{ft^2} \checkmark$$

Ok, within the allowable range.

Specify two tanks, each with $V = 2330 \ ft^2$

(d) Filtration: To calculate area, need HLR.

$HLR = 2\text{-}6 \ \frac{gpm}{ft^2}$

Choose $HLR = 2 \ \frac{gpm}{ft}$

Try 4 filters (Problem stated that need to be able to have two filters out of service.)

$HLR = \frac{Q}{A}$

$$A_{tot} = \frac{Q}{HLR} = \frac{3.25 \times 10^6 \ \frac{gal}{day}}{2 \ \frac{gal}{min \ ft^2} \times 24 \ \frac{h}{day} \times 60 \ \frac{min}{h}} = 1129 \ ft^2$$

With four filters, $A_{filter} = \frac{A_{tot}}{4} = \frac{1{,}129}{4} = 282\ ft^2$

Now check HLR with two filters out of service.

$A = 2 \times 282 = 564\ ft^2$

$HLR = \frac{Q}{A} = \frac{3.25 \times 10^6 \frac{gal}{day} \times \frac{1\ day}{24h} \times \frac{1h}{60min}}{564\ ft^2}$

$HLR = 4 \frac{gpm}{ft^2}$ OK ✓ within allowable range

$\boxed{\text{Specify four filters, each with } A = 282\ ft^2}$

(e) Disinfection

Assume $\theta_{min} = 30$ minutes for average hourly flow

$\forall = \theta Q$

$\forall_{tot} = 3.25 \times 10^6\ gpd \times 30min \times \frac{1\ day}{24h} \times \frac{1h}{60min}$

$\forall_{tot} = 67{,}708\ gal$

Assume two tanks – $\forall_{tank} = \frac{\forall_{tot}}{2} = \frac{67{,}708}{2} = 33{,}854\ gal$

Check θ with one tank out of service:

$\theta = \frac{\forall_{tank}}{Q} = \frac{33{,}854\ gal}{3.25 \times 10^6\ gpd \times \frac{1\ day}{24h} \times \frac{1h}{60min}}$

$\theta = 15\ min$, which is θ_{min} @ peak hourly flow,

so OK ✓

$\boxed{\text{Specify two tanks, each with } \forall = 33{,}845\ gal\text{, PFRs}}$

TOPS 35500

Filtration cont. Determine chlorine dose:

Chlorine residual = 2 mg/L

40% consumption of chlorine in tank

$C_{in} \rightarrow \boxed{-0.4 C_{in}} \rightarrow C_{out} = 2\,mg/L$ Steady State

$C_{in} - C_{out} - C_{consump} = 0$

$C_{in} - 0.4 C_{in} - C_{out} = 0$

$C_{in} - 0.4 C_{in} - 2\,mg/L = 0$

$0.6 C_{in} = 2\,mg/L$

$C_{in} = \frac{2}{0.6} = 3.3$

$\boxed{C_{in} = 3.3\,mg/L}$ - Dose of chlorine

2

a Percent Removal $= 100 - \frac{100}{10^{LR}}$

$= 100 - \frac{100}{10^{2.5}}$

$\boxed{\text{Percent Removal} = 99.68\%}$

b Log Removal

$99.96 = 100 - \frac{100}{10^{LR}}$

$-0.04 = \frac{-100}{10^{LR}}$

$\frac{0.04}{100} = \frac{1}{10^{LR}}$

$10^{LR} = \frac{100}{0.04}$

$LR = \log\left(\frac{100}{0.04}\right)$

$\boxed{LR = 3.4}$