CE EN 431
Engineering Hydrology
Winter 1994
Section 1

Lab 8: Runoff Distribution by Unit Hydrograph Principle: Stratford, Wisconsin

Submitted to:
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by
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Contents

Introduction

This report uses streamflow records from King Hill, Idaho. King hill is located in south-west Idaho. I have obtained the following information about the gaging station and watershed at King Hill, Idaho:

- **Location: 43 degrees latitude, 115 degrees, 12 minutes longitude**
- **Area of watershed above gaging station: 35,800 square miles**
- **Type of water stage measurement instrument: Water-stage recorder**
- **Reliability of record: Records are excellent. Record from 1909 to present**
- **Shape of watershed: See contour map in appendix C**
- **Size of watershed: Huge watershed, covering much of eastern and central Idaho**
- **Topography and elevation of watershed: Rugged, mean elevation of 6040 ft**
- **Other factors:** Flow in the Snake River at King Hill is regulated by American Falls Reservoir 168.4 miles upstream. Occasional fluctuation in the river is caused by hydroelectric plants upstream. At times, practically the entire flow is diverted at Milner (upstream) during irrigation season. Lots of the flow at King Hill is derived from springs and seepage entering below Milner. Diversions above the station irrigate about 2.45 million acres.

The American Falls Reservoir, located 168.4 miles upstream from the King Hill gaging station, regulates flow through King Hill. This means there are not large deviations in flows through King Hill from one year to the next.

The purpose of this report was to analyze the daily streamflow records for an entire year at the King Hill gaging station. Using the daily streamflow records at King Hill, I plotted a hydrograph for the year. Using this hydrograph, I plotted the flow duration curve. The resulting graph and values are in appendix C.

Using the flow duration curve, I calculated the output of a power plant with 200 ft. of head and the flow available 60% of the time. Then, I calculated the number of days that water would be available if 75% of the median year average flow was necessary for the project.

Objectives/Procedure

For the objectives and procedure, I have included the lab handout. You can find the lab handout in the appendix.

Results

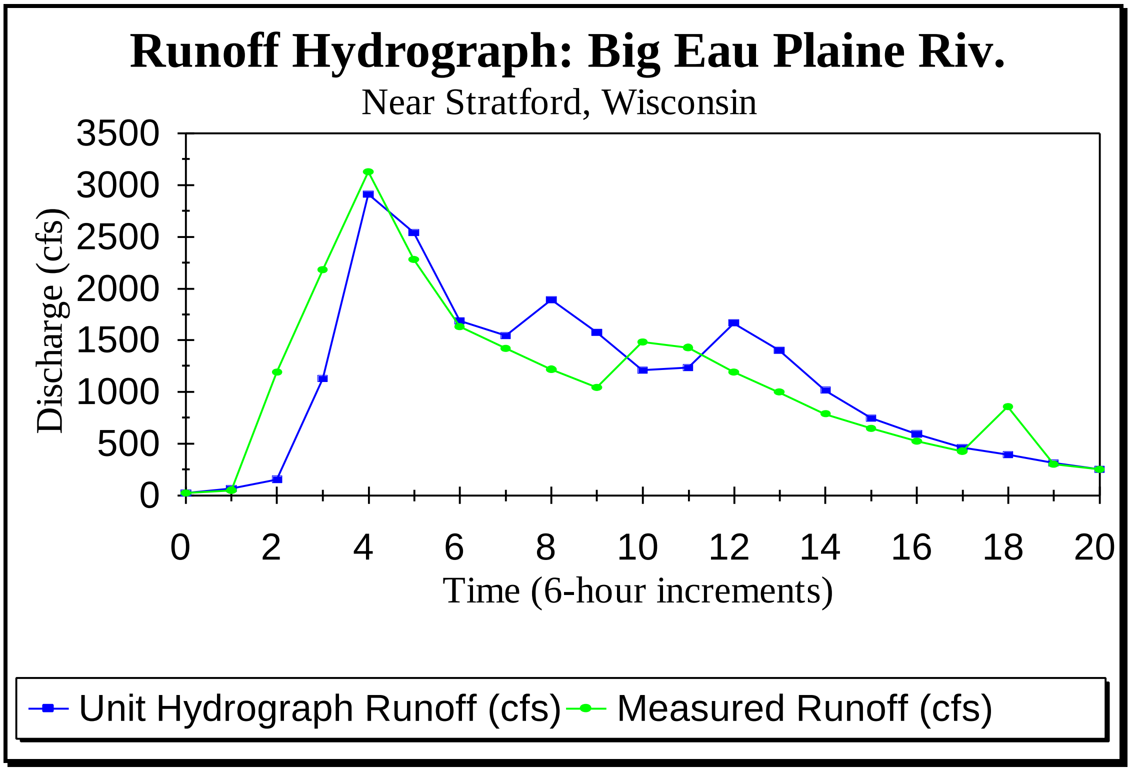

Figure 1: Comparison between unit hydrograph calculations and measured runoff for the Big Eau Plaine River at a gaging station near Stratford, Wisconsin. Hydrograph goes from May 28 at 2100 hours to June 2 at 2100 hours. Storm data and calculations are located below, in tables 1 and 2.

Table 1: Flow data, output from a hydroelectric plant, and irrigation period values collected from the Snake River at King Hill, Idaho. Median water year--1970.

1961 Date	Begin Time	End Time	Peroid	Medford	Marshfield	Theissen Rainfall	Runoff
May 28	2100	300	1	1.88	1.78	1.840	0.73600
May 29	300	900	2	0.00	0.00	0.000	0.00000
May 29	900	1500	3	0.00	0.00	0.000	0.00000
May 29	1500	2100	4	0.00	0.00	0.000	0.00000
May 29	2100	300	5	0.27	0.56	0.386	0.25090
May 30	300	900	6	0.00	0.00	0.000	0.00000
	900	1500	7	0.00	0.00	0.000	0.00000
	1500	2100	8	0.00	0.00	0.000	0.00000
	2100	300	9	0.18	0.70	0.388	0.25220

Time Period (6 hour inc.)	Unit Hydrograph (cfs/in)	Time 1 R1= 0.736	Time 2 R2= 0.2509	Time 3 R3= .2522	Total (cfs)	Base Flow (cfs)	Total + Base Flow (cfs)
0	0	0.00			0.00	25.00	25.00
1	60	44.16			44.16	25.00	69.16
2	180	132.48			132.48	25.00	157.48
3	1500	1104.00			1104.00	25.00	1129.00
4	3920	2885.12	0.00		2885.12	25.00	2910.12
5	3400	2502.40	15.05		2517.45	25.00	2542.45
6	2200	1619.20	45.16		1664.36	25.00	1689.36
7	1550	1140.80	376.35		1517.15	25.00	1542.15
8	1200	883.20	983.53	0.00	1866.73	25.00	1891.73
9	930	684.48	853.06	15.13	1552.67	25.00	1577.67
10	800	588.80	551.98	45.40	1186.18	25.00	1211.18
11	600	441.60	388.90	378.30	1208.80	25.00	1233.80
12	480	353.28	301.08	988.62	1642.98	25.00	1667.98
13	390	287.04	233.34	857.48	1377.86	25.00	1402.86
14	320	235.52	200.72	554.84	991.08	25.00	1016.08
15	250	184.00	150.54	390.91	725.45	25.00	750.45
16	200	147.20	120.43	302.64	570.27	25.00	595.27
17	150	110.40	97.85	234.55	442.80	25.00	467.80
18	120	88.32	80.29	201.76	370.37	25.00	395.37
19	100	73.60	62.73	151.32	287.65	25.00	312.65
20	80	58.88	50.18	121.06	230.12	25.00	255.12
21	60	44.16	37.64	98.36	180.15	25.00	205.15
22	40	29.44	30.11	80.70	140.25	25.00	165.25
23	20	14.72	25.09	63.05	102.86	25.00	127.86
24	10	7.36	20.07	50.44	77.87	25.00	102.87
25	8	5.89	15.05	37.83	58.77	25.00	83.77
26	6	4.42	10.04	30.26	44.72	25.00	69.72
27	4	2.94	5.02	25.22	33.18	25.00	58.18
28	2	1.47	2.51	20.18	24.16	25.00	49.16
29	1	0.74	2.01	15.13	17.88	25.00	42.88
30	0	0.00	1.51	10.09	11.59	25.00	36.59
31	0	0.00	1.00	5.04	6.05	25.00	31.05
32	0	0.00	0.50	2.52	3.02	25.00	28.02
33	0	0.00	0.25	2.02	2.27	25.00	27.27

34	0	0.00	0.00	1.51	1.51	25.00	26.51
35	0	0.00	0.00	1.01	1.01	25.00	26.01
36	0	0.00	0.00	0.50	0.50	25.00	25.50
37	0	0.00	0.00	0.25	0.25	25.00	25.25
38	0	0.00	0.00	0.00	0.00	25.00	25.00

Discussion

You can see the results in figure 1 and table 1.

Streamflow hydrograph. From the streamflow hydrograph, you can see that the flow varies as you would expect. Through much of the year, the streamflow stays fairly constant. But when the spring runoff occurs, there is a huge peak in flow.

Flow duration curve. The flow duration curve shows the number of days during the year that the streamflow will be at a certain value. The peak streamflow will only occur one day out of the year, so it appears in the upper left of a flow-time graph. The minimum streamflow will occur all days of the year, so it appears at the lower right of the flow-time graph.

The "run-of-the-river" power plant. The run-of-the-river power plant can be constructed without a dam. One of these power stations would take advantage of the steep slope of the river. Flow would be diverted from the river, run along the river at a small slope, and the resulting head and flow would be used downstream to generate power. There is one of these old contraptions here in Provo, but it is no longer in operation. As you can see in table 2 above, a power plant on the Snake River at King Hill would generate 111,680 kW with an available head of 200 ft, flow available 60% of the time, and an efficiency of 75%.

The proposed irrigation project. If it was determined that 75% of the median year average flow was necessary for a proposed irrigation project on the river, water would be available 294 days out of the year. This means water would be available 80.5% of the time. The lab asks why the number of days is not necessarily 0.75(365)=274 days if I am using 75% of the average flow. *It is because the flow duration curve is not linear*.

Calculations

The calculations were fairly straightforward and involved tabulating the data, calculating the average value over the 1-year study period, and determining the flow duration curve. *My calculations, data, and graphs are located in Appendix C.*

The calculations for the power produced at the run-of-the-river power plant and the number of days water would be available for irrigation was a little more involved. To calculate the power produced at the power plant, I used the power equation:

$$\boxed{Power = efficiency \times g \times Q \times H}$$

where γ is the unit weight of water, 62.4 pcf, Q is the flowrate, and H is the head (height of water) above the plant.

I used the appropriate conversion factors to convert to horsepower and kilowatts.

To determine the irrigation project requirements, I took 75% of the average yearly flow. Using the flow duration curve, I determined that 75% of the average yearly flow would be available 80.5% of the time.

Conclusions/Applications

Streamflow hydrographs and flow duration curves are extremely useful in sizing and determining the capacity of water projects.

From the flow duration curve, engineers can determine the minimum and maximum flows and the flowrate that would be available for a certain percentage of time at a station. Engineers and hydrologists can create these flow duration curves from a streamflow hydrograph. The flow duration curve can be used for the following purposes:

- When an engineers size dams or water control structures, they can use a flow duration curve to determine the flows that would occur and how long those flows would occur.
- Engineers can use flow duration curves to determine the amount of flow that would be available for a given percentage of time. Just as in this lab, this flow could be used to determine the power generated in a run-of-the-river power plant or to determine the amount of irrigation water available for a given percent of time.

Appendix

Appendix A: References

- Wanielista, Martin. **Hydrology and Water Quantity Control**. John Wiley and Sons, Inc. 1990.
- United States Department of Interior, Geological Survey. **Water Supply Papers-Basin 13, 1970 data**.

The lab handout and my calculations are located on the following pages.

Appendix B: Lab Handout

Appendix C: Calculations and Data