Project Two

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CE 441-1

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Contents

1 Oxidation Design Factors

The growth of town's population is expected to increase to 13,000 over the next 10 years, which is the lifetime of this project. The population is estimated to increase by 6,000 people due to the change of climate, and harsh winters in other parts of the US causing an exodus to a warmer climate. The town is water-conscious.

1A I. Flow

The town of Brooksdale is water-conscious, as they are settled in the heart of southern California, near San Diego. The average flow was calculated with the following method:

$$Q_{avg} = 56gcpd * 13,000people = 0.728MGD$$

The maximum flow needs to account for the most extreme cases possible, and was calculated by multiplying the average flow my 3.5, along with a 20% contingency factor. The minimum flow was calculated to be 1/5 of the maximum flow. These calculations are shown below:

$$Q_{max} = 0.728 * 3.5 * 1.2 = 3.05MGD$$
$$Q_{min} = 0.2 * 3.05 = 0.61MGD$$

In order to account for the minimum and maximum flows, a smaller oxidation ditch was designed to handle the minimum flow, and a large oxidation ditch was designed to handle the maximum flow.

1B II. Loading

$$BOD_s = (A+B)*15\frac{mg}{L} = 13*15\frac{mg}{L} = 195\frac{mg}{L}$$
$$SS = (A+B)*20\frac{mg}{L} = 13*20\frac{mg}{L} = 260\frac{mg}{L}$$

The overall organic load on the oxidation ditch is approximately 195 $\frac{mg}{L}$, and the suspended solid load is approximately 260 $\frac{mg}{L}$.

$$BOD_{Q_{min}} = (195\frac{mg}{L} * 0.61MGD * 8.34 = 1,000lb\frac{BOD}{Day}$$
$$BOD_{Q_{max}} = (195\frac{mg}{L}) * (2.05 - 0.61MGD) * (8.34) = 4,000lb\frac{BOD}{Day}$$

The BOD for the small oxidation ditch is 1,000 $lb\frac{BOD}{Day}$, and the BOD for the large oxidation ditch is 4,000 $lb\frac{BOD}{Day}$

1C III. Ditch Dimensions

This process aerates using an activated sludge modification process. This process was assumed to tread 13.5 pound of BOD per day per 1,000 ft^3 of ditch volume.

$$Vol_{small} = (1,000 lb \frac{BOD}{Day}) * (74 \frac{ft^3}{lb \frac{BOD}{Day}}) = 74,000 ft^3$$
$$Vol_{large} = (4,000 lb \frac{BOD}{Day}) * (74 \frac{ft^3}{lb \frac{BOD}{Day}}) = 296,000 ft^3$$

The small oxidation ditch was designed to operate with two rotors, and the large oxidation ditch was designed to operate with four rotors. The design velocity was decided to be 2 ft/s, as the velocity of each flow must be greater than 1 $\frac{ft}{s}$.

$$\text{L} = \text{vt}$$
$$\text{L} = (2fps) * (180s) = 360ft$$

Where L is the distance between rotors

t = the time it takes for water to travel between the rotors, aka the capacity of the rotors. This was assumed to be 3 minutes so as to be conservative.

$$\text{A*L} = \frac{VOL}{2}$$
$$\text{A} = \frac{VOL}{2L}$$
$$A_{small} = \frac{74{,}000 ft^3}{2*360 ft} = 120 ft^2$$
$$A_{large} = \frac{296{,}000 ft^3}{2*360} = 420 ft^2$$

The area of the small oxidation pond is 120 ft^2 and the area of the large oxidation ditch is 420 ft^2.

1D Aerators - MUST FINISH

$$N = BOD * \frac{lbO_2 supplied}{lbBOD}$$

$$N_{small} = 992lb\frac{BOD}{Day} * 2.35\frac{lbO_2 supplied}{lbBOD}$$

$$N_{small} = 2400lb\frac{O_2}{Day}$$

$$N_{Large} = 4,000lb\frac{BOD}{Day} * 2.35\frac{lbO_2 supplied}{lbBOD}$$

$$N_{large} = 9,400lb\frac{O_2}{Day}$$

$$N_0 = \frac{1.5N}{\alpha(\frac{(\beta C_{sw} - C_L)}{C_{st}})*(1.024^{T-20})}$$

$$N_{0,small} = \frac{1.5*2,400}{0.85(\frac{(0.2*11,2ppm-2ppm)}{9.2ppm})*(1.024^{16-20})}$$

$$N_{0,small} = 6600\frac{lbO_2}{day}$$

$$N_{0,small/rotor} = 3300\frac{lbO_2}{day}$$

$$N_{0,large} = \frac{1.5*9,400}{0.85(\frac{(0.8*(9.2ppm-2ppm)}{9.2ppm})*(1.024^{3-20})}$$

$$N_{0,large} = 25,874\frac{lbO_2}{day}$$

$$N_{0,large/rotor} = 6500\frac{lbO_2}{day}$$

Where $N_0 = lb\frac{O_2}{Day}$ into the water at 0 DO and 20° C

α = oxygen transfer ratio (this has been assumed to be 0.85)

β = the ratio of saturation waste at operating temperature

C_{SW} = the saturation value of oxygen in the waste at the Aerators operating temperature

C_{ST} = the saturation value of oxygen in the waste at an operating temperature of 20°C, a pressure of 1 atm, and 0 $\frac{mg}{L}Cl^-$

The worst case for the saturation value of oxygen in waste at operating temperature is during the winter months. Due to the cold temperature, less O_2 is dissolved. The San Diego facility has a lowest yearly temperature of 30°F, which is 16°C. In order to calculate the C_sw for the equation, the slope of the two values given at 30°C and 20°C was calculated, and the ultimate C_sw value was 11.2.

1E Dimension Rotor Design

1E.1 Small Ditch

The small ditch will utilize a smaller rotor type with a 27.5" diameter and a 6" immersion. The design rotor speed is 105 rpm. The rotor design capacity was determined to be:

$$RotorCapacity = 4.5\frac{lb\frac{O_2}{hr}}{rotorft} * (\frac{60hrs}{day} = 270\frac{lb\frac{O_2}{day}}{rotorft}$$
$$\frac{3{,}300*\frac{lbO_2}{day}}{rotor} * \frac{1ftofrotor}{270\frac{lbO_2}{day}} = 12ftofrotorperrotor$$

This calculation indicates that two 12 foot rotors are to be used for the small ditch, which is within the length required for the 27.5" rotors. The depth of the ditch was calculated as follows:

$$\frac{120ft^2}{12ftperrotor} = 10ftdepth$$

The width of the ditch is 1.8x the width the rotor:

W = 1.8*rotor length

W = 1.8* 12 = 21.6 ft width

A = WD

120f^2 = (21.6 ft)(D)

Depth of small ditch = 5.5 ft

Power P = 12*2*0.6 =14.4 kW at the rotor/unit

Thus it has been determined that the depth of the small ditch is 10 ft, the width of the small ditch is 21.6 ft, and the power is 14.4 kW at the rotor/unit.

1E.2 Large Ditch

The large ditch will utilize a larger rotor type with a 12" immersion and a design speed of 63 rpm. The rotor design capacity was determined to be:

$$RotorCapacity = 4.5\frac{lb\frac{O_2}{hr}}{rotorft} * (\frac{60hrs}{day} = 270\frac{lb\frac{O_2}{day}}{rotorft}$$
$$\frac{6{,}500*\frac{lbO_2}{day}}{rotor} * \frac{1ftofrotor}{270\frac{lbO_2}{day}} = 24ftperrotor$$

This calculation indicates that four 24 foot rotors are to be used for the large ditch, which is within the length required for the magna rotor.

The width of the ditch is 1.8x the width the rotor:

$$W = 1.8 * \text{rotor length}$$

$$W = 1.8 * 24 = 38.88 \text{ ft width}$$

$$A = WD$$

$$427 ft^2 = (38.88 \text{ ft})(D)$$

$$\text{Depth of large ditch} = 11 \text{ ft}$$

$$\text{Power } P = 26 \text{ ft/rotor } * 4 \text{ rotors} * 0.8 = 124 \text{ kW at the rotor/unit}$$

Thus it has been determined that the depth of the large ditch is 11 ft, the width of the large ditch is 40 ft, and the power is 124 kW at the large rotor/unit.

1F Summary of Oxidation Ditch Design and Unit Conversions

	Small Ditch (English/SI)	Large Ditch (English/SI)
Cross Sectional Area	120 ft$^2/11.5m^2$	420 ft$^2/40m^2$
Width	21.6 ft/6.58 m	38.88 ft/11.8 m
Depth	5.5 ft/ 1.68 m	11 ft/ 3.35 m
Distance Between Rotors, L	360 ft / 110 m	360 ft / 110 m
Number of Rotors	2	4
Type of Rotor	27.5" dia, 6" immersion, rotor speed = 105 rpm	42" dia, 12" immersion
		design speed = 64 rpm
Rotor Power	14.4 kW	124 kW

P&ID 1 Depicts the cross sectional view of both the large and small oxidation ditches.

P&ID 2 Depicts the planar view of the large and small oxidation ditches.

2 Design of Final Clarifier

The surface overflow rate for the final clarifier is 740 $\frac{GPD}{ft^3}$, which takes into account the size of the town as well as the overall water consumption. The diameter of the clarifier was determined with the following calculations:

$$\frac{Q_{avg}}{SOR} = A$$

$$\frac{7.32*10^5 gpd}{740\frac{gpd}{ft^3}} = 989.9ft = 1000ft^2$$

$$\frac{\pi D^2}{4} = 1,000ft^2$$

D = 35.7 ft = 36 ft

The height of the clarifier was determined with the average flow and the detention time of the clarifier, which was assumed to be 1.5 hours.

t = $\frac{Vol}{Q_{avg}}$

1.5 hrs * $\frac{3600s}{hr} = \frac{Vol}{0.61MGD*1.55cfsperMGD}$

Vol = $5,800ft^2$

A*H = Vol = 5,800 ft^3 $= H * 1,000$ft^2

H = 5.8 ft

P&ID 3 Figures 1 and 2 Depict the Planar and Cross Sectional View of the Clarifier

3 Cost Estimate

Everything will be multiplied by a factor of 0.85 due to Brookesville being just outside of San Diego, CA, whose cost adjustment is 0.98.

3A Cost of Unit Process

C = $(4.43x10^4)Q^{0.58}$

Where Q is the max design flow. Thus,

$$C = 0.8 \text{ MOD (millions of dollars)}$$

3B Sitework Including Excavation

$$C = (1.96 * 10^5)Q^{0.66}$$

Where Q is the design flow. Thus,

$$C = 0.48 \text{ MOD (Millions of Dollars)}$$

3C Cost of Mobilization

$$C = (6.34 * 10^4)Q^{0.69}$$

$$C = 0.1 \text{ MOD (Millions of Dollars)}$$

3D All Piping

$$C = (12.23 * 10^5)Q^{0.77}$$

$$C = 0.4 \text{ MOD (Millions of Dollars)}$$

3E Small Oxidation Ditch Cost

$$Q = (7.08 * 10^5)Q^{0.67} {*} 3$$

$$Q = 0.62 \text{ MOD (Millions of Dollars)}$$

3F Large Oxidation Ditch Cost

$$Q = (7.08 * 10^5)Q^{0.67*}3$$

Q = 0.84 MOD (Millions of Dollars)

3G TOTAL COST

The total cost of this project is set to be:

$((0.8 + 0.48 + 0.1 + 0.4 + 0.62 + 0.84) * 0.98) = 3.22$ Million Dollars, plus 25% for the cost of engineering:

(3.22*1.25) = 4 Million Dollars.

To account for todays inflation:

4 million x 5.71 (factor in inflation from 1978 to 2022 = $16.13 MOD