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BASIC DESIGN CONSIDERATIONS

(2-5) (a) Arithmetic Method

$$K_a = \frac{Y_2 - Y_1}{T_2 - T_1} = \frac{(42,300 - 36,900)}{(1990 - 1980)} = 540$$

$$Y_t = Y_2 + K_a (T - T_2)$$

$$Y_{2000} = 42,300 + 540 (2000 - 1990) = 47,700$$

(b) Geometric Method

$$K_p = \frac{\ln Y_2 - \ln Y_1}{T_2 - T_1} = \frac{\ln 42,300 - \ln 36,900}{(1990 - 1980)} = 0.0137$$

$$\ln Y_t = \ln Y_2 + K_p (T - T_2) = \ln 42,300 + 0.0137 (2000 - 1990)$$

$$= 10.79$$

$$Y_{2000} = 48,511$$

(c) Decreasing rate of increase

$$Z = \frac{2Y_0 Y_1 Y_2 - Y_1^2 (Y_0 + Y_2)}{Y_0 Y_2 - Y_1^2}$$

$$= \frac{2(31,600)(36,900)(42,300) - (36,900)^2 (31,600 + 42,300)}{(31,600)(42,300) - (36,900)^2}$$

$$Z = 79,262$$

$$K_d = \frac{-\ln[(Z - Y_2) / (Z - Y_1)]}{(T_2 - T_1)} = \frac{-\ln[(79,262 - 42,300) / (79,262 - 36,900)]}{(1990 - 1980)}$$

$$K_d = 0.0136$$

$$Y_t = Y_2 + (Z - Y_2) [1 - e^{-K_d(T - T_2)}]$$

$$= 42,300 + (79,262 - 42,300) (1 - e^{-0.0136(2000 - 1990)})$$

$$Y_{2000} = 47,000$$

(d) Logistic curve – fitting methods

$$a = \frac{Z - Y_0}{Y_0} = \frac{(79,262 - 31,600)}{31,600} = 1.508$$

$$b = \frac{1}{n} \ln \left[\frac{Y_0 (Z - Y_1)}{Y_1 (Z - Y_0)} \right] = \frac{1}{10} \ln \left[\frac{31,600 (79,262 - 36,900)}{36,900 (79,262 - 31,600)} \right]$$

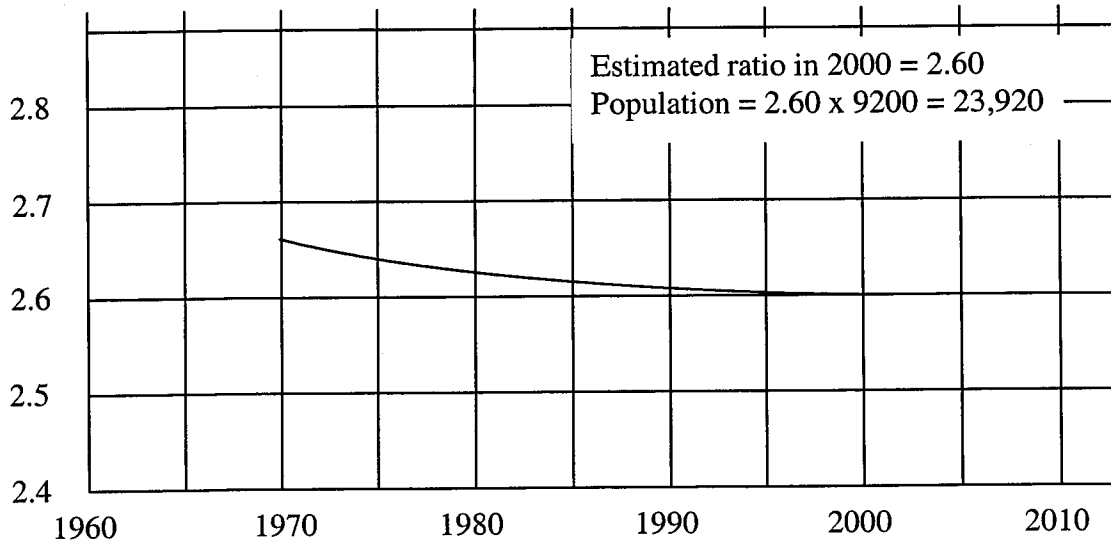
$$= -0.0273$$

$$Y_t = \frac{Z}{1 + ae^{b(T-T_0)}} = \frac{79,262}{1 + 1.508e^{-0.0273(2000-1970)}}$$

$$Y_{1990} = 47,610$$

(2-6) Employment Forecast Method
Estimate 2000 Population

Year	Population	Employment	Ratio Population Employment
1970	20,000	7,500	2.67
1980	21,000	8,000	2.63
1990	23,000	8,800	2.61
2000	?	9,200	2.60



(2-7) Initial flow in 1995 = 600 Lpcd x 35,000 people x $10^{-3} \text{ m}^3/\text{L}$
= 21,000 m^3/d

Design flow in 2015 = 600 Lpcd x 76,000 people x $10^{-3} \text{ m}^3/\text{L}$
= 45,600 m^3/d

Flow growth factor = $\frac{45,600 \text{ m}^3/\text{d}}{21,000 \text{ m}^3/\text{d}}$
= 2.2

Since the flow growth factor exceeds 1.8 (Table 2-1), the staging period should be 10 years or less.

(3-3) From Fig. 3-1.

- (a) Calculate average water demand. The area under the water demand curve (using trapezoidal rule).

$$A_1 = 1/2 (2) [21.25 + 2(13.75 + 8.75 + 17.5 + 82.5 + 66.25 + 37.5 + 38.75 + 47.5 + 68.75 + 72.50 + 50) + 21.25]$$

$$= 1,050 \text{ m}^3$$

The average daily water demand (Q_{av_1})

$$Q_{av_1} = \frac{1,050}{24} = 43.75 \text{ m}^3/\text{h}$$

- (b) The area under the wastewater flow curve (using trapezoidal rule)

$$A_2 = 1/2 (2) [27.5 + 2(21.25 + 18.125 + 20 + 27.5 + 41.25 + 57.5 + 63.75 + 53.75 + 46.25 + 54.375 + 42.5) + 27.5]$$

$$= 947.5 \text{ m}^3$$

The average daily wastewater flow (Q_{av_2})

$$Q_{av_2} = \frac{947.50}{24} = 39.48 \text{ m}^3/\text{h}$$

- (c) The percent of water usage returned to the wastewater treatment facility (P)

$$P = \frac{39.48}{43.75} \times 100 = 90.2\%$$

(3-4) Typical non-conserving home percent water usage (Table 3-2)

Toilet flush	= 33
Shower and bathing	= 28
Wash basin (faucet)	= 11
Kitchen (dishwasher 3%; faucet 6%)	= 9
Laundry and washing machine	= 16
Lawn sprinkling and miscellaneous	= 3
Average water consumption	= 380 Lpcd
Number of residents per home	= 3.5 persons
Population of subdivision	= 200 x 3.5
	= 700 persons
Water demand (conventional)	= 700 persons x 380 Lpcd
	= 266,000 Lpd
Flow from various water uses (Lpcd)	
Toilet flush	= 380 x 0.33 = 125.4 Lpcd
Shower and bathing	= 380 x 0.28 = 106.4 Lpcd
Wash basin (faucet)	= 380 x 0.11 = 41.8 Lpcd

Kitchen faucet	= 380 x 0.06 = 22.8 Lpcd
Kitchen dishwasher	= 380 x 0.03 = 11.4 Lpcd
Laundry and washing machine	= 380 x 0.16 = 60.8 Lpcd
Lawn sprinkling and miscellaneous	= 380 x 0.03 = 11.4 Lpcd
Total	= 380.0 Lpcd

Calculate water conservation achievable after conservation devices (Table 3-7)

Use average percent savings

Total flush (shallow trap 35%)	= 125.4 x 0.35	= 43.9 Lpcd
Shower and bathing (flow limiting showerhead, 11.5%)	= 106.4 x 0.115	= 12.2 Lpcd
Wash basin (faucet), use faucet aerators (1.5%)	= 41.8 x 0.015	= 0.6 Lpcd
Kitchen, efficient dishwasher (7%)	= 11.4 x 0.07	= 0.8 Lpcd
Kitchen faucet with aerator (1.5%)	= 22.8 x 0.015	= 0.3 Lpcd
Laundry and washing machine (level controller or efficient washer, 3%)	= 60.8 x 0.03	= 1.8 Lpcd
Lawn sprinkling and miscellaneous	= 11.4 x (0)	= no savings
Total savings		= 59.6 Lpcd

$$\text{Savings \%} = \frac{59.6 \text{ Lpcd}}{380.0 \text{ Lpcd}} \times 100 = 15.7\%$$

$$\text{Annual Savings} = 59.6 \text{ Lpcd} \times 700 \text{ persons} \times 365$$

$$= 15.23 \times 10^6 \text{ L/y} = 15.23 \times 10^3 \text{ m}^3/\text{y}$$

(3-5) PRV will affect shower (not much effect on bathing), all faucets, and lawn sprinkling

Water uses in homes that will be affected by PRV from Table 3-2 are:

Shower and bathing	= 28 percent
Wash basin faucet	= 11 percent
Kitchen faucet	= 6 percent
Lawn sprinkling and miscellaneous	= <u>3 percent</u>
Total	= 48 percent

$$\begin{aligned} \text{Water consumption in home} &= 350 \text{ Lpcd} \times 4 \text{ persons} \\ &= 1,400 \text{ Lpd} \end{aligned}$$

Average water savings achieved by PRV

$$\text{(Table 3-7)} = 25\%$$

$$\begin{aligned} \text{Quantity of water saved in the home due to PRV} &= 1,400 \text{ Lpd} \times 0.48 \times 0.25 \\ &= 168 \text{ Lpcd} \end{aligned}$$

$$\begin{aligned} \text{Percent saving} &= \frac{168 \text{ Lpcd}}{350.0 \text{ Lpcd}} \times 100 \\ &= 48 \% \end{aligned}$$

$$(3-6) \quad \text{Total water consumption} = 80 \text{ gpcd} \times \frac{4 \text{ persons}}{\text{home}} = 320 \text{ gpd/home}$$

$$\text{Losses due to leaks} = 80 \times 0.04 = 3.2 \text{ gpcd}$$

$$\text{Water lost per home due to leaks at 50 psi} = 3.2 \frac{\text{gal}}{\text{d}} \times 4 \frac{\text{person}}{\text{home}} = 12.8 \text{ gpd/home}$$

$$Q_1 = C_d \times \sqrt{2gh_1} \times A$$

$$Q_2 = C_d \sqrt{2gh_2} \times A$$

where Q_1 and Q_2 are leaks at pressures h_1 and h_2 , respectively.

C_d = coefficient of discharges

A = Orifice area or area of all cracks and openings combined

$$\frac{Q_1}{Q_2} = \frac{\sqrt{h_1} A}{\sqrt{h_2} A}$$

$$\frac{Q_1}{Q_2} = \frac{\sqrt{h_1}}{\sqrt{h_2}}$$

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Total leak $Q_1 = 12.8$ gpd at pressure 50 psig

$$\frac{12.8}{Q_2} = \frac{\sqrt{50}}{\sqrt{16}}$$

$$Q_2 = \frac{\sqrt{16}}{\sqrt{50}} \times 12.8 = 7.24 \text{ gpd/home at 16 psig}$$

Total water savings = $(12.8 - 7.24)$ gpd/home
= 5.56 gpd/home

$$\text{Overall savings} = \frac{5.56 \text{ gpd/home}}{320 \text{ gpd/home}} \times 100 = 1.74\%$$

$$(3-7) \quad \text{Average wastewater flow} = \frac{87}{100} \times 340 \text{ Lpcd}$$

$$= 295.8 \text{ Lpcd}$$

$$\text{Average dry weather wastewater flow} = 295.8 \text{ Lpcd} \times 45,000 \text{ people} \times 10^{-3} \text{ m}^3/\text{L}$$

$$= 13,311 \text{ m}^3/\text{d}$$

Calculate M using Eq. (3-1)

$$M = 1 + \frac{14}{4 + \sqrt{45}} = 2.31$$

$$\text{Maximum dry weather flow} = 13,311 \text{ m}^3/\text{d} \times 2.31$$

$$= 30,748 \text{ m}^3/\text{d}$$

(3-8) Water demand from Table 3-4

Residential

Single family low income	= 500 persons x 270 Lpcd = 135,000 Lpd
Single family medium income	= 800 persons x 310 Lpcd = 248,000 Lpd
Single family high income	= 1,500 persons x 380 Lpcd = 570,000 Lpd
Apartments	= 500 persons x 230 Lpcd = 115,000 Lpd
Subtotal residential	= 1,068,000 Lpd

Institutional and commercial

Hotel/motel	= 500 units x 380 Lpd/unit = 190,000 Lpd
Hospital	= 300 bed x 950 Lpd/bed = 285,000 Lpd
Rest home	= 150 beds x 380 Lp/bed = 57,000 Lpd
Boarding school	= 1,500 students x 300 Lpd/student = 450,000 Lpd
Restaurant	= 1,900 customers x 30 Lpd/customer = 57,000 Lpd
Bar	= 150 customers x 8 Lpd/customer = 1,200 Lpd
Shopping center	= 250 employees x 40 Lpd/employee = 10,000 Lpd
Office building	= 1,500 employees x 65 Lpd/employee = 97,500 Lpd
Barber shop	= 30 chairs x 210 Lpd/chair = 6,300 Lpd
Beauty salon	= 20 stations x 1,026 Lpd/station = 20,520 Lpd
Commercial laundry	= 20 machines x 3,000 Lpd/machine = 60,000 Lpd
Service station	= 3,800 Lpd + 9 x 1,900 Lpd = 20,900 Lpd
Movie theater	= 500 seats x 8 Lpd/seat = 4,000 Lpd
Institutional and commercial	= 1,259,420 Lpd
Avg total water demand for the community	= 2,327,420 Lpd = 2327 m³/d
