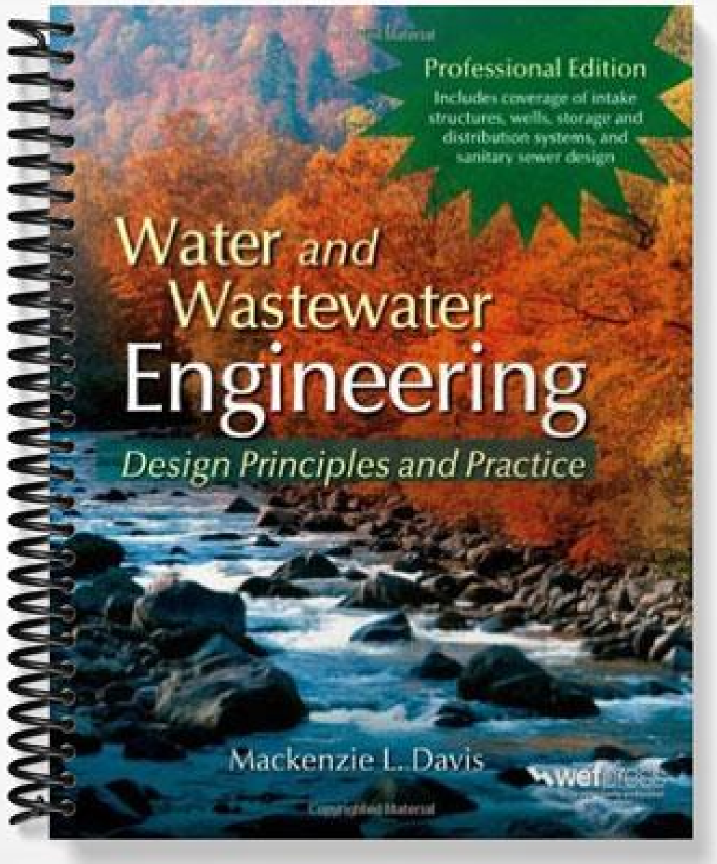
SOLUTIONS MANUAL



CHAPTER 2
SOLUTIONS

2-1 Subdivision Demand

Given: 333 houses; AWWA household average demand

Solution:

a. The AWWA average household water use is 1,320 L/d

b. For the average day

(333 houses)(1,320 L/d) = 439, 560 L/d or 440,000 L/d or 440 m^3/d

c. With the assumption of 3 residents per house the population of the subdivision

(333 houses)(3 people/house) = 999 people

d. From Figure 2-1 and a population of 1,000, read a ratio of 5.5 for peak to average. The maximum day demand is then on the order of

(5.5)(440,000 L/d) = 2,420,000 L/d or 2,400,000 L/d or 2,420 m^3/d

2-2 Gross estimate of average day

Given: Population of 7,000; location is Arizona; Hutson's data applies

Solution:

a. Using the website http://www.usgs.gov search to find
http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table05.html

b. At Arizona find under "public water supply"

population = 4,870,000
total water = 1.08×10^9 gal/d

c. Calculate per capita demand as

$$\frac{1.08x10^9 \ gal/d}{4.87x10^6 \ people} = 221.77 \text{ gal/d x person}$$

d. For 7000 people

$$(221.77 \text{ gal/d x person})(7{,}000 \text{ people})(3.79 \text{ x } 10^{-3} \text{ m}^3/\text{gal}) = 5{,}884 \text{ m}^3$$

2-3 Ski Lift Development

Given: 250 room hotel; restaurant to seat 250 people; dormitory-style quarters for 25 people; hotel occupancy of 2 people/room

Solution:

a. From Table 2-2, assume 190 L/guest x d in hotel. The average water demand is estimated to be

(250 rooms)(2 people/room)(190 L/guest x d) = 95,000 L/d

b. From Table 2-2, assume 35 L/customer x d and that the restaurant serves 3 meals per day per seat

(250 seats)(3 meals)(35 L/customer x d) = 26, 250 L/d

c. From Table 2-4 with 25 staff in dormitory

(150 L/person x d)(25 people) = 3,750 L/d

d. Total average day

95,000 L/d + 26, 250 L/d + 3,750 L/d = 125,000 L/d

2-4 Complete series analysis for Squannacook River

Given: Mean monthly discharge for the period Jan 1951 through Dec 1969

Solution:

a. Using a spreadsheet type in monthly discharge

b. Set up 3 columns:

Rank	Monthly discharge	% of time equaled or exceeded

c. Sort the monthly discharge data in descending order

d. Calculate the % of time equaled or exceeded as

$$\frac{Rank}{Total\ \#\ of\ data\ points} \text{ x } 100\%$$

For example, for the data point with rank no.1 (14.73 m^3/s)

$$\left(\frac{1}{(19\ years)(12\ months)}\right) = \frac{1}{228}$$

% of time equaled or exceeded = $\left(\frac{1}{228}\right)$ (100%) = 0.44%

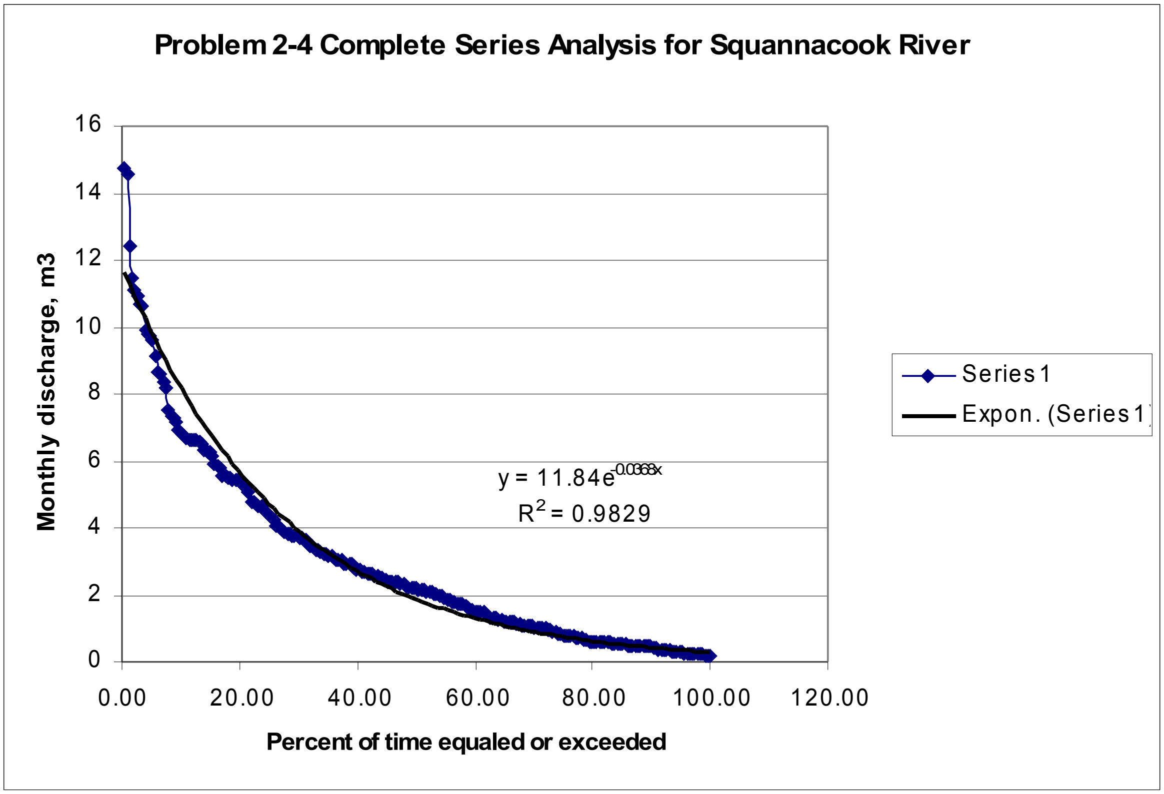
e. Plot mean monthly discharge (y-axis) against % of time (x-axis)

f. From the data columns at 50.0% find the discharge = 2.18 m^3/s

g. The safe yield with a 6.0% restriction is

(0.06)(2.18 m^3/s) = .131 m^3/s

h. The plot of the yield curve is shown below



2-5 Complete series analysis for Clear Fork Trinity River

Given: Mean monthly discharge for the period Oct 1940 through Sep 1970

Solution:

a. Using a spreadsheet type in monthly discharge

b. Set up 3 columns:

Rank	Monthly discharge	% of time equaled or exceeded

c. Sort the monthly discharge data in descending order

d. $\left(\dfrac{1}{(30\,years)(12months)}\right) = \dfrac{1}{360}$

$$\%\text{ of time equaled or exceeded} = \left(\frac{1}{360}\right)(100\%) = 0.246\%$$

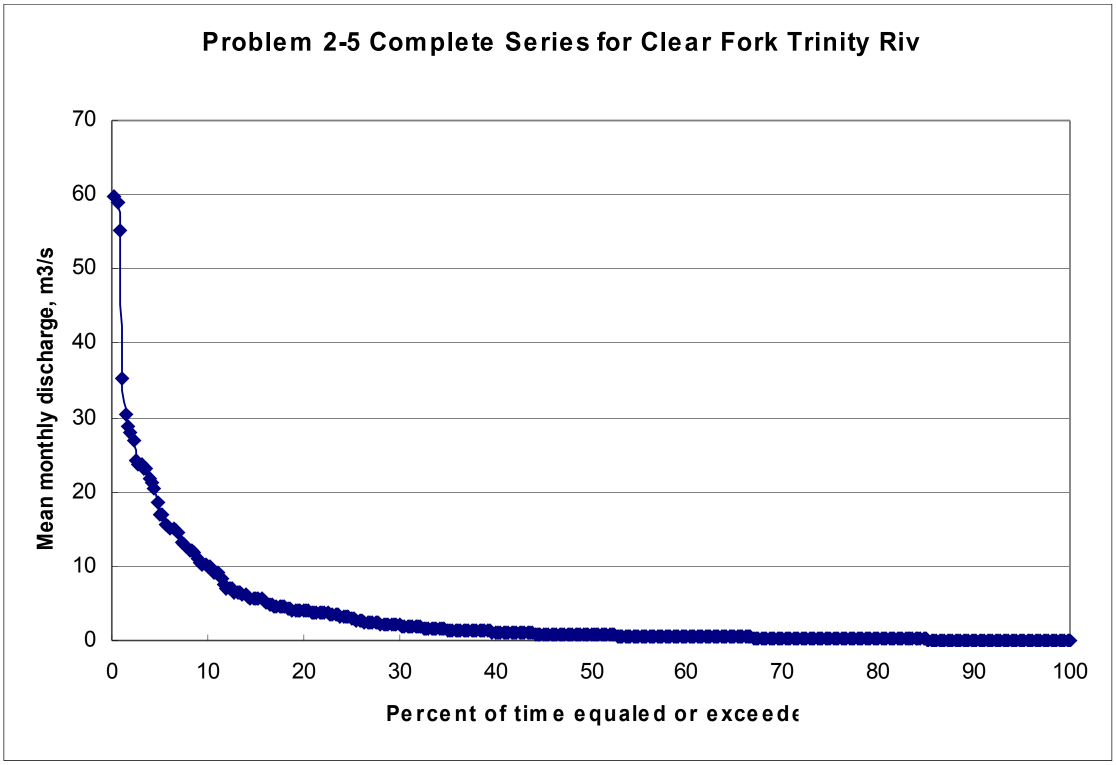
e. Plot mean monthly discharge (y-axis) against % of time (x-axis)

f. From the data column at 50.0% find the discharge = 0.714 m^3/s

g. The safe yield with a 3.0% restriction is

$$(0.03)(0.714\ m^3/s) = 0.021\ m^3/s$$

h. The plot of the yield curve is shown below



2-6 Annual Minima for Clear Fork Trinity River

Given: Mean monthly discharge for the period Oct 1940 through Sep 1970

Solution:

a. Using a spreadsheet type in monthly discharge

b. The data are already arranged by hydrologic year. By convention the first hydrologic year is called the 1941 year.

c. For each hydrologic year find the minimum value.

d. Set up the following columns

Sort	Rank	Return period

e. Perform the sort. Assign the lowest discharge a row of 1.

f. $T = \frac{30+1}{1} = 31$ years

g. The restriction is 3%; set up the columns and calculate

Annual minima	3% of minima

h. By observation, the mean monthly discharge never exceeds 0.021 m^3/s. Thus, storage will be required.

i. The mean annual drought is about 0.06 m^3/s.

Annual Minima for year	Sort	Rank	Return Period, years	Annual Minima by rank	6% of Minima	
0.69	0.18	1	19.00	0.18	0.011	1952
0.29	0.19	2	9.50	0.19	0.011	1953
0.51	0.21	3	6.33	0.21	0.013	1954
0.46	0.22	4	4.75	0.22	0.013	1955
0.4	0.24	5	3.80	0.24	0.014	1956
0.22	0.29	6	3.17	0.29	0.017	1957
0.29	0.29	7	2.71	0.29	0.017	1958
0.59	0.4	8	2.38	0.4	0.024	1959
1.09	0.46	9	2.11	0.46	0.028	1960
0.8	0.46	10	1.90	0.46	0.028	1961
0.5	0.47	11	1.73	0.47	0.028	1962
0.24	0.48	12	1.58	0.48	0.029	1963
0.21	0.5	13	1.46	0.5	0.030	1964
0.19	0.51	14	1.36	0.51	0.031	1965
0.18	0.59	15	1.27	0.59	0.035	1966
0.47	0.69	16	1.19	0.69	0.041	1967
0.48	0.8	17	1.12	0.8	0.048	1968
0.46	1.09	18	1.06	1.09	0.065	1969

2-7 Annual Minima for Squannacook River

Given: Mean monthly discharge for the period Jan 1951 to Dec 1969

Solution:

a. Using a spreadsheet type in monthly discharge

b. Rearrange data into hydrologic years (Oct through Sep). The first 9 months of 1951 and the last 3 months of 1969 cannot be used. The first hydrologic year begins with Oct 1951. By convention it is called the 1952 hydrologic year.

c. For each hydrologic year find the minimum value.

d. Set up the following columns

Sort	Rank	Return period

e. Perform the sort. Assign the lowest discharge a row of 1.

f. Calculate the return period as

$$T = \frac{n+1}{m}$$

For the first value

$$T = \frac{18+1}{1} = 19 \text{ years}$$

g. The restriction is 6%; set up two columns and calculate

Annual minima	6% of minima

h. By observation, the mean monthly discharge never exceeds 0.131 m^3/s. Thus, storage will be required.

i. From the Gumbel plot below, the mean annual drought is between 0.36 and 0.42 m^3/s. The scatter of the data precludes a more definitive value.

Annual Minima	Sort	Rank	Return Period	Annual Minima	3% of Minima

for year				by rank		
0	0	1	31.000	0	0	1941
0.595	0	2	15.500	0	0	1942
0	0	3	10.333	0	0	1943
0	0	4	7.750	0	0	1944
0.162	0	5	6.200	0	0	1945
0.153	0	6	5.167	0	0	1946
0.054	0	7	4.429	0	0	1947
0	0	8	3.875	0	0	1948
0	0.008	9	3.44	0.008	0.000	1949
0.614	0.019	10	3.10	0.019	0.001	1950
0	0.024	11	2.82	0.024	0.001	1951
0	0.03	12	2.58	0.03	0.001	1952
0	0.054	13	2.38	0.054	0.002	1953
0.008	0.068	14	2.21	0.068	0.002	1954
0.024	0.097	15	2.07	0.097	0.003	1955
0.019	0.14	16	1.94	0.14	0.004	1956
0.03	0.153	17	1.82	0.153	0.005	1957
0.456	0.162	18	1.72	0.162	0.005	1958
0.097	0.169	19	1.63	0.169	0.005	1959
0.379	0.206	20	1.55	0.206	0.006	1960
0.241	0.236	21	1.48	0.236	0.007	1961
0.236	0.241	22	1.41	0.241	0.007	1962
0.268	0.249	23	1.35	0.249	0.007	1963
0.249	0.268	24	1.29	0.268	0.008	1964
0.351	0.351	25	1.24	0.351	0.011	1965
0.169	0.379	26	1.19	0.379	0.011	1966
0.068	0.456	27	1.15	0.456	0.014	1967
0.144	0.459	28	1.11	0.459	0.014	1968
0.206	0.595	29	1.07	0.595	0.018	1969
0.459	0.614	30	1.03	0.614	0.018	1970

2.8 Continuation of Example 2-3

Given: Example 2-3

Solution:

Month	Q_{in}, m^3/s	$(0.05)(Q_{in})$	$(0.05)(Q_{in})(\delta t)$ 10^6 m^3	Qout, m^3/s	(Qout)(δt) 10^6 m^3	ΔS 10^6 m^3	$\Sigma(\Delta S)$ 10^6 m^3
1996							
Dec							-0.517

1997							
Jan	13.8	0.690	1.848	0.25	0.670	1.178	
Feb	6.91	0.346	0.836	0.25	0.605	0.231	
Mar	12.9	0.645	1.728	0.25	0.670	1.058	
Apr	11.3	0.565	1.464	0.25	0.648	0.816	
May	3.74	0.187	0.501	0.25	0.670	-0.169	-0.169
Jun	1.98	0.099	0.257	0.25	0.648	-0.391	-0.560
Jul	1.33	0.067	0.178	0.25	0.670	-0.491	-1.052
Aug	1.16	0.058	0.155	0.25	0.670	-0.514	-1.566
Sep	0.85	0.043	0.110	0.25	0.648	-0.538	-2.104
Oct	2.63	0.132	0.352	0.25	0.670	-0.317	-2.421
Nov	6.49	0.325	0.841	0.25	0.648	0.193	-2.228
Dec	5.52	0.276	0.739	0.25	0.670	0.070	-2.158
1998							
Jan	4.56	0.228	0.611	0.25	0.670	-0.059	-2.217
Feb	8.47	0.424	1.025	0.25	0.605	0.420	-1.798
Mar	59.8	2.990	8.008	0.25	0.670	7.339	
Apr	9.8	0.490	1.270	0.25	0.648	0.622	
May	6.06	0.303	0.812	0.25	0.670	0.142	
Jun	5.32	0.266	0.689	0.25	0.648	0.041	
Jul	2.14	0.107	0.287	0.25	0.670	-0.383	-0.383
Aug	1.98	0.099	0.265	0.25	0.670	-0.404	-0.787
Sep	2.17	0.109	0.281	0.25	0.648	-0.367	-1.154
Oct	3.4	0.170	0.455	0.25	0.670	-0.214	-1.368
Nov	8.44	0.422	1.094	0.25	0.648	0.446	-0.923
Dec	11.5	0.575	1.540	0.25	0.670	0.870	-0.052
1999							
Jan	13.8	0.690	1.848	0.25	0.670	1.178	
Feb	29.6	1.480	3.580	0.25	0.605	2.976	
Mar	38.8	1.940	5.196	0.25	0.670	4.526	
Apr	13.5	0.675	1.750	0.25	0.648	1.102	
May	37.2	1.860	4.982	0.25	0.670	4.312	
Jun	22.8	1.140	2.955	0.25	0.648	2.307	
Jul	6.94	0.347	0.929	0.25	0.670	0.260	
Aug	3.94	0.197	0.528	0.25	0.670	-0.142	-0.142
Sep	2.92	0.146	0.378	0.25	0.648	-0.270	-0.412
Oct	2.89	0.145	0.387	0.25	0.670	-0.283	-0.694
Nov	6.74	0.337	0.874	0.25	0.648	0.226	-0.469
Dec	3.09	0.155	0.414	0.25	0.670	-0.256	-0.724
2000							
Jan	2.51	0.126	0.336	0.25	0.670	-0.333	-1.058
Feb	13.1	0.655	1.641	0.25	0.605	1.036	-0.021
Mar	27.9	1.395	3.736	0.25	0.670	3.067	
Apr	22.9	1.145	2.968	0.25	0.648	2.320	

May	16.1	0.805	2.156	0.25	0.670	1.487	
Jun	9.77	0.489	1.266	0.25	0.648	0.618	
Jul	3.44	0.172	0.461	0.25	0.670	-0.209	-0.209
Aug	1.42	0.071	0.190	0.25	0.670	-0.479	-0.688
Sep	1.56	0.078	0.202	0.25	0.648	-0.446	-1.134
Oct	1.83	0.092	0.245	0.25	0.670	-0.425	-1.559
Nov	2.58	0.129	0.334	0.25	0.648	-0.314	-1.872
Dec	2.27	0.114	0.304	0.25	0.670	-0.366	-2.238
2001							
Jan	1.61	0.081	0.216	0.25	0.670	-0.454	-2.692
Feb	4.08	0.204	0.494	0.25	0.605	-0.111	-2.803
Mar	14	0.700	1.875	0.25	0.670	1.205	
Apr	12.8	0.640	1.659	0.25	0.648	1.011	The reservoir is full

The maximum storage required remains at 3.695 x 10^6 m^3 from FEB 1996

The maximum storage required for this problem is 2.803 x 10^6 m^3 in FEB 2001

2.9 Storage for the Hoko River

Given: Mean monthly discharge data for the period Jan 1963 through Dec 1973

Solution:

Month	Q_{in}, m^3/s	$(0.05)(Q_{in})$	$(0.05)(Q_{in})(\delta t)$ 10^6 m^3	Qout, m^3/s	(Qout)(δt) 10^6 m^3	ΔS 10^6 m^3	$\Sigma(\Delta S)$ 10^6 m^3
1969							
Jan	17.2	1.032	2.764	0.35	0.937	1.827	
Feb	18.5	1.110	2.685	0.35	0.847	1.839	
Mar	12.9	0.774	2.073	0.35	0.937	1.136	
Apr	12.8	0.768	1.991	0.35	0.907	1.083	
May	3.74	0.224	0.601	0.35	0.937	-0.336	-0.336
Jun	2.23	0.134	0.347	0.35	0.907	-0.560	-0.897
Jul	1.19	0.071	0.191	0.35	0.937	-0.746	-1.643
Aug	0.81	0.049	0.130	0.35	0.937	-0.807	-2.450
Sep	6.15	0.369	0.956	0.35	0.907	0.049	-2.401
Oct	7.84	0.470	1.260	0.35	0.937	0.322	-2.079
Nov	9.15	0.549	1.423	0.35	0.907	0.516	-1.563
Dec	15.9	0.954	2.555	0.35	0.937	1.618	

1970							
Jan	17.3	1.038	2.780	0.35	0.937	1.843	
Feb	12.1	0.726	1.756	0.35	0.847	0.910	
Mar	8.5	0.510	1.366	0.35	0.937	0.429	
Apr	17.7	1.062	2.753	0.35	0.907	1.846	
May	3.85	0.231	0.619	0.35	0.937	-0.319	-0.319
Jun	1.32	0.079	0.205	0.35	0.907	-0.702	-1.021
Jul	0.932	0.056	0.150	0.35	0.937	-0.788	-1.808
Aug	0.708	0.042	0.114	0.35	0.937	-0.824	-2.632
Sep	4.22	0.253	0.656	0.35	0.907	-0.251	-2.883
Oct	7.96	0.478	1.279	0.35	0.937	0.342	-2.541
Nov	13.9	0.834	2.162	0.35	0.907	1.255	-1.287
Dec	25.4	1.524	4.082	0.35	0.937	3.144	
1971							
Jan	32.7	1.962	5.255	0.35	0.937	4.318	
Feb	21	1.260	3.048	0.35	0.847	2.201	
Mar	21.1	1.266	3.391	0.35	0.937	2.453	
Apr	8.13	0.488	1.264	0.35	0.907	0.357	
May	3.43	0.206	0.551	0.35	0.937	-0.386	-0.386
Jun	2.83	0.170	0.440	0.35	0.907	-0.467	-0.853
Jul	1.83	0.110	0.294	0.35	0.937	-0.643	-1.497
Aug	0.932	0.056	0.150	0.35	0.937	-0.788	-2.284
Sep	2.22	0.133	0.345	0.35	0.907	-0.562	-2.846
Oct	10.7	0.642	1.720	0.35	0.937	0.782	-2.064
Nov	22.7	1.362	3.530	0.35	0.907	2.623	
Dec	22	1.320	3.535	0.35	0.937	2.598	
1972							
Jan	27.4	1.644	4.403	0.35	0.937	3.466	3.466
Feb	26.9	1.614	4.044	0.35	0.847	3.197	6.663
Mar	25.4	1.524	4.082	0.35	0.937	3.144	
Apr	14.6	0.876	2.271	0.35	0.907	1.363	
May	3	0.180	0.482	0.35	0.937	-0.455	
Jun	1	0.060	0.156	0.35	0.907	-0.752	
Jul	5.32	0.319	0.855	0.35	0.937	-0.082	-0.082
Aug	0.841	0.050	0.135	0.35	0.937	-0.802	-0.885
Sep	2	0.120	0.311	0.35	0.907	-0.596	-1.481
Oct	1.14	0.068	0.183	0.35	0.937	-0.754	-2.235
Nov	11.8	0.708	1.835	0.35	0.907	0.928	-1.307
Dec	37.8	2.268	6.075	0.35	0.937	5.137	3.830
1973							
Jan	28	1.680	4.500	0.35	0.937	3.562	7.392
Feb	9.23	0.554	1.340	0.35	0.847	0.493	7.885
Mar	11.3	0.678	1.816	0.35	0.937	0.879	
Apr	4.13	0.248	0.642	0.35	0.907	-0.265	
May	5.3	0.318	0.852	0.35	0.937	-0.086	

Jun	4.93	0.296	0.767	0.35	0.907	-0.140	
Jul	1.63	0.098	0.262	0.35	0.937	-0.675	-0.675
Aug	0.736	0.044	0.118	0.35	0.937	-0.819	-1.495
Sep	0.81	0.049	0.126	0.35	0.907	-0.781	-2.276
Oct	13.1	0.786	2.105	0.35	0.937	1.168	-1.108
Nov	29.8	1.788	4.634	0.35	0.907	3.727	
Dec	31.5	1.890	5.062	0.35	0.937	4.125	

The maximum storage required is 2.883 x 10^6 m^3 in SEP 1970
Note September 1970 $\Sigma(\Delta S)$ 10^6 m^3 is the maximum deficit

2.10 Eudora's Maximum Sustained Pumping Rate

Given: D = 10.0 m; piezometric surface = 40.0 m above bottom confining layer; medium san aquifier; non-pumping wellis 200.0 m from the pumping well; drawdown at non-pumping well is 1.00 m, the pumping well is 1.0 m in diameter

Solution:

a. From Table 2-9, select hydraulic conductivity (K)' of 1.5 x 10^{-4} m/s

b. Estimate T as

$$T = KD = (1.5 \times 10^{-4}\ m/s)(10\ m) = 1.5 \times 10^{-3}\ m^2/s$$

c. Calculate h_1 and h_2 from the following sketch

SKETCH GOES HERE!

$h_2 = 40.0\ m – 1.0\ m = 39.0\ m$
$h_1 = 10.0\ m$

d. Estimate maximum allowable sustained pumping rate using Equation 2-6

$$Q = \frac{2\pi\left(1.5x10^3\ m^2/s\right)\left(39.0\,m - 10.0m\right)}{\ln\left(\frac{200\,m}{0.5\,m}\right)}$$

$$= \frac{0.27\,m^3/s}{5.99} = 0.0456\ m^3/s \text{ or } 0.046\ m^3/s$$

This is greater than the desired 0.025 m^3/s therefore the larger pumping rate is acceptable.

2.11 Maximum sustained pumping rate in confined aquifer

Given: Well boring log; well diameter = 1.0 m; 2 m safety factor; drawdown 100m for pumping wellis 0.0 m

Solution:

a. From Table 2-9, select hydraulic conductivity of fractured rock which is the aquifer based on the well log K = 5.8 x 10^{-5} m/s

b. Estimate T as

$$T = KD = (5.8 \times 10^{-5}\ m/s)(55\ m) = 0.0032\ m^2/s$$

c. Calculate h_1 and h_2 from the following sketch

SKETCH GOES HERE!

h_2 = 10 m + 2 m + 55 m = 67 m
h_1 = 55 m + 2 m safety = 57 m

$$Q = \frac{2\pi\left(0.0032\,m^2/s\right)\left(67\,m - 57\,m\right)}{\ln\left(\frac{100\,m}{0.5\,m}\right)} = \frac{0.201}{5.30} = 0.038\ m^3/s$$

Estimated maximum sustainable pumping rate is 0.038 m^3/s

2.12 Cumulative frequency distribution for Lake Michigan turbidity

Given: Mean monthly turbidity for 2005 through 2007

Solution:

a. Arrange data and sort in ascending order

b. "Compute percent less than." For example, for start value:

$$\% \text{ less than} = \left(\frac{1}{36}\right) * (100\%) = 2.78\%$$

c. Spreadsheet comparability and plot are on following page

d. The report should note the following:

- About half the time (50%) the variability is between 0.5 and 1.5 NTV. The overall range of variability is more than 10 fold.
- The plant operator will need substantial flexibility in operation to care for this range of variation.
- Because only monthly summaries were provided, a more thorough analysis of daily values may reveal an even greater variation in turbidity. Analysis of daily values is recommended.

	Turbidity, NTU	Sort	Percent Less Than
1	6.89	0.59	2.78
2	4.63	0.59	5.56
3	3.42	0.66	8.33
4	1.40	0.67	11.11
5	1.25	0.73	13.89
6	0.91	0.79	16.67
7	1.18	0.84	19.44
8	0.79	0.87	22.22
9	1.07	0.91	25.00
10	1.06	1.01	27.78
11	5.41	1.06	30.56
12	6.15	1.07	33.33
13	4.26	1.07	36.11
14	2.95	1.09	38.89
15	2.07	1.11	41.67
16	1.56	1.18	44.44
17	1.11	1.25	47.22
18	0.59	1.40	50.00
19	1.01	1.56	52.78
20	0.59	1.68	55.56
21	1.09	2.07	58.33
22	2.70	2.09	61.11
23	1.07	2.31	63.89
24	4.51	2.70	66.67
25	5.76	2.95	69.44
26	4.37	3.42	72.22
27	3.59	3.59	75.00
28	2.31	4.26	77.78
29	0.66	4.37	80.56
30	0.73	4.51	83.33
31	0.84	4.63	86.11
32	0.67	5.41	88.89
33	0.87	5.76	91.67
34	2.09	6.15	94.44
35	1.68	6.20	97.22
36	6.20	6.89	100.00

2.13 Cumulative frequency distribution for Alma river turbidity

Given: Daily turbidity for Alma

Solution:

a. Arrange data and sort in ascending order

b. “Compute percent less than.” For example, for start value:

$$\% \text{ less than} = \left(\frac{1}{31}\right) * (100\%) = 3.23\%$$

c. Spreadsheet comparability and plot are on following page

d. The report should note the following:

- About 65% of the data fall between 2 and 4 NTV. The overall range of turbidity is 30 fold.
- The plant operator will need substantial flexibility in operation to care for this range of variation.
- Because only one month of data was provided, a more thorough analysis is recommended. Analysis of at least one year of daily turbidity is recommended.

Day	Turbidity, NTU	Sort	Percent Less Than
1	11.50	1.95	3.23
2	5.53	1.95	6.45
3	7.40	2.00	9.68
4	5.83	2.03	12.90
5	3.35	2.10	16.13
6	2.80	2.10	19.35
7	3.00	2.15	22.58
8	3.20	2.30	25.81
9	2.75	2.47	29.03
10	2.47	2.63	32.26
11	1.95	2.65	35.48
12	4.00	2.75	38.71
13	63.67	2.77	41.94
14	59.60	2.80	45.16
15	24.33	3.00	48.39
16	12.70	3.20	51.61
17	8.47	3.35	54.84
18	7.10	3.60	58.06
19	6.47	3.77	61.29
20	3.77	4.00	64.52
21	3.60	5.53	67.74
22	2.65	5.83	70.97
23	2.77	6.47	74.19
24	2.63	7.10	77.42
25	2.30	7.40	80.65
26	2.10	8.47	83.87
27	2.03	11.50	87.10
28	2.10	12.70	90.32
29	1.95	24.33	93.55
30	2.15	59.60	96.77
31	2.00	63.67	100.00