Wastewater Engineering

Class 2 Wastewater Flow and Equalization

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Wastewater Flow

TABLE 2-1
Typical municipal water use in the United States[a]

Use	Flow, gal/capita · d Range	Flow, gal/capita · d Average	Percent based on average flow
Domestic	40–130	60	36.4
Industrial (nondomestic)	10–100	70	42.4
Public service	5–20	10	6.0
Unaccounted system losses and leakage	10–40	25	15.2
	65–290	165	100.0

[a] Ref. 8.
Note: gal × 3.7854 = L

Domestic loading (international data)

Table 3.4 Variations in person load (Henze *et al.*, 2001)

Parameter	Unit	Range
COD	g/cap.d	25-200
BOD	g/cap.d	15-80
Nitrogen	g/cap.d	2-15
Phosphorus	g/cap.d	1-3
Wastewater	m^3/cap.d	0.05-0.40

Table 3.5. Person load in various countries in kg/cap.yr (based on Henze *et al.*, 2002)

Parameter	Brazil	Egypt	India	Turkey	US	Denmark	Germany
BOD	20-25	10-15	10-15	10-15	30-35	20-25	20-25
TSS	20-25	15-25		15-25	30-35	30-35	30-35
N total	3-5	3-5		3-5	5-7	5-7	4-6
P total	0.5-1	0.4-0.6		0.4-06	0.8-1.2	0.8-1.2	0.7-1

Country/Area	Per capita water consumption Gal/d	Per capita water consumption L/d
China	21	80
Africa	4–9	15–35
Southeast Asia	8–19	30–70
Western Pacific	8–24	30–90
Eastern Mediterranean	11–23	40–85
Algeria, Morocco, Turkey	5–17	20–65
Latin America and Caribbean	19–51	70–190
World average	9–24	35–90

[a] Adapted, in part, from Salvato (1992).

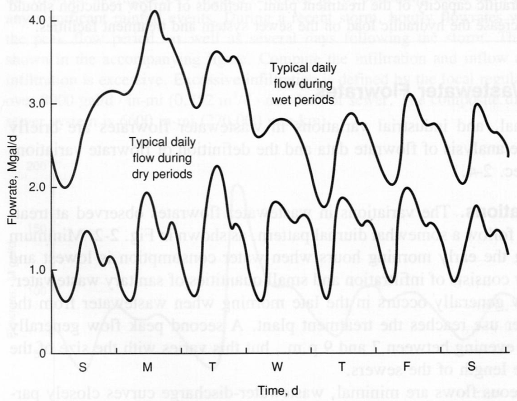
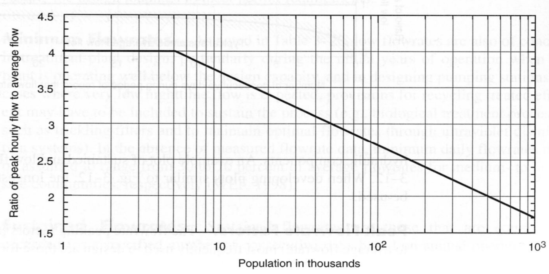
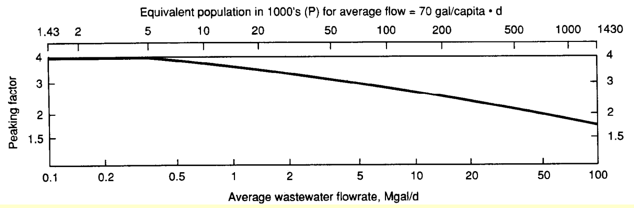


FIGURE 2-3
Typical daily and weekly variations in domestic wastewater flowrates.

Estimating peaking factor

Figure 3-13
Peaking factor curve (ratio of peak hourly to average daily flow).





Impact of Flowrate and Mass-Loading Factors on Design

- **Rated capacity** - average annual daily flowrate
- **Peak hydraulic flowrates** - control the size of unit processes and interconnecting conduits
- **Peak process loading rates** - control the size of unit processes and support systems
- **Goal** - provides a wastewater treatment system that is capable of coping with a wide range of probable wastewater conditions while complying with the overall performance requirements. This is specially important as the discharge limits get more and more stringent.

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Typical Design Flowrate and Loading Factors Used for Sizing

Flowrate based

Factor	Application
Peak hour	Pumping facilities and conduits, bar-rack; grit chambers, sedimentation tanks, and filters; chlorine-contact tanks
Max. day	Sludge pumping system
> 1-day max.	Screenings and grit storage
Max. week	Record-keeping and reporting
Max. month	Record-keeping and reporting, chemical storage facilities
Min. hour	Turndown of pumping facilities and low range of plant flowmeter
Min. day	Influent channels to control solids deposition
Min. month	Min. number of operating units required during low-flow periods

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Typical Design Flowrate and Loading Factors Used for Sizing

Mass loading based

Factor	Application
Max. day	Selected biological processing units
> 1-day max.	Sludge-thickening and -dewatering systems
Sustained peaks	Selected sludge processing units
Max. month	Sludge storage facilities
Min. month	Process turndown requirements
Min. day	Trickling-filter recycle

Procedure for selecting design flow rate:

average flowrates based on population projections, industrial flow contributions, and allowances for infiltration/inflow

Peak flowrate = Average flowrate □ Peaking factor

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Forecasting Design Flowrates

Expansion project; current population of 15,000, 25,000 resident expected after 20 years plus 1000 visitors per day from a proposed college (assume 15 gal/capita/day);

a new industry - ave. = 0.22 Million gal/day, peak = 0.33 Mgal/day for 24 hr operation;

present wastewater ave. daily flowrate = 1.6 Mgal/day; infiltration/inflow = 25 gal/capita/day at ave. flow and 37.5 gal/capita/day at peak flow occurring during day shift;

residential water use in the new home is expected to be 10% less than in the current residences because of the installation of water-saving appliances and fixtures. Compute future average, peak, and min. design flowrates. Assume that the ratio of min. to ave. flowrate is 0.35 for residential min. flow rates and the industrial plant is shut down one day a week.

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Solution

1. **Compute the present and future wastewater flowrates**

- For present conditions, compute the ave. domestic flowrate excluding infiltration

  Infiltration: 15,000□25 gal/capita/day=375,000 gal/day

  Domestic: Total ave. flow - Infiltration

  = 1,600,000 - 375,000 = 1,225,000 gal/day

- Compute present per capita flowrate

  Per capita flow rate = 1,225,000 □ 15,000 persons

  = 81.7 gal/capita/day

- Future conditions: 10% reduction

  Future flow rate = 81.7 □ 0.9 = 73.5 gal/capita/day

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Solution - continued

2. **Compute future ave. flowrate**

a. Existing residents = 1,225,000 GPD

b. Future residents = 10,000 □ 73.5 = 735,000 GPD

c. Day students = 1,000 □ 15 gal/capita/day = 15,000 GPD

d. Industrial flow (given) = 220,000 GPD

e. Infiltration = 25,000 □ 25 gal/capita/day = 625,000 GPD

Total future flow rate = 2,820,000 GPD = <u>2.82 Mgal/day</u>

3. **Compute min. flow rate**

a. Residential min. flowrate = 0.35 □ 1.6 = 0.56 Mgal/day

b. Industrial min. flowrate = 0 Mgal/day

Total min. flow rate = <u>0.56 Mgal/day</u>

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Solution - continued

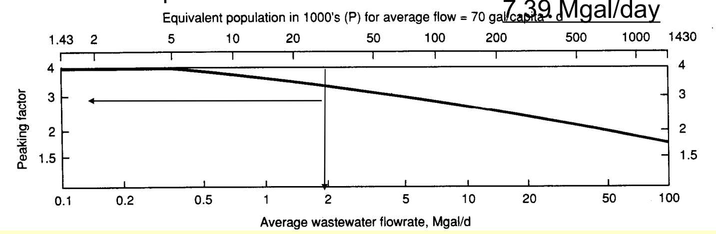
4. **Compute future peak flow rate**

a. Peak hourly = 1.975 Mgal/day □ 3.1 = 6.12 Mgal/day

b. Industrial peak (given) = 0.33 Mgal/day

c. Infiltration = 25,000 □ 37.5 gal/capita/day□ = 0.94 Mgal/day

Total future peak flowrate = 7.39 Mgal/day



Flow Equalization

- **To overcome operational problems caused by flowrate variations**
- **To improve the performance of the downstream processes**
- **To reduce the size and cost of downstream treatment facilities**

Principal Applications

- **Dry-weather flows**
- **Wet-weather flows from separate sanitary sewers**
- **Combined stormwater and sanitary wastewater flows**

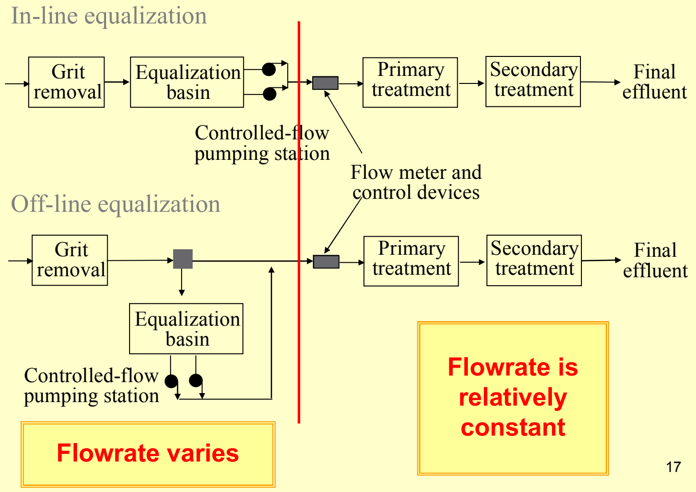
Principal Benefits

- Enhanced biological treatment because of reduced shock loadings, dilution of inhibiting substances, and stable pH
- Improved effluent quality and thickening performance of secondary sedimentation tanks due to constant solids loading
- Reduced effluent-filtration surface-area requirements, improved filter performance, and uniform filter-backwash cycle
- Improved chemical feed control and process reliability by damping mass loading
- Attractive option for upgrading the performance of overloaded treatment plants

Disadvantages of flow equalization

- Relatively large land areas or sites are needed;
- Equalization facilities may have to be covered for odor control near residential areas;
- Additional operation and maintenance is required;
- Capital cost is increased.

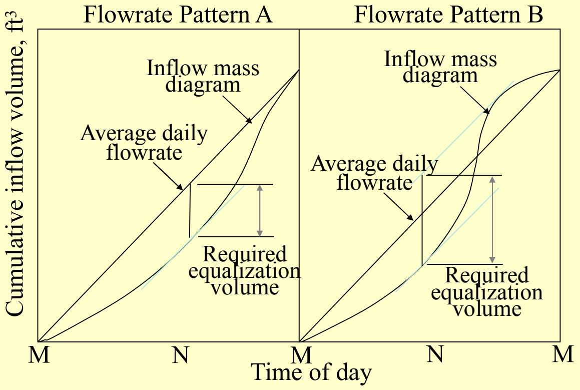
Theoretical Analysis



Design Considerations

- **Location of equalization facilities**
  - **Sufficient mixing to prevent solids deposition**
  - **Concentration variations**
  - **Aeration to prevent odor problems**
- **Type of equalization flow sheet**
  - **in-line**
  - **off-line**
- **Required basin volume**
- **Control of potential odors**
- **Deposition of solids**

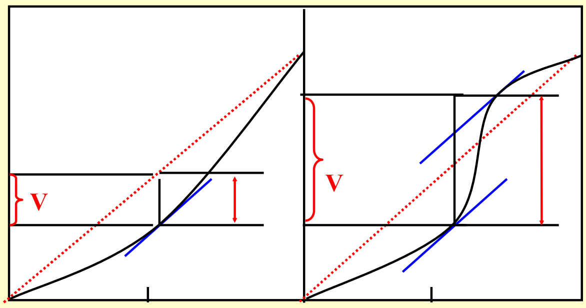
Volume Requirement



Design volume = 1.1~1.2 □ Theoretical volume

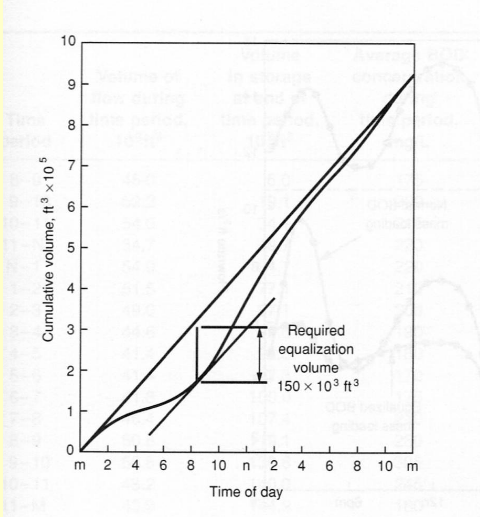
Volume requirement

Cumulative inflow volume



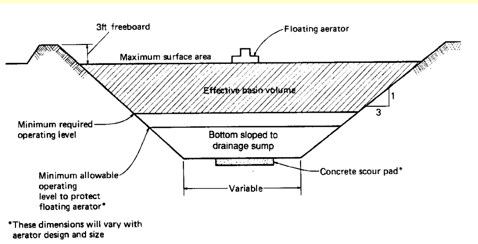
Time period	Average flowrate during time period, ft^3/s	Average BOD concentration during time period, mg/L	Cumulative volume flow at end time period, $10^3 ft^3$	BOD mass loading during time period, lb/hr
	Given data		Derived data	
M–1	9.7	150	34.9	329
1–2	7.8	115	63.0	202
2–3	5.8	75	83.9	98
3–4	4.6	50	100.5	52
4–5	3.7	45	113.8	37
5–6	3.5	60	126.4	47
6–7	4.2	90	141.5	85
7–8	7.2	130	167.4	211
8–9	12.5	175	212.4	492
9–10	14.5	200	264.6	652
10–11	15.0	215	318.6	725
11–N	15.2	220	373.3	752
N–1	15.0	220	427.3	742
1–2	14.3	210	478.8	675
2–3	13.6	200	527.8	612
3–4	12.4	190	572.4	530
4–5	11.5	180	613.8	466
5–6	11.5	170	655.2	440
6–7	11.6	175	697.0	457
7–8	12.9	210	743.4	609
8–9	14.1	280	794.2	888
9–10	14.1	305	844.9	967
10–11	13.4	245	893.2	738
11–M	12.2	180	937.1	494
Average	10.8			471

Note: $ft^3/s \times 0.0283 = m^3/s$
$ft^3 \times 0.0283 = m^3$
$lb \times 0.4536 = kg$



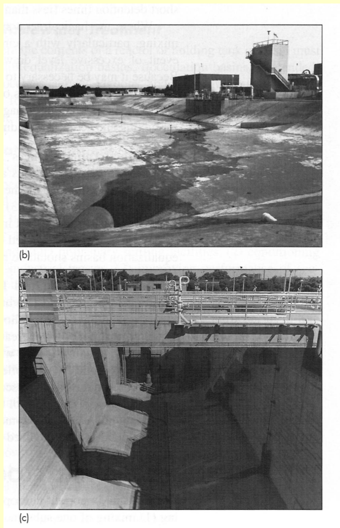
Basin Construction

- Construction materials: earthen, concrete, or steel



- Basin geometry: a complete-mix reactor
- Operational appurtenances: facilities for flushing any solids and grease, emergency overflow in case of pump failure, a high water takeoff for the removal of floating materials and foam, and water sprayer

Equalization tank



Mixing and Air Requirement

- To minimize mixing requirement, install grit chamber ahead of equalization basins where possible.
- Mixing requirements for medium-strength municipal wastewater with SS of 220 mg/L: 0.02~0.04 hp/10^3 gal of storage (0.004~0.0088 kW/m^3)
- Air supply: 1.25~2 $ft^3/10^3$ gal·min (0.01~0.015 m^3/m^3·min)
- If equalization tanks are located after primary sedimentation tanks, aeration may not be required.
- For mixing and aeration, use mechanical aerators.
- Min. operating levels for floating aerators: > 1.7 m.
- Pumping facilities are required.
- Provide a flow-measuring device on the outlet