1) 220 mg/L SS
200 mg/L BOD

$A_p = 500\ m^2$

$Q_{max} = 28{,}000\ m^3/day$.

Max. SOR $= \frac{Q_{max}}{A_p} = \frac{28{,}000\ m^3/day}{500\ m^2} = m^3/d/m^2$ O.K. $= 56\ \frac{m^3}{d \cdot m^2}$

$t = 1\ h = 0.0417\ d = \frac{500\ m^2 \cdot D\ m}{28{,}000\ m^3/day}$

$D = 2.34\ m$.

R_{BOD} at $Q_{max} = \frac{1}{0.018 + 0.02(1)} = 26.3\%$ removed.
73.7% remains or 147.4 $\frac{mg}{L}$

R_{SS} @ $Q_{max} = \frac{1}{0.0075 + 0.014(1)} = 46.5\%$ removed
53.5% remains or 117.7 $\frac{mg}{L}$

SS removed contributes to sludge.

$$\text{Sludge} = 28{,}000\ \frac{m^3}{d}\left(220\ \frac{mg}{L}\right)(0.465)\left(\frac{100}{5}\right)\frac{kg}{10^6\ mg}\ \frac{10^3\ L}{m^3}$$

$$= 57{,}288\ \frac{kg}{d}$$

2) $12{,}000\ m^3/d = Q$ Max SOR $= \frac{Q}{A_p} = 61\ m^3/m^2/d$

$A_p = \frac{12{,}000\ m^3/d}{61\ m^3/m^2/d} = 196.7\ m^2 = \frac{\pi D^2}{4}$; $D = 15.8\ m$.

use $D = 16\ m$ let depth $= 2.1\ m$.

$\frac{V}{Q} = \frac{(\pi \cdot 8^2 m^2)(2.1)}{12{,}000\ m^3/d} = 0.0352\ d = 0.844\ h$

let depth $= 2.5\ m$ to give $t = 1\ h$

WOR $= \frac{12{,}000\ m^3/d}{\pi \cdot 16\ m} = 238.7\ m^3/day/m = 2.76\ L/s/m$ O.K.

3) $BoD_5 = 150\ mg/L$ Effluent to be $20\ mg/L$
Filter Depth $= 2.20\ m$
$Q = 3{,}000\ m^3/day$
$E_1 = E_2$
Recycle ratio $= 2:1$

a) $E_{overall} = \left(\frac{150-20}{150}\right) = 86.7\%$

$E_1 = \frac{150-C}{150}$; $E_2 = \frac{C-20}{C}$ $\qquad \frac{150-C}{150} = \frac{C-20}{C}$

$C^2 = 3000$; $C = \sqrt{3000} = 54.77.$

$\frac{150-54.7}{150} = 0.635 = 63.5\%.$

$F = \frac{1+2}{\left(1+\frac{2}{10}\right)^2} = 2.08$

$\frac{mg}{L} \times \frac{g}{1000\,mg} \times \frac{1000\,L}{m^3} = \frac{g}{m^3}$

$W_1 = 150\frac{g}{m^3} \times 3000\frac{m^3}{d} \times \frac{kg}{1000\,g} = 450\ kg\ \frac{BOD}{d}$

$E_1 = \frac{100}{1+0.4432\sqrt{\frac{450}{\forall_1 \times 2.08}}} = 63.5\% = \frac{100}{1+6.5189\sqrt{\frac{1}{\forall_1}}}$

$1 + 6.5189\left(\frac{1}{\forall_1}\right)^{0.5} = 1.5748$; $\qquad 6.5189\left(\frac{1}{\forall_1}\right)^{0.5} = 0.5748$

$\left(\frac{1}{\forall_1}\right) = 0.00777748$; $\qquad \forall_1 = 128.6\ m^3$

$A = \frac{\forall}{D} = \frac{128.6}{2.2} = 58.46\ m^2 = \pi r^2$; $\quad r = 4.314\ m$
$d = 8.62\ m$
$\approx 9.0\ m$

$$W_2 = (1-E_1)W_1 = (1-0.635)\left(450\ kg\ \frac{BOD}{d}\right) = 164.25\ kg\ \frac{BOD}{d}$$

$$63.5 = \frac{100}{1 + \frac{0.4432}{1-0.635}\left(\frac{164.25}{V_2 - 2.08}\right)^{0.5}} = \frac{100}{1 + 10.788\left(\frac{1}{V_2}\right)^{0.5}}$$

$$1 + 10.788\left(\frac{1}{V_2}\right)^{0.5} = 1.5748 \quad ; \quad 10.788\left(\frac{1}{V_2}\right)^{0.5} = 0.5748$$

$$\left(\frac{1}{V_2}\right)^{0.5} = 0.05328 \quad ; \quad V_2 = 352.25\ m^3$$

$$A = \frac{V}{D} = \frac{352.25\ m^3}{2.20\ m} = 160.11\ m^2 = \pi r^2$$

$$r = 7.139$$

$$d = 14.28 \approx 15\ m$$

Filter ① BOD loading: $\frac{450\ kd/d}{\pi \cdot 4.5^2 \cdot 2.2} = 3.214\ \frac{kg}{m^3 \cdot d}$

Hydraulic loading: $\frac{(1+2)(3000\ m^3/d)}{\pi \cdot 4.5^2} = 141.5\ \frac{m^3}{m^2 \cdot day}$

FILTER ② BOD loading: $\frac{164.25\ kg/d}{\pi \cdot 7.5^2 \times 2.2} = 0.422\ \frac{kg}{m^3 \cdot d}$

Hydraulic loading: $\frac{(9000\ m^3/d)}{\pi \cdot 7.5^2} = 50.93\ \frac{m^3}{m^2 \cdot day}$

b) $F = \frac{1+1}{\left(1+\frac{1}{10}\right)^2} = 1.653$ $\quad V_1 = V_2 = \pi(7.5^2)2.2 = 389\ m^3$

$$E_1 = \frac{100}{1 + 0.4432\left(\frac{450}{389 \cdot 1.653}\right)^{0.5}} = 72.95\ \%$$

$$E_2 = \frac{100}{1 + \frac{0.4432}{1-0.7295}\left(\frac{121.7}{389 \cdot 1.653}\right)^{0.5}} \quad 0.455$$

$W_2 = (450)(0.2705) = 121.7$

$$= \frac{100}{1 + 0.4185\ (0.1893)} = 58.38\ \%$$

$$E_{overall} = 0.7295 + 0.5838\left(1 - \overset{0.2705}{0.7295}\right) = 0.887 \text{ or } 88.7\%.$$

BOD in effluent $= 0.1125\ (450\ g/m^3) = 16.88\ g/m^3$

FILTER ① BOD loading: $\frac{450\ kg\ BOD}{389\ m^3\ d}$ $\quad A = \pi(7.5)^2 = 177\ m^2$

$$= 1.16\ \frac{kg\ BOD}{m^3 \cdot d}$$

Hydraulic loading $= \frac{(1+1)(3000\ m^3/d)}{177\ m^2} = 33.9\ \frac{m^3}{m^2 \cdot d}$

FILTER ② BOD loading: $W_2 = (450)(0.2705) = 122\ \frac{kg\ BOD}{d}$.

$$\frac{122\ kg\ BOD/d}{389\ m^3} = 0.314\ \frac{kg\ BOD}{m^3 \cdot d}$$

Hydraulic loading $= 33.9\ \frac{m^3}{m^2 \cdot d}$ (same as for Filter ①)

c) E_{15} (1st Filter) $= E_{20}(1.035)^{15-20}$

$= 72.95(1.035)^{-5}$

$= 61.42\%$.

E_{15} (2nd Filter) $= 0.9838(1.035)^{-5}$

$= 49.15\%$.

$E_{overall} = 0.6142 + 0.4915\,(1 - 0.6142)$ (0.3858.)

$= 0.8038$.

BOD_5 in effluent $= 0.1962\,(150\ g/m^3) = 29.42\ g/m^3$.