



# CE 3372 WATER SYSTEMS DESIGN

DEMAND ESTIMATION PART 2 (FALL 2020)

# WATER USAGE

- The forecasting helps establish the target population to be served, next the use per person needs to be established.
- Components include:
  - Average Daily Demand (by user category)
  - Hourly Variation
  - Fire Demand

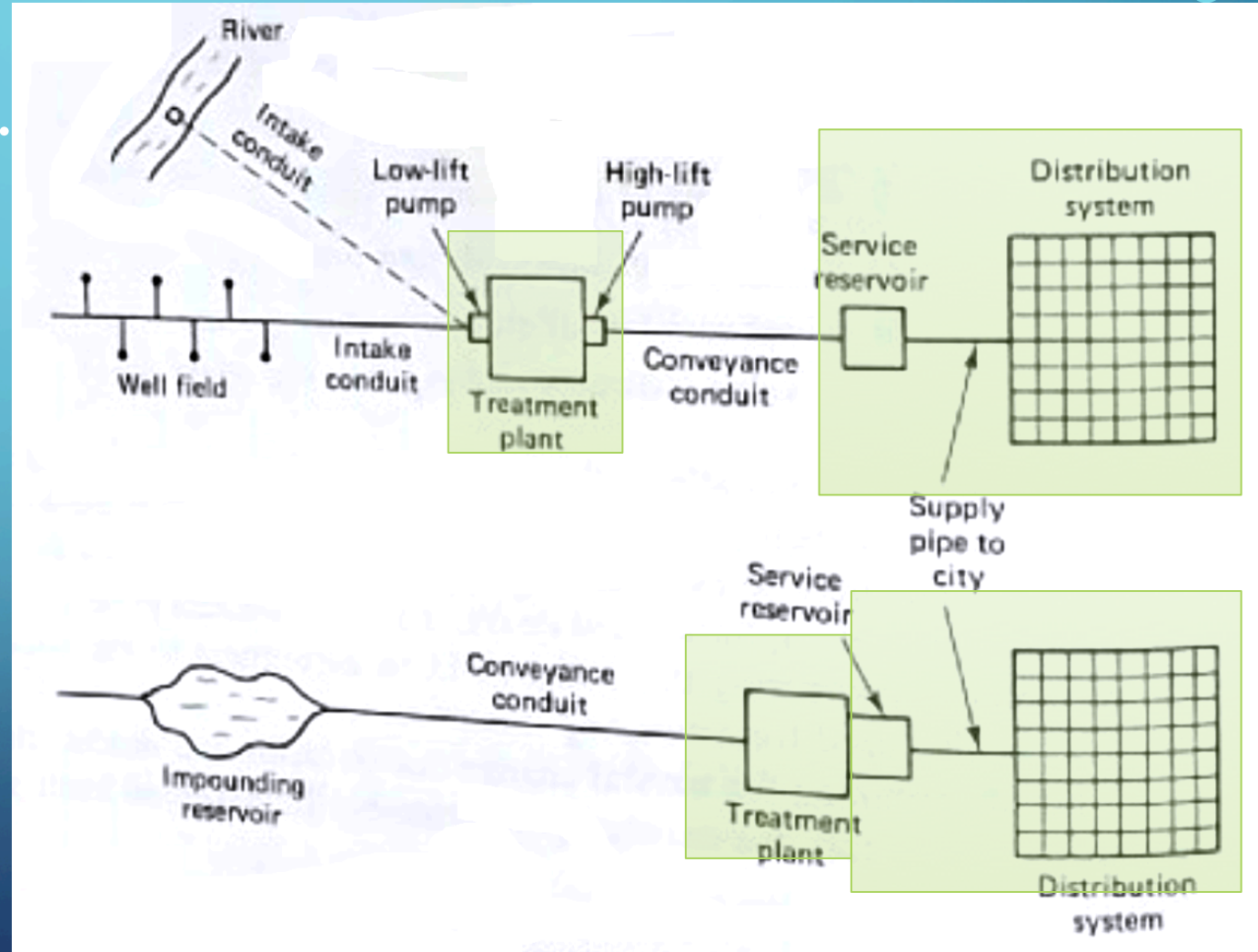
# PER CAPITA WATER USAGE – DESIGN LIFE

- Design life varies by system component (or statute).
- Maintenance/replacement needs to be planned for components that will fail within the overall design (service) life



# MAJOR COMPONENTS

- Components differ by system type.
- For example consider the two systems in the figure – there are some common components, however each system will have unique components to consider.





Structure	Design Period* (years)	Required Capacity
1. Source of supply		
a. River	Indefinite	Maximum daily (requirements)
b. Wellfield	10–25	Maximum daily
c. Reservoir	25–50	Average annual demand
2. Conveyance		
a. Intake conduit	25–50	Maximum daily
b. Conduit to treatment plant	25–50	Maximum daily
3. Pumps		
a. Low-lift	10	Maximum daily plus one reserve unit
b. High-lift	10	Maximum hourly plus one reserve unit
4. Treatment plant	10–15	Maximum daily
5. Service reservoir	20–25	Working storage (from hourly demand and average pumping) plus fire demand plus emergency storage
6. Distribution		
a. Supply pipe or conduit	25–50	} Greater of (1) maximum daily plus fire demand or (2) maximum hourly requirement
b. Distribution grid	Full development	

# AVERAGE DAILY USAGE

- Residential

- Water for drinking, landscape, swimming, fires, street cleaning, etc.
- Usually two demand peaks (morning and evening)

- Commercial

- Motels, hotels, offices, shopping centers
- Usually less peak demand and less varied than residential

- Industrial

- Water for fabrication, cooling, petroleum refining, etc.
- Water use depends on type of industry



# AVERAGE DAILY USAGE

- Estimation tools:
  - USGS Circular 1200
  - Authorative sources
  - Approximation (for preliminary design)
  - Per-connection calculation

## ESTIMATED USE OF WATER IN THE UNITED STATES IN 1995

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U.S. GEOLOGICAL SURVEY CIRCULAR 1200



# USGS CIRCULAR 1200

**Table 4. Total water withdrawals by water-use category and State, 1995**

[Figures may not add to totals because of independent rounding. All values in million gallons per day]

STATE	PUBLIC SUPPLY	DOMESTIC		COMMER- CIAL	IRRIGATION	LIVESTOCK	INDUSTRIAL		MINING		THERMOELECTRIC		TOTAL	
	Fresh	Fresh	Fresh	Fresh	Fresh	Fresh	Fresh	Saline	Fresh	Saline	Fresh	Saline	Fresh	Saline
Alabama	813	62	4.9	139	129	733	0	11	9.1	5,200	0	7,090	9.1	
Alaska	81	8.6	11	6	5	55	1.8	24	116	31	0	211	117	
Arizona	807	39	21	5,670	32	39	0	144	14	62	0	6,820	14	
Arkansas	381	38	100	5,940	354	187	0	1	0	1,770	0	8,800	0	
California	5,620	120	385	28,900	459	538	36	76	151	205	9,450	36,300	9,640	
Colorado	705	27	8.6	12,700	59	123	0	52	17	114	0	13,800	17	
Connecticut	393	55	27	28	1.4	9.6	0	1.7	0	760	3,180	1,280	3,180	
Delaware	89	12	2.6	48	4.1	61	3.2	0	0	534	740	752	743	
D.C.	0	0	0	0	0	0	0	0	0	0	9.7	0	10	0
Florida	2,070	297	50	3,470	56	345	8.0	296	0	636	11,000	7,210	11,000	
Georgia	1,150	99	46	722	48	633	32	12	0	3,040	33	5,750	64	
Hawaii	214	3.7	46	652	10	19	9	5	0	67	903	1,010	922	
Idaho	189	65	306	13,000	1,460	47	0	29	0	0	0	15,100	0	
Illinois	1,820	129	104	180	56	452	0	50	25	17,100	0	19,900	25	
Indiana	669	115	93	116	46	2,270	0	137	0	5,690	0	9,140	0	
Iowa	373	45	43	39	110	258	0	43	0	2,120	0	3,030	0	
Kansas	370	24	5.2	3,380	109	53	0	24	0	1,270	0	5,240	0	
Kentucky	496	25	22	12	46	347	0	28	0	3,440	0	4,420	0	
Louisiana	638	39	11	769	325	2,580	0	1.8	0	5,480	0	9,850	0	
Maine	100	35	11	27	1.9	11	0	5.0	0	30	105	221	105	
Maryland	834	73	24	62	35	65	261	5.2	0	360	6,000	1,460	6,270	
Massachusetts	725	34	12	82	10	85	0	3.2	0	196	4,370	1,150	4,370	
Michigan	1,300	194	41	227	14	1,850	3.6	58	8	8,370	0	12,100	4.4	
Minnesota	485	88	66	157	62	140	0	298	0	2,090	0	3,390	0	
Mississippi	344	33	18	1,740	396	290	0	3.7	0	263	112	3,090	112	
Missouri	699	58	14	567	76	39	0	24	0	5,550	0	7,030	0	
Montana	143	18	0	8,550	52	60	0	6.6	13	22	0	8,850	13	
Nebraska	286	42	21	7,550	142	30	0	141	4.7	2,350	0	10,500	4.7	
Nevada	468	11	21	1,640	5.7	15	0	68	11	27	30	2,260	42	
New Hampshire	98	32	30	6.3	8	43	0	7.0	0	229	877	446	877	
New Jersey	1,040	86	18	125	1.5	201	195	90	0	580	3,780	2,140	3,980	
New Mexico	311	26	20	2,990	30	8.3	0	61	0	56	0	3,510	0	
New York	3,000	144	200	30	34	259	0	45	16	6,570	6,490	10,300	6,500	
North Carolina	769	172	7.6	239	297	369	0	16	0	5,860	1,550	7,730	1,560	
North Dakota	73	12	2	117	24	11	0	5.8	0	880	0	1,120	0	
Ohio	1,420	140	68	27	27	557	0	93	0	8,190	0	10,500	0	
Oklahoma	567	30	23	864	147	21	0	5.4	259	124	0	1,780	259	
Oregon	504	68	756	6,170	23	378	0	1.2	0	9.0	0	7,910	0	
Pennsylvania	1,550	181	30	16	55	1,680	0	252	0	5,920	0	9,680	0	
Rhode Island	114	7.3	1.5	2.3	3.6	1.1	0	6.2	0	0	275	136	275	
South Carolina	543	71	1.7	52	25	700	0	2.9	0	4,810	0	6,200	0	
South Dakota	88	9.4	10	269	46	5.1	0	27	0	5.4	0	460	0	
Tennessee	777	54	20	24	37	863	0	5.5	0	8,300	0	10,100	0	
Texas	3,290	130	44	9,450	315	1,300	996	211	409	9,590	3,870	24,300	5,280	
Utah	497	9.4	3.8	3,530	108	86	1	16	150	48	6.7	4,300	157	
Vermont	47	19	26	3.9	5.3	9.4	0	3.0	0	453	0	565	0	
Virginia	786	125	41	30	36	516	67	39	0	3,890	2,730	5,470	2,800	
Washington	1,180	125	24	6,470	34	611	38	3.5	0	376	0	8,820	38	
West Virginia	176	41	46	0	18	1,320	0	11	5	3,010	0	4,620	5	
Wisconsin	600	92	17	169	92	441	0	12	0	5,830	0	7,250	0	
Wyoming	90	10	1.6	6,590	25	2.8	0	96	18	220	0	7,040	18	
Puerto Rico	431	12	2.7	107	6.3	11	0	4.2	0	2.2	2,260	576	2,260	
Virgin Islands	6.5	1.4	8	0	1	3.0	17	0	0	0	173	12	190	
Total	40,200	3,390	2,890	134,000	5,490	20,700	1,660	2,560	1,210	132,000	57,900	341,000	60,800	

- Contains maps and tables by location
- Useful gross estimate tool

# AVERAGE DAILY USE (APPROXIMATIONS)

- Water Distribution Systems "Water Distribution Systems" in Land Development Handbook, Ed. S.O. Dewberry, Dewberry Inc., McGraw-Hill -- has tables similar to:

Use	Average Use (gpcd) <sup>a</sup>	Percent of Total
Household	60	40
Commercial	20	13
Industrial	45	30
Public	15	10
Loss	10	7
Total	150	100

# PER-CONNECTION (PLUMBER ESTIMATE)

- How Much Water Can You Actually Get?
  - Flow Rates are measured in gallons per minute (gpm).
  - For our purposes, we will talk about the amount of water that you can get through a pipe at a velocity of 8 feet per second (a standard velocity used to engineer a plumbing system).
- Plumbing diameter will limit the flow rate you can get – the larger the pipe, the more water you can get. A home with 1" plumbing can use substantially more water than a home with 3/4" plumbing.

Inside home

## Flow Rates for Type M Copper







1/2" .....	8.0 gpm
3/4" .....	13.5 gpm
1" .....	21.0 gpm
1.25" .....	32.0 gpm
1.5" .....	46.0 gpm
2" .....	80.0 gpm
2.5" .....	120.0 gpm
3" .....	175.0 gpm
4" .....	280.0 gpm
5" .....	500.0 gpm
6" .....	700.0 gpm

Meter to house



# PER-CONNECTION (PLUMBER ESTIMATE)

- 1. Think about the maximum number of fixtures and appliances you might operate at the same time.
- 2. Look at the chart to see how many gallons per minute each device requires.
- 3. Add up the flow rates for all the devices you selected.
- You just figured out the **PEAK FLOW RATE** that you need.
- Now, think about your continual water use, or water use that may run for more than 10 minutes. Add up the fixtures again, and you just calculated your **SERVICE FLOW RATE**.

	Faucets <b>2.5 - 3.0gpm</b>
	Toilets <b>2.2 - 5.0gpm</b>
	Bathtubs <b>4.0 - 8.0gpm</b>
	Shower <b>2.5 - 5.0gpm</b>
	Dishwasher <b>2.0 - 3.0gpm</b>
	Washing Machine <b>4.0 - 5.0gpm</b>

Flow Rate Guide

# PER-CONNECTION (RURAL ESTIMATE)

Table 2. Minimum flow rates (GPM) for homes based on number of bedrooms and bathrooms. (From Private Water Systems Handbook, 1992.)

# of bedrooms in home	Number of bathrooms in home			
	1	1.5	2	3
2	6 GPM	8 GPM	10 GPM	
3	8 GPM	10 GPM	12 GPM	
4	10 GPM	12 GPM	14 GPM	16 GPM
5		13 GPM	15 GPM	17 GPM
6			16 GPM	18 GPM

- <http://extension.psu.edu/natural-resources/water/drinking-water/best-practices/water-system-planning-estimating-water-use>

# PER-CONNECTION (TCEQ)

§290.45 Minimum Water System Capacity Requirements TCEQ Publication RG-195

**Table A**

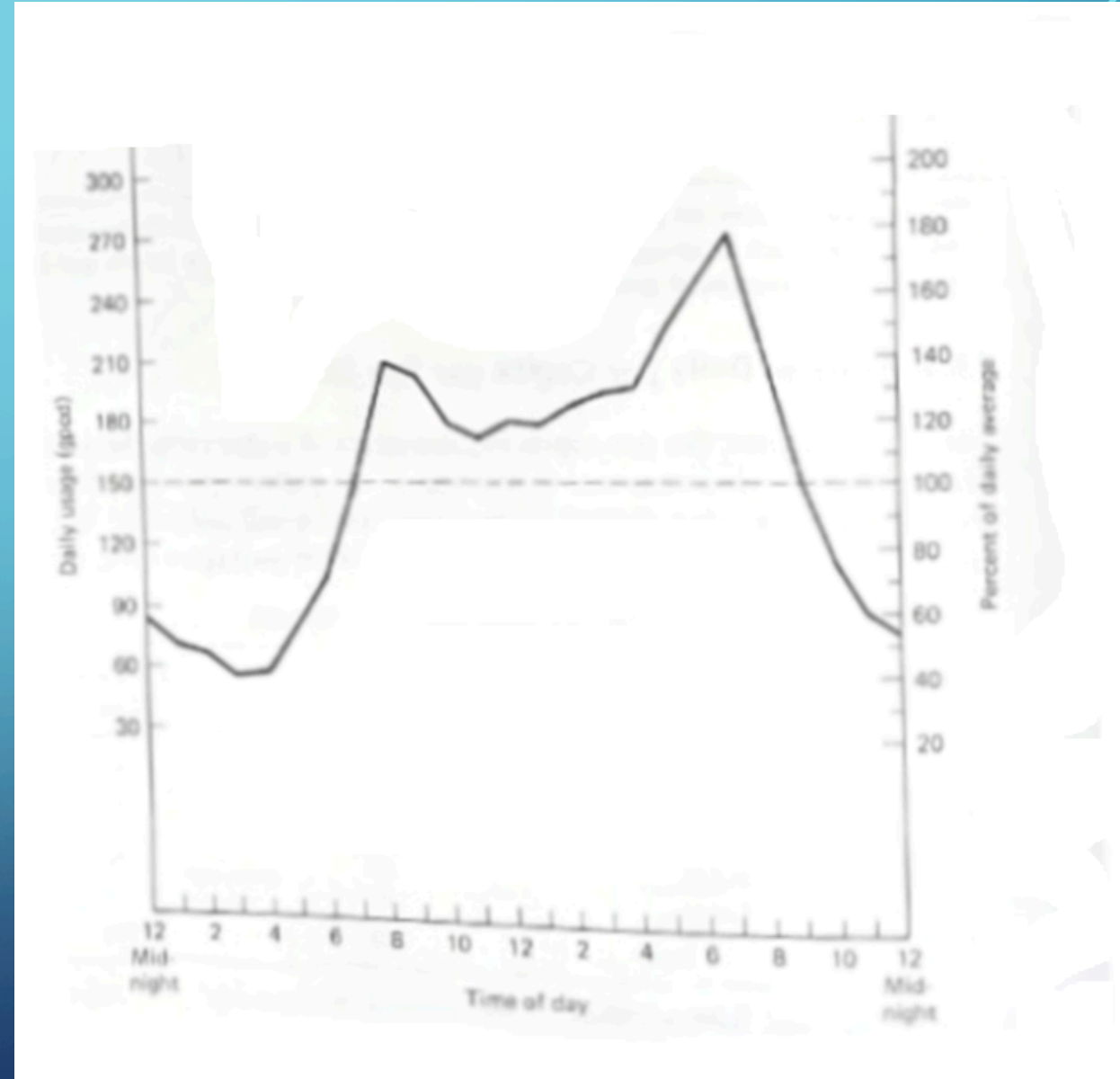
<b>Type of Establishment</b>	<b>Gallons/Person/Day</b>
Restaurants	18
Schools without cafeterias, gymnasiums, or showers	18
Schools with cafeterias, but no gymnasiums or showers	24
Schools with cafeterias, gymnasiums, and showers	30
Youth camps without flush toilets, showers, or dining halls	6
Youth camps with flush toilets, but no showers or dining halls	24
Youth camps with flush toilets, showers, and dining halls	42
Office buildings	18
Hospitals (based on number of beds)	720
Institutions, other than hospitals	240
Factories (exclusive of industrial processes)	24
Parks	6
Swimming pools	12
Country clubs	120
Airports (per passenger)	6
Self-service laundries	60
Service stations/stores	12

It should be noted that this table is used to determine minimum capacities only and that the overriding criteria will be the ability of the system to maintain a minimum pressure of 35 psi under normal operating conditions. Minimum distribution pressure shall not be less than 20 psi at any time.



# USAGE VARIATION (WITHIN A DAY)

- The average estimates are for long-duration (years) usage.
- Use changes with seasons, days within a week, and special cases (the big flush at half-time during the Superbowl)



## USAGE VARIATION (WITHIN A DAY)

- In absence of any supporting data one can employ a rule-of-thumb estimate

$$\%U = \frac{180\%}{T^{0.1}}$$

- $T$  is in units of days. The rule-of-thumb is intended for use over a time frame for 1 hours up to 365 days.

# FIRE DEMAND

- Fire usage on an annual basis is probably negligible, but when fire demand arises the rate of withdrawal is high.
- Designers are required to design and build the system to be able to provide fire demand (hence service reservoirs will have excess capacity expressly to supply fire flow!)



# FIRE DEMAND

- Required flow rates are by:
  - Statute (consider the requirement in the Houston IDM for a fire hydrant)
  - Insurance organizations, for example:

$$Q_{fire,GPM} = 1020\sqrt{P}(1 - 0.01\sqrt{P})$$

$P$  = population, thousands

# INDUSTRIAL DEMAND

- Large industries usually supply their own water
- If the community will supply the industry, then industrial requirements will need to be estimated.

Industry	Average Water Usage
Thermal Power	80 gal/kWh
Steel Production	35,000 gal/ton
Paper Production	50,000 gal/ton
Textile Production	140,000 gal/ton
Carbon (Coke) Production	3,600 gal/ton
Petroleum Refining	770 gal/barrel

# WASTE ASSIMILATION DEMAND

- Treated (or even untreated) wastewater is eventually discharged back into the environment and this demand for assimilative capacity needs to be estimated.
- Many methods are employed – TMDL, DO Sag, and similar modeling approaches.
- Preliminary values can be estimated by a simple linear relationship

$$Q_W = \frac{Q_S}{40 - 0.38 \cdot \%T}$$



# IRRIGATION DEMAND

- Irrigation (Agricultural) – outside scope of this class but use categories are:
  - Biomass (how much is bound in the actual crop)
  - Evapotranspiration – Consumptive
  - Farm Losses
  - Conveyance Losses

# OTHER DEMANDS

- Hydropower
  - Run-of-river
  - Storage release
- Navigation
  - Regulation of river
  - Artificial canal
  - Lock-and-Dam