CEL 795

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Water Demand, Sources and Population Forecasting

Week 2

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Water Demand

- Total demand depends on following requirements:
  - Residential demand
  - Commercial demand
  - Industrial demand
  - Fire-fighting demand
  - Public use
  - Water lost or unaccounted for

- It depends on following factors:
  - Climate
  - Geographic location
  - Size, population and economic condition of community,
  - Extent of industrialization
  - Metered water supply, cost of water, supply pressure

Water Source Types

- River/stream water
- Lake water
- Ground water (Tube well water)
- Rain water
- Wastewater effluent (treated for human consumption)
  – An effort towards reuse and recycle!
  – Is it acceptable to use it for human consumption?

Municipal Water Demand-
Community's drinking water consumption

- Say one person consumes=X liters per day (i.e., "X" lpcd(a short form of liters per capita per day)
- Total number of population in a community ="P"
- Total daily water demand = (X) *(P) liters per day
- Say amount of water required for duration = "T" days
- Total amount of water required (V_{total})= (X)*(P)*(T) liters
- The water source should have this much (i.e.,V_{total}) to be considered as a potential water source.

Water Demand

- Per capita demand is different in normal conditions and in drought conditions.

- Water demand also fluctuates
  - Seasonally (maximum demand in July and August)
  - Daily (more for working days than holidays)
  - Hourly (more in morning and evening per day, i.e., two hours of peak demand over a 24-hour duration)

Consideration for water quality in selecting a water source

- But, what about water quality of this water source? What if this water source doesn't have good water and we might need to provide further treatment?
  - Leads to the consideration for water quality aspect of a given water source!
- Among different water source types, consider following for evaluating their potential
  - Levels of different water quality parameters
  - Amount of treatment required to meet water quality characteristics for the desired use

  (The water quality characteristics are improved depending on water's final usage and thus, its important to know the final use of the water)

- Overall: Water quality and available water volume-Both aspects should be considered during selection of a particular water source for a particular type of water usage.

Some definitions on water demand

Demand type	Definitions	Remarks
Annual average day demand	Average daily demand over a period of one year	
Maximum day demand	Amount of water required during the day	Useful for peak capacity of production and treatment facilities
Peak hour demand	Amount of water required during the maximum consumption hour in a given day	Useful for analyzing peak capacity requirement of distribution system
Annual maximum daily demand	Maximum daily demand over a period of one year	This estimate is important to meet the worst-case water demand.

- All water demand types are expressed as ratio of mean average daily flow

- In the absence of water demand data, use the following equation:

$$p = 180(t)^{-0.10} \qquad (1)$$

p= % of the annual average daily demand for time (t) in days

- Peak hourly demand = 150% of maximum daily demand

  -An acceptable relationship

Conditions	Time (day)	Calculated % of annual average daily demand using Eq. (1)	Reported % annual average daily demand
Daily average in maximum month	30	$=180(30)^{-0.10}$ =128	Average =120 (range: 110-140)
Daily average in maximum week	7	**<u>??? (solve)</u>**	Average =140 (range: 120-170)
Maximum day in a year	1	**<u>??? (solve)</u>**	Average =180 (range: 160-220)
Peak hour within a day (2 hours out of 24 hours)	=2/24 day	**<u>??? (solve)</u>**	Average =270 (range: 225-320)

- # Fire demand:

➢ Small demand (annually)-but high demand during periods of need

➢ Required fire flow demand must be available in addition to coincident maximum daily flow rate.

$$Q = 3.86\left(-0.01P_* + \sqrt{P_*}\right) \qquad (2)$$

Q	Fire flow rate (m^3/min)
P^*	Population in thousands

Design Considerations

1. Design capacity of water treatment plant = Maximum day demand

2. Design capacity of water distribution system
   – Maximum [peak hour flow, (maximum daily demand + fire flow demand)]

Class Problem 1

- Population at design year= 1,20,000
- Municipal demand = 610 lpcd
- Calculate
  - Design flow of water treatment plant?
  - Fire flow demand?
  - Design capacity of water distribution system?

Class Problem 1: Solution

Average daily water demand	=(610 L/person/day) *(120000 persons)*(0.001 m^3) =73,200 m^3/day = (73,200 m^3/day)/[(24 h/day)*(60 min/h)] ***=50.83 m^3/min*** **(answer)**
Maximum day demand	Using Eq. (1) (Slide 10) to determine percentage value of average daily water demand: $=180(1)^{-0.10}$ =180% = (180/100)*(50.83 m^3/min)***=91.49 m^3/min*** **(answer)**
Peak hour demand	1.5 times of the maximum day demand = (1.5)*(91.49 m^3/min) ***=137.24 m^3/min*** **(answer)**
Fire flow demand	= 3.86*[-0.01*(120000/1000)+$(120000/1000)^{0.5}$] = 3.86*[-0.01*(120)+$(120)^{0.5}$]=***37.65 m^3/min***

Class Problem 1: Solution contd…

Design capacity of water treatment plant	= Maximum daily demand ***=91.49 m³/min*** **(answer)**
Design capacity of water distribution system	=maximum [peak hour flow, (daily maximum demand +fire flow rate)] = maximum [137.24 m^3/min, (91.49 m^3/min+ 37.65m^3/min)] = maximum [137.24 m^3/min, 129.14 m^3/min] =***137.24 m^3/min*** (i.e., peak hour flow governs the design of water distribution system) **(answer)**

Population Projection Methods

- Different methods are available to use past population information to project future populations

Methods

1. Arithmetic growth method

2. Geometric growth method

3. Logistic growth curve method

4. Decreasing rate of increase method

5. Others (ratio method, employment forecast, birth cohort, etc.)
[NOT COVERED IN THIS COURSE]

Methods- Assumptions, scope, and limitations

Method type	Assumptions, scope and limitations
Arithmetic method	1. Constant rate of population increase, 2. Average value of proportionality is assumed to be constant over several decades, and 3. Used for short term estimate (1-5 years).
Geometric method	1. Population is assumed to increase in proportion to the number present, 2. Average value of proportionality is assumed to be constant over several decades, and 3. Used for short term estimate (1-5 years) .
Logistic growth curve method	1. Population growth is assumed to follow a logistical mathematical relationship (i.e., a S-shaped curve).
Decreasing rate of increase method	1. Population is assumed to reach some limiting value or saturation point.

Arithmetic method

$$\frac{dP}{dt} = K_a \qquad (2a)$$

$$P_t = P_2 + K_a\left(T - T_2\right) \qquad (2b)$$

$$K_a = \frac{P_2 - P_1}{T_2 - T_1} \qquad (2c)$$

P_t	Population in year t (generally, time interval is 10 years)
K_a	Constant population growth (unit: population/year)
P_1 and P_2	Populations in year T1 and T2 (say, for example in year 1980 and 1990, it would be P_{1980} and P_{1990})

Geometric growth method

$$\frac{dP}{dt} = K_a P \tag{3a}$$

$$\ln P_t = \ln P_2 + K_a\left(T - T_2\right) \tag{3b}$$

or $$P_t = P_2 e^{\left[K_a\left(T - T_2\right)\right]}$$

$$K_a = \frac{\ln\left(\dfrac{P_2}{P_1}\right)}{T_2 - T_1} \tag{3c}$$

K_a	Geometric population growth rate (unit: population/year)

Logistic curve growth method

$$P_t = \frac{Z}{1 + ae^{b(T - T_0)}} \qquad (4a)$$

$$Z = \frac{2P_0P_1P_2 - (P_1{}^2)(P_0 + P_2)}{P_0P_2 - (P_1{}^2)} \qquad (4b)$$

$$a = \frac{Z - P_0}{P_0}; \qquad b = \left(\frac{1}{n}\right)\ln\left[\frac{P_0(Z - P_1)}{P_1(Z - P_0)}\right] \qquad (4c)$$

a, b	Model constants
Z	Saturated population
n	Constant interval between T_0, T_1, and T_2 (generally 10 years, but see the data also; $(T_2-T_1)=(T_1-T_0)$ years)

Decreasing rate of increase growth method

$$\frac{dP}{dt} = K_a(Z - P) \tag{5a}$$

$$P_t = P_2 + (Z - P_2)\left[1 - e^{-K_a(T - T_2)}\right] \tag{5b}$$

$$Z = \frac{2P_0P_1P_2 - (P_1^{\,2})(P_0 + P_2)}{P_0P_2 - (P_1^{\,2})} \tag{5c}$$

$$K_a = \left(-\frac{1}{T_2 - T_1}\right)\ln\left(\frac{Z - P_2}{Z - P_1}\right) \tag{5d}$$

K_a	Constant for decreasing rate of increase
Z	Saturated population

Class Problem 2: Population Prediction-
Arithmetic method

Data (student population in a class)	
August	28 students (P0)
September	??? (P)
Constant student increase rate (K_a)	1 student per 15 days (i.e., =1/15 student/day ***<u>=0.067 student/day)</u>***

Question: Using <u>arithmetic method</u>, calculate population of the class at the start of September?

Solution: Here, T0= 0 days (say), T2= Duration from T0 time= 31 days (total days in august).

So, $P_{Sep\,=}\,P_{Aug}+K_a(T2\text{-}T0)$

= (28)+(0.067)*(31-0)

<u>=30 students</u> **(answer)**

Class Problem 3: Population Prediction-
<u>Geometric method</u>

Data (student population in a class)	
August	28 students (P0)
September	??? (P)
Geometric student increase rate (K_a)	1% of initial student strength per 15 days (i.e., =(1/100*28)/15 student/day ***=0.0187 student/day)***

Question: Using geometric growth method, calculate student population at the start of September?

Solution: Here, T0= 0 days (say), T2= Duration from T0 time= 31 days (total days in august).

So, $P_{Sep} = (P_{Aug})*e^{[Ka(T2-T0)]}$

$= (28)e^{[0.0187*(31-0)]}$

=50 students **(answer)**

Class Problem 4: Population Prediction

Data	
Time	Population
1970 (T0)	10000 (P0)
1980 (T1)	15000 (P1)
1990 (T2)	18000 (P2)
2000 (T)	??? (P)

Question: Predict population using (1) arithmetic and (2) logistic curve growth methods and compare?

Class Problem 4: Solution

Arithmetic method	
Ka	200
Population in year 2000	***21000*** (answer)
Logistic curve growth method	
Z	20000
a	1
b	-0.10986
Population in year 2000	***19286*** (answer)

=> Predicted population value is approximately equal from both methods.