2
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

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

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

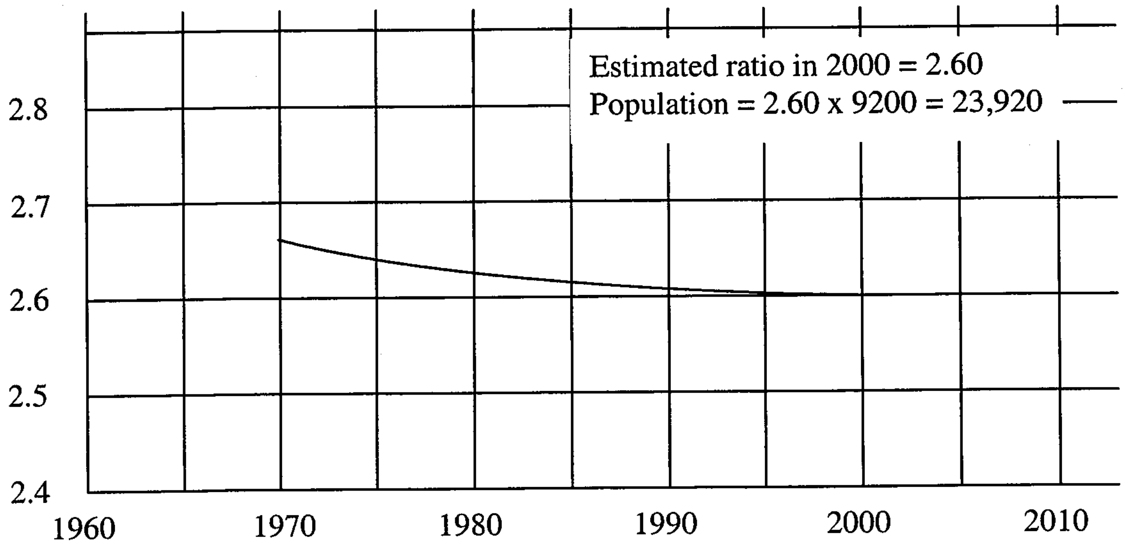
$$= -0.0273$$

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

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

(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} m^3/L
= 21,000 m^3/d
Design flow in 2015 = 600 Lpcd x 76,000 people x 10^{-3} m^3/L
= 45,600 m^3/d

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

= 2.2

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

3
WASTEWATER CHARACTERISTICS

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

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

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

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

The average daily water demand (Qav_1)

$$Qav_1 = \frac{1{,}050}{24} = 43.75\ m^3/h$$

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

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

$= 947.5\ m^3$

The average daily wastewater flow (Qav_2)

$$Qav_2 = \frac{947.50}{24} = 39.48\ m^3/h$$

(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 subdivion	= 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	= 3 percent
Total	= 48 percent

Water consumption in home = 350 Lpcd x 4 persons
= 1,400 Lpd

Average water savings achieved by PRV

(Table 3-7) = 25%

Quantity of water saved in the home due to PRV = 1,400 Lpd x 0.48 x 0.25
= 168 Lpcd

$$\text{Percent saving} = \frac{168 \text{ Lpcd}}{350.0 \text{ Lpcd}} \times 100$$

$$= 48\ \%$$

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

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

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

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

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

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

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

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

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

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

(3-7) Average wastewater flow $= \frac{87}{100} \times 340 \text{ Lpcd}$
$= 295.8 \text{ Lpcd}$

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)

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

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 m^3/d**

(3-9) Total residential water demand

$= 60{,}000$ residents x 350 Lpcd x 10^3 $m^3/L = 21{,}000$ m^3/d

Commercial water demand $= 200$ ha x 20 $m^3/ha.d$ $= 4{,}000$ m^3/d

Industrial water demand $= 300$ ha x 23 $m^3/ha.d$ $= 6{,}900$ m^3/d

Assume total municipal water demand is Q m^3/d

Q = residential demand + commercial demand + industrial demand + public water use + water unaccounted for

$Q = 21{,}000\ m^3/d + 4{,}000\ m^3/d + 6{,}900\ m^3/d + 0.1\ Q + 0.06\ Q$

$Q - 0.1\ Q - 0.06\ Q = 31{,}900$

$Q = 37{,}976\ m^3/d$

Residential demand $= \dfrac{21{,}000\ m^3/d}{37{,}976\ m^3/d} \times 100 = 55\%$

Commercial $= \dfrac{4{,}000\ m^3/d}{37{,}976\ m^3/d} \times 100 = 11\%$

Industrial $= \dfrac{6{,}900\ m^3/d}{37{,}976\ m^3/d} \times 100 = 18\%$

Public use $= \dfrac{0.1 \times 37{,}976\ m^3/d}{37{,}976\ m^3/d} \times 100 = 10\%$

Unaccounted for $= \dfrac{0.06 \times 37{,}976\ m^3/d}{37{,}976\ m^3/d} \times 100 = 6\%$

100%

(3-10) I/I allowance $= 3{,}500 \dfrac{L}{ha.d} \times 1{,}650\ ha = 5{,}775{,}000\ L/d$

Estimated population $= 25 \dfrac{persons}{ha} \times 1{,}650\ ha$ $= 41{,}250$ persons

I/I allowance $= 5{,}775{,}000\ L/d \times \dfrac{1}{41{,}250\ persons}$ $= 140$ Lpd per person

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(3-11) Total I/I flow $= \dfrac{1{,}400\ L}{d.cm \times km} \times 200\ km \times 21\ cm$ $= 5{,}880{,}000\ L/d$

Population $= \dfrac{200\ km \times 1{,}000\ m/km}{8\ m/person}$ $= 25{,}000$ persons

I/I per capita per day $= \dfrac{5{,}880{,}000\ L/d}{25{,}000\ persons}$ $= 235.2$ Lpcd

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