Appendix D

Dworshak Summer Operations

INTRODUCTION

Each year, the Water Quality Unit (WQU) of the Reservoir Control Center (RCC) provides technical information and analysis to the Regional Forum Technical Management Team (TMT) in support of the Lower Snake River summer flow augmentation and temperature control operations at Dworshak dam. These operations are in accordance the Biological Opinions for anadromous fish recovery in the Columbia River watershed, the most recent of which was completed in 2004. As part of this assistance during the summer of 2005, the Water Quality Unit provided TMT with Snake and Clearwater River flow rates and water temperatures, Dworshak reservoir thermocline data, and analyses related to impacts of potential operational actions at Dworshak dam. Utilizing this information, members of TMT developed recommendations concerning Dworshak outflow rates and temperature targets as part of the drafting of the reservoir from 1600 feet on June 30th to 1520 feet in mid-September.

Actual Operations and Final Results:

The management of Dworshak outflows during the summer of 2005 was similar to operations that have occurred in recent years. The following analysis of the 2005 actual operations includes: The flow augmentation and temperature; Dworshak water release temperatures and changes; Dworshak release temperatures at the end of flow augmentation; operational trends; Dworshak total project flow; effects of releases on Lower Granite tailwater and TDG levels.

Flow Augmentation and Temperatures

Dworshak summer operations began on July 1st when release flows were increased from 2.2 kcfs to 4.2 kcfs at a temperature of 45 °F. Flows were increased to 8.6 kcfs on July 6th at a temperature of 45 °F. These operations were maintained until July 14th. These initial operations provided a mild cooling affect on Lower Granite tailwaters (see Figures D-6 through D-8). The water temperature at Lower Granite tailwater peaked on July 9 and July 11 at 67.8 °F, the highest during the 2005 spill season. On July 15th, the water releases were increased to 12 kcfs with a water temperature 44 °F. When this water arrived at Lower Granite, a noticeable cooling influence on Lower Granite tailwater water temperature was observed, dropping it from 67 °F to 65 °F by July 22 and maintained the temperatures at 65 to 66 °F through August 5th. The Lower Granite tailwater water temperature did not creep back up even after the Dworshak water release temperatures were raised on August 4th to 46 °F with a constant flow of 12 kcfs. Through August and September, the Dworshak releases temperatures were maintained between 45 and 47 °F while the outflow decreased to 10 kcfs on August 11 then 7 kcfs on August 18th then 3.5 kcfs on September 15th and finally 1.5 on September 18th.

Dworshak Water Release Temperatures and Changes:

The actual water release temperatures from Dworshak that occurred shows hourly temperatures ranging from 42.5 to 60.1°F with an average hourly reading of 45.8°F. Table D-2 provides the water release temperature ranges (as calculated from the maximum and minimum) and averages for the time periods between June 23 and September 19, 2005. The daily averages temperature varied between 42.5 to 49.5°F. An average water temperature of 43.9 °F was maintained for 18 days from July 15 through

August 3, 2005. This was the longest period during the last six years of Dworshak summer operations that Dworshak water release temperatures were maintained voluntarily so low, between 43 and 44 ^{o}F. This factor makes the 2005 summer operations unique.

The Dworshak temperature release requests were for 45 to 46 ^{o}F from July 1 – 14th, 43 to 44 ^{o}F from July 15 to August 3rd, and 45 to 47 ^{o}F from August 4 to September 12th (see Table D-2). These were target temperatures requested at TMT and these requests were satisfied. TMT made the request that 48 to 50 ^{o}F, not to exceed 52 ^{o}F be maintained after September 12 but it was not physically possible. As flows were reduced and the project switched to one unit on minimum generation of 1.6 kcfs, they were able to get 46 ^{o}F with the gate in the undershot position or 59 ^{o}F water with the gate in the overshot position. The following is a discussion of this choice.

Dworshak Release Temperatures at the End of Flow Augmentation

The 2005 choice of selecting between 46^{o}F (undershot) and 59^{o}F (overshot) at the end of Dworshak flow augmentation highlights an observed trend: that the range between overshot and undershot appears to be getting wider. The 2005 13^{o}F range between overshot and undershot was the widest yet based on a six year comparison. Table D-3 shows the range between the overshot and undershot temperatures for 2000 to 2005. The six year (2000 – 2005) average undershot temperature is 46^{o}F and the average overshot temperature is 54^{0}F with an average range between overshot and undershot of 8^{o}F. The 2005 range between undershot and overshot is nearly twice the six year average.

End of season undershot temperatures are fairly constant from year to year, however, the overshot temperatures are not. Reviewing the 2000 – 2005 temperatures, the undershot temperature available at the end of flow augmentation was fairly constant, ranging from 44 to 47^{o}F with an average of 46^{o}F. The 2005 undershot temperature is the same as the six-year average. The six-year range of overshot temperatures available at the end of flow augmentation showed greater variability, ranging from 49 to 59^{0}F with an average of 54^{o}F. The 2005 overshot temperature of 59^{o}F is 5^{o}F above the six-year average of 54^{o}F. Since Dworshak water release temperatures have been cooler and cooler, the range between overshot and undershot at the end of Dworshak flow augmentation have been becoming wider. Whether this wide range can be attributed to the Dworshak low release temperatures is unknown, but it is reasonable that releasing 43 to 46 ^{0}F for 10 weeks could produce this type of effects.

Figure D-1 shows the daily average temperature against the daily average flows. This figure shows that during the 18 days of 43 to 44 ^{o}F cool water releases, the outflow was at it highest level that will occur during the augmentation season. This figure also shows that the daily average temperature of Dworshak cool water releases dropped below 43 ^{o}F three times on July 20th; August 18th and August 21st.

Figure D-4 is the temperature thermocline graph from the floating forebay temperature string and Figure D-5 is the temperature profile chart from the fixed temperature string.

Both graphs show water temperatures at various depths and this information was used to predict what temperature would occur at undershot or overshot gate settings.

Operational Trends

There are several operational trends that Figure D-2 and Figure D-3 highlight,

- The number of days that augmentation occurs has been increasing since 2000 from 59 to 82 days. In 2005, there was 79 days of augmentation, which is higher than the 2000 – 2005 six-year average of 70.5 days.
- The overall trend towards cooler water being released from Dworshak reservoir for longer periods of time during summer operations continues.
- The overall temperature during the augmentation period is dropping. The augmentation seasonal average temperature has significantly dropped from the 47 to 48 ^{o}F during 2000 – 2002 time period to the 45 ^{o}F range during 2003 - 2005.
- The number of days that the Dworshak release temperatures were between 43 and 44 ^{o}F is also increasing from zero in 2000 to 15 in 2005.
- The number of days with daily average temperatures of 42 ^{o}F is also increasing.

Dworshak Total Project Flows:

Table D-1 shows that the flow augmentation from Dworshak during the 2005 summer operations lasted from July 1st through September 18th (79 days) with total project flows ranging from 2.2 to 12.2 kcfs with an average of 8.7 kcfs. The 2005 average total project outflow of 8.7 kcfs is slightly below to the six-year (2000 – 2005) average of 9.5 kcfs, suggesting that there was less precipitation in the Clearwater Basin during 2005 summer than most years. Table D-1 also shows the outflow ranges, (as calculated from the maximum and minimum) and averages for the time periods between June 25 and September 19, 2005.

Effects of Releases on Lower Granite Tailwater:

Dworshak outflow and cool water releases on the Snake River can be seen in most clearly at Lower Granite tailwater and appear to diminish as the water passes through subsequent projects on the Lower Snake River. Figure D-8 shows Lower Granite tailwater temperatures, the dates when changes in Dworshak outflow temperature were made and what the target temperatures were. As Figures D-6 and D-7 show, Lower Granite tailwater temperatures were below the State water quality standard of 68^{o}F all spring and summer, in spite of high water temperatures coming into Lower Granite reservoir from the Middle Snake River (as measured at the Anatone gauge). The Anatone gauge is the last gauge on the Middle Snake River and immediately upstream from the confluences of the Clearwater and Lower Snake Rivers. Because of its location, it gives a good indication of what the Lower Snake temperatures would be without the cool waters from the Clearwater River. The Anatone temperature exceeded the State water quality standard of 68^{o}F for 65 days on a 24 hour daily average and for 68 days on an hourly basis(see Table E-2 of Appendix E). Anatone exceeded 68^{o}F on July 4 and continued to rise to a high of 74.6 ^{o}F on August 7th and then began to decline until on September 10, temperatures dropped below 68^{o}F (see Appendix H, Figure H-6).

As Table D-4 shows, the Lower Granite tailwater temperature remained below 68 ^{o}F the entire spill season resulting in no temperature exceedances. The maximum hourly temperature reading during the July 1st – September 15th period during 2005 was 67.8 ^{o}F, 1.2 ^{o}F less than the seven-year maximum hourly temperature reading average of 69.0 ^{o}F. This can be credited to efforts made to control Dworshak outflow temperature and flow, but also to the fact that Lower Granite tailwater temperature was 64.8 ^{o}F as a daily average on July 1st, which allowed time for Dworshak augmentation and temperature control to take effect. Having a water temperature of 64.8 ^{o}F is a good situation to begin augmentation that did not exist in 2004 when the daily average temperature was 67.5 ^{o}F on July 1st. In 2004, temperature exceedances began before augmentation flow could arrive at Lower Granite. Table D-4 shows how the Lower Granite tailwater average temperatures compare to other years and the seven-year average. The 2005 Lower Granite tailwater daily average temperatures on September 15th was the lowest of the last seven years, a natural consequence of achieving a spill season with no temperature exceedances.

Table D-5 contains an 11-year statistical analysis of Lower Granite tailwater temperatures with the hours of exceedance and cumulative magnitude of exceedance for 1995 through 2005. The cumulative magnitude of exceedances is calculated by multiplying the number of hours that the 68 ^{o}F temperature standard was exceeded by the number of degrees above the measured water temperature above that standard. This value provides an indication of the degree to which the temperature standard was exceeded through the entire year. As is shown, 2005 and 2000 were the only years without temperature exceedances.

TDG Levels

From October 1, 2004 through September 30, 2005 Idaho TDG state standard of 110% was exceeded at Dworshak for a total of 12 hours: As Figure D-9 shows, these 12 hours of TDG exceedances occurred sporadically throughout the year, but not during flow augmentation period of July 1 through September 18. The TDG exceedances can be attributed to flood control and maintenance activities. Percent TDG during these exceedances ranged from 110.1 to 118.0%.

TABLE D-1

2005 OUTFLOW RANGE		
2005 - Dates	**Outflow Ranges (kcfs)**	**Flow (kcfs)**
6/25 - 6/30	2.2	2.2
7/1 - 7/5	4.0 - 7.3	4.2
7/6 - 7/14	7.1 - 12.2	8.6
7/15 - 8/10	9.9 - 12.2	12
8/11 - 8/17	5.1 - 10.2	10
8/18 - 9/14	4.6 - 7.8	7.1
9/14 - 9/17	2.3 - 3.6	3.5
9/18/04	1.5	1.5
7/1 - 9/18	**1.5 - 12.2**	**8.7**

TABLE D-2

2005 TEMPERATURE RANGE		
2005 - Dates	**Temperature Ranges (^{o}F)**	**Average Temp. (^{o}F)**
6/23 - 6/30	46.3 - 47.9	46.8
7/1 - 7/14	44.8 - 47.4	46.0
7/15 - 8/3	42.9 - 49.7	43.9
8/4 - 9/12	42.5 - 53.5	46.5
9/13 - 9/19	44.2 - 48.2	45.7
7/1 - 9/19	**42.5 - 60.1**	**45.8**

TABLE D-3
Overshot and Undershot Comparison

Years	Undershot	Overshot	Difference
2000	46.22	50.72	4.5
2001	43.7	not available	N/A
2002	46.5	52.88	6.38
2003	46.4	not available	N/A
2004	47.3	54.32	7.02
2005	45.68	59.054	13.374
Average	46.0	54.2	7.8

TABLE D-4

Lower Granite Temperatures from July 1st - September 15th								
	2005	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**	**7 YR AVG**
Maximum Hourly Temperature Reading	67.8	68.5	71.7	68.5	69.9	68.0	68.5	69.0
Minimum Hourly Temperature Reading	62.3	62.8	62.9	60.5	62.0	61.8	59.9	61.8
Average Temp	65.5	65.4	66.2	64.5	65.9	65.4	65.2	65.4
July 1 beginning Temp	64.8	67.8	63.6	62.2	65.1	65.8	60.4	64.2
Sept. 15 ending Temp	62.6	63.4	63.5	63.3	67.5	65.2	65.5	64.5
Date DWR Elevation reached 1520 ft	9/18	9/20	9/15	9/11	8/31	8/31	9/13	---

Table D-5
Lower Granite Tailwater Thermal Exceedances
(1995-2005)

Year	Hours of Exceedance	Average Number of Degrees an Exceedance is above the 68^{o} F Water Temperature Standard	Standard Deviation (^{o}F)	Exceedance Range (^{o}F)	Cumulative Magnitude of Exceedance (Degree-Hours)
2005	0	N/A	N/A	N/A	0
2004	7	0.23	0.13	68.0 – 68.36	2
2003	63	0.23	0.18	68.0 – 68.76	14
2002	17	0.25	0.13	68.0 – 68.54	4
2001	172	0.72	0.55	68.0 – 69.15	123
2000	0	N/A	N/A	N/A	0
1999	23	0.28	0.13	68.0 – 68.54	6
1998	981	1.75	1.34	68.0 – 72.5	1,721
1997	137	0.41	0.23	68.0 – 69.08	56
1996	526	1.17	0.64	68.0 – 70.70	613
1995	593	0.61	0.33	68.0 – 69.62	363

11-Year Statistics of Cumulative Magnitude of Exceedance

Hours of Exceedance
- Range: High = 981 hrs (1998)
  Low = 0 hrs (2000, 2005)
- Average 1995-1999: 452 hrs
- Average 2000-2005: 43 hrs
- 11-Year Average: 229 hrs

Cumulative Magnitude of Exceedance
- Range: High = 1,721 degree-hrs(1998)
  Low = 0 degree-hrs(2000, 2005)
- Average 1995-1999: 552 degree-hrs
- Average 2000-2005: 24 degree-hrs
- 11-Year Average: 264 degree-hrs

Cumulative Magnitude of Exceedance = $(\#\text{ of hours above } 68^{o}\text{ F})_i \times (\text{Temp above } 68^{o}\text{ F})_i$

FIGURE D-1

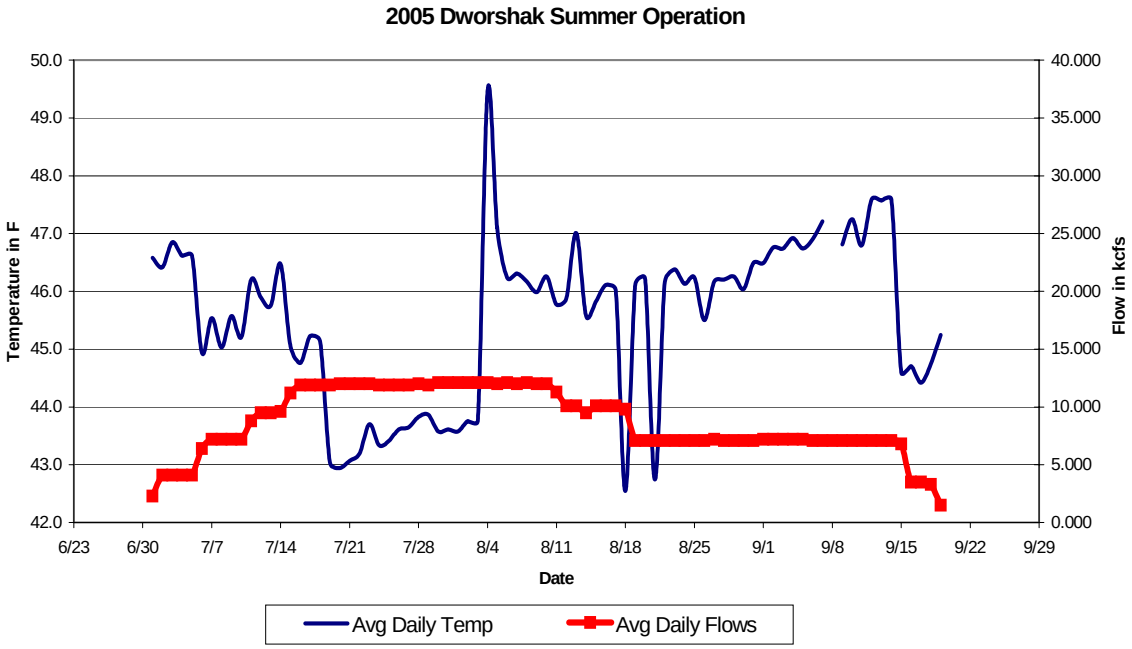

FIGURE D-2

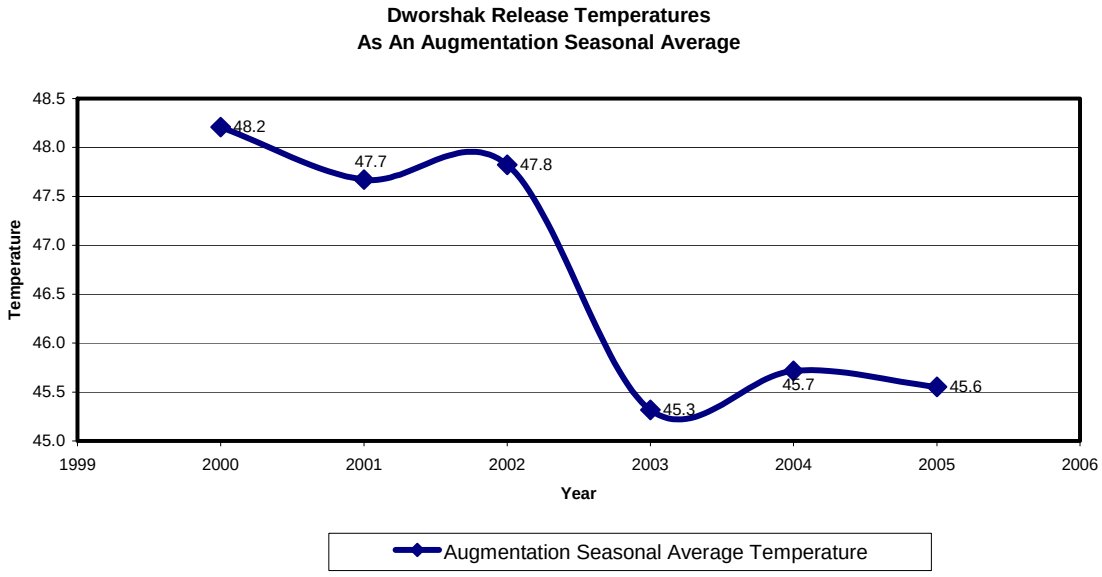

FIGURE D-3

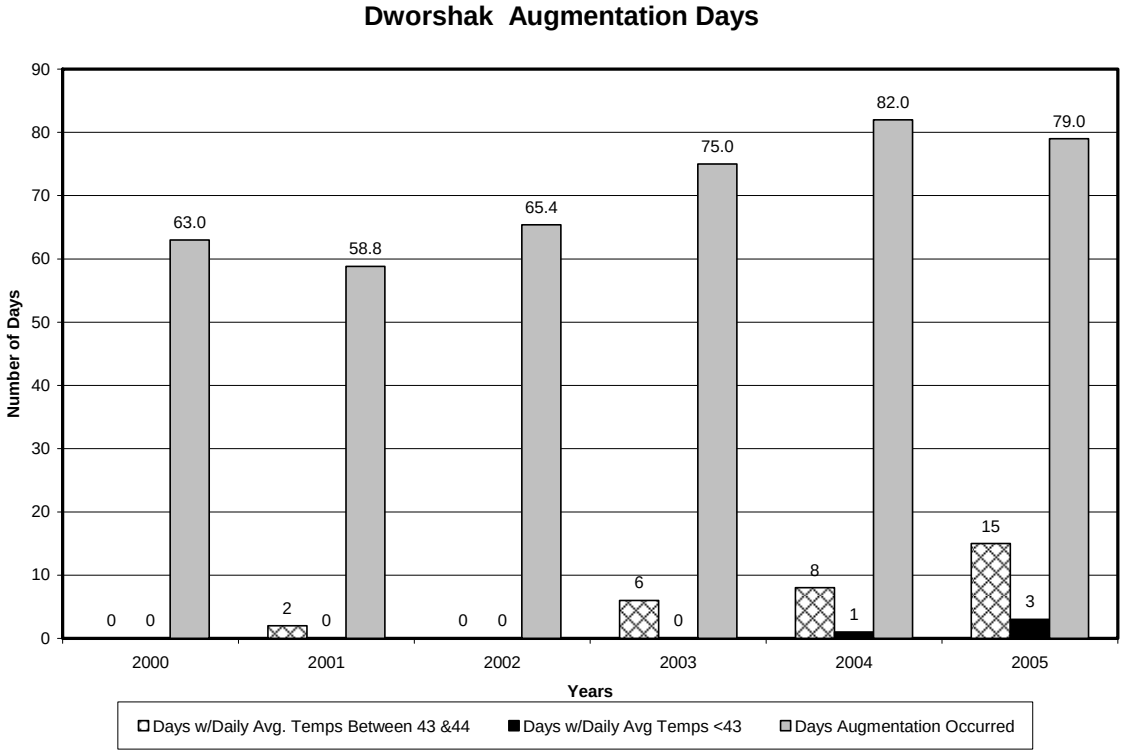
Dworshak Augmentation Days
Number of Days
90
80
70
60
50
40
30
20
10
0
0 0 63.0
2 0 58.8
0 0 65.4
6 0 75.0
8 1 82.0
15 3 79.0
2000
2001
2002
2003
2004
2005
Years
Days w/Daily Avg. Temps Between 43 &44
Days w/Daily Avg Temps <43
Days Augmentation Occurred

FIGURE D-4

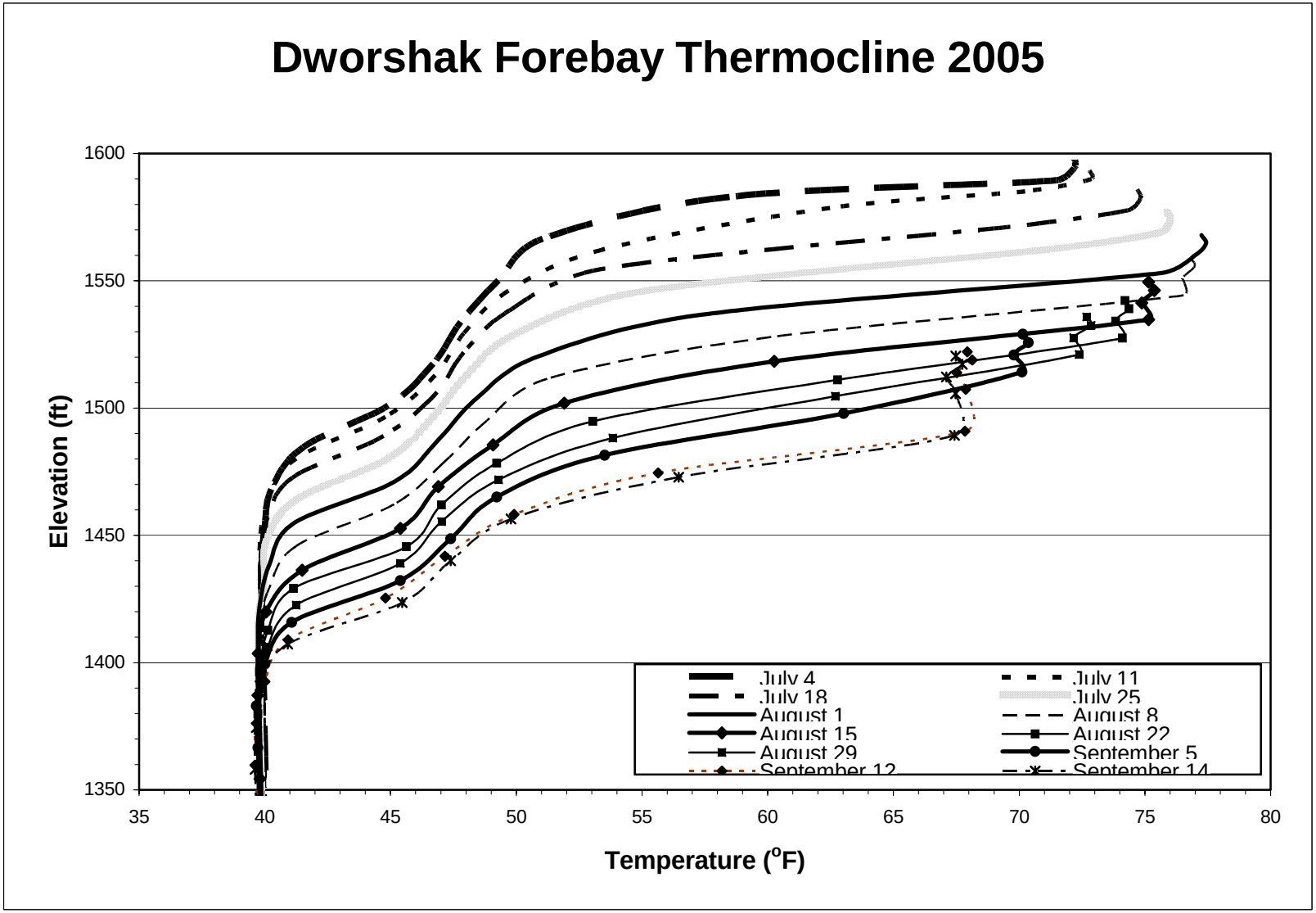
Dworshak Forebay Thermocline 2005
Elevation (ft)
1600
1550
1500
1450
1400
1350
35
40
45
50
55
60
65
70
75
80
Temperature (°F)
July 4
July 11
July 18
July 25
August 1
August 8
August 15
August 22
August 29
September 5
September 12
September 14

FIGURE D-5
DWORSHAK TEMPERATURE PROFILES
From A Fixed Temperature String
January – September 2005

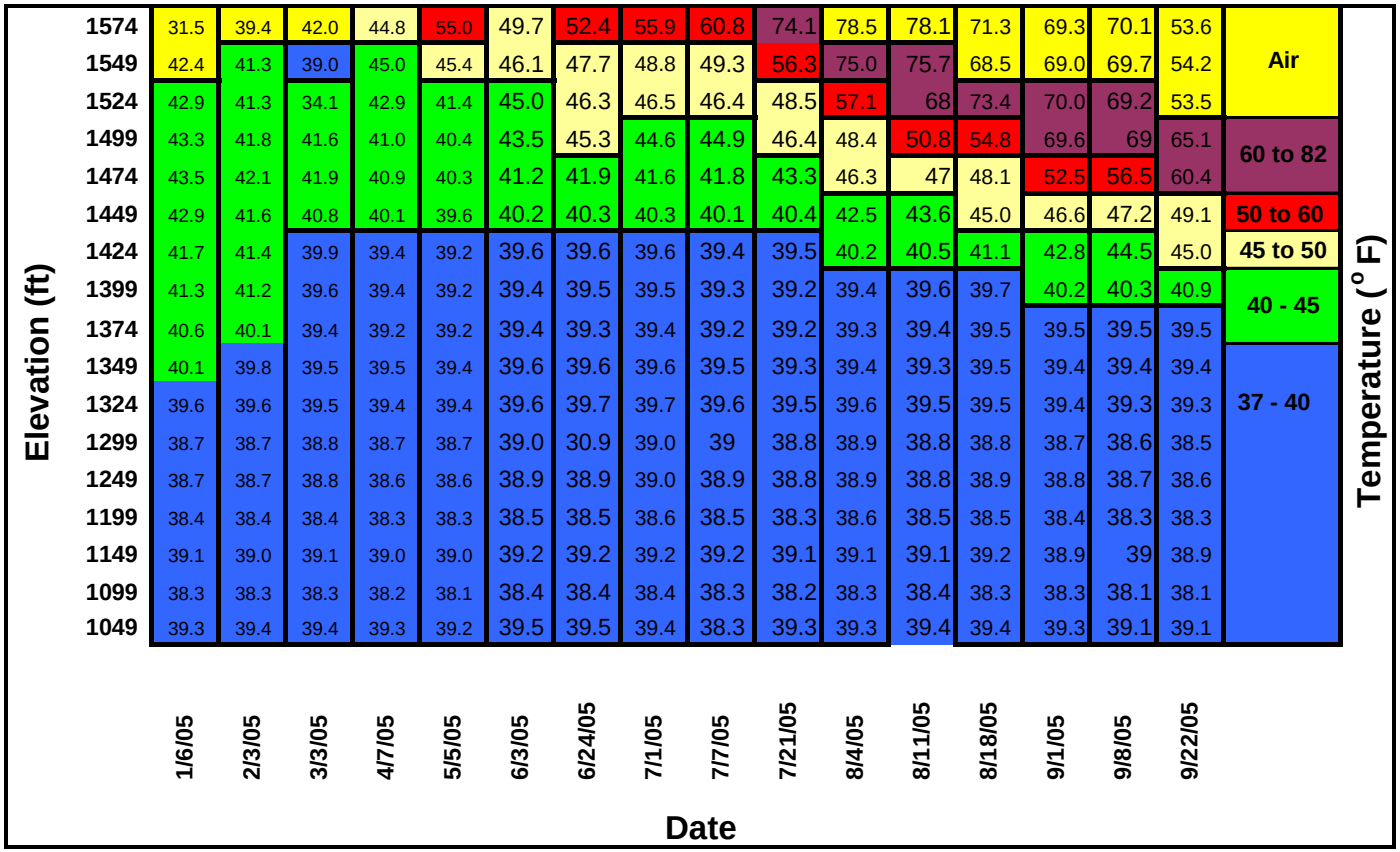

FIGURE D-6
Anatone, Lower Granite Tailwater Hourly Temperatures
With Dworshak Water Release Temperature Request

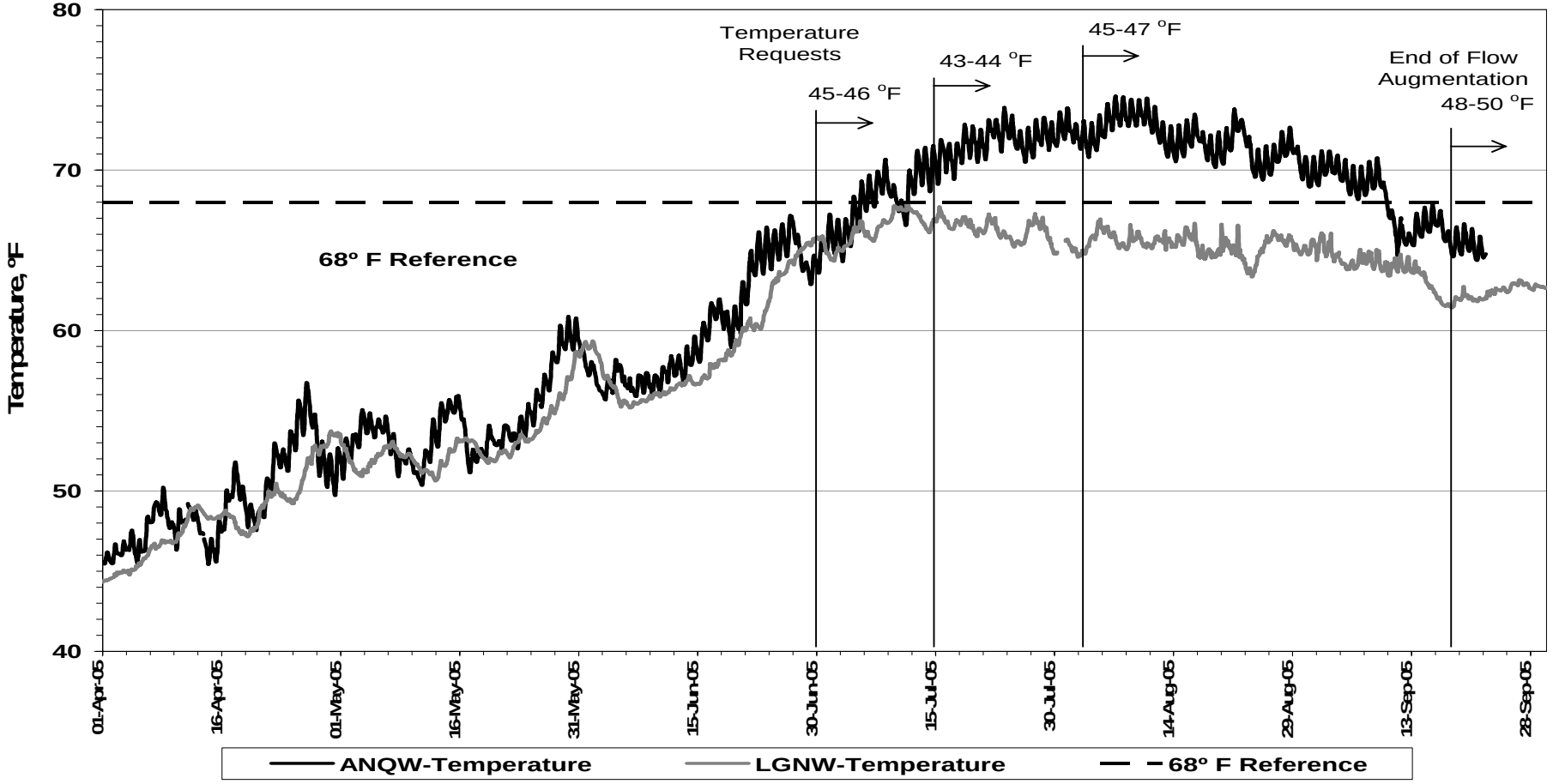

FIGURE D-7

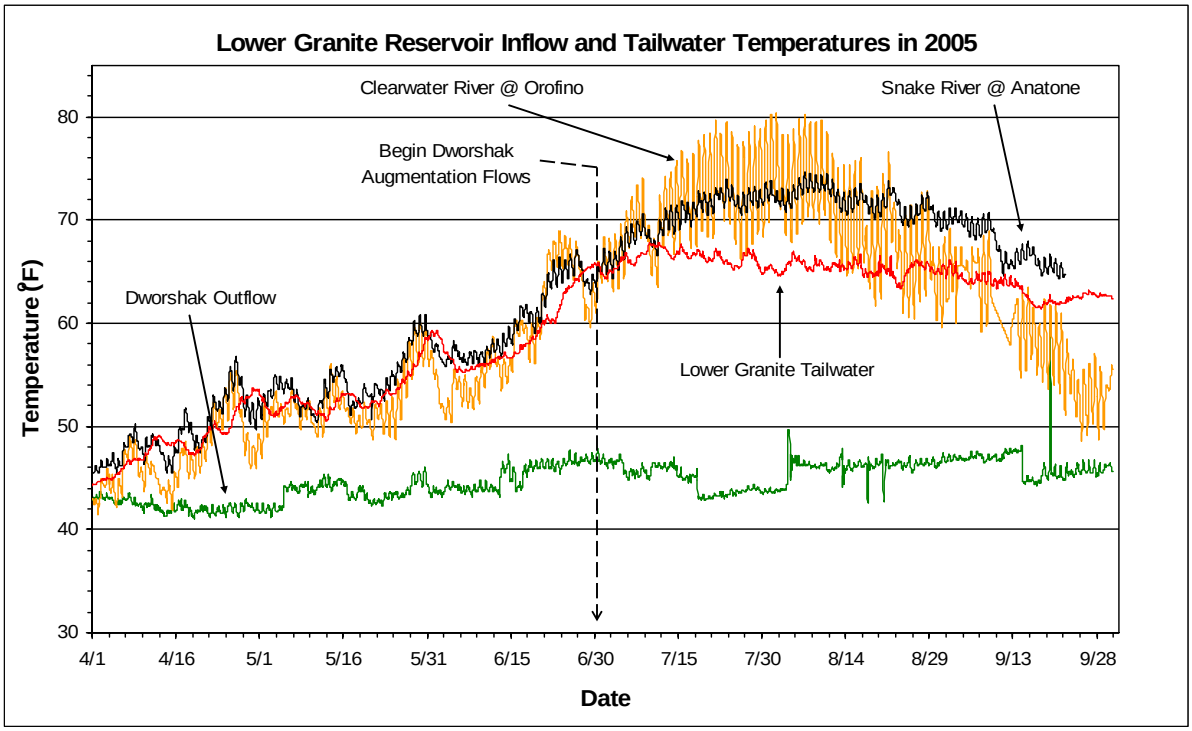

FIGURE D-8

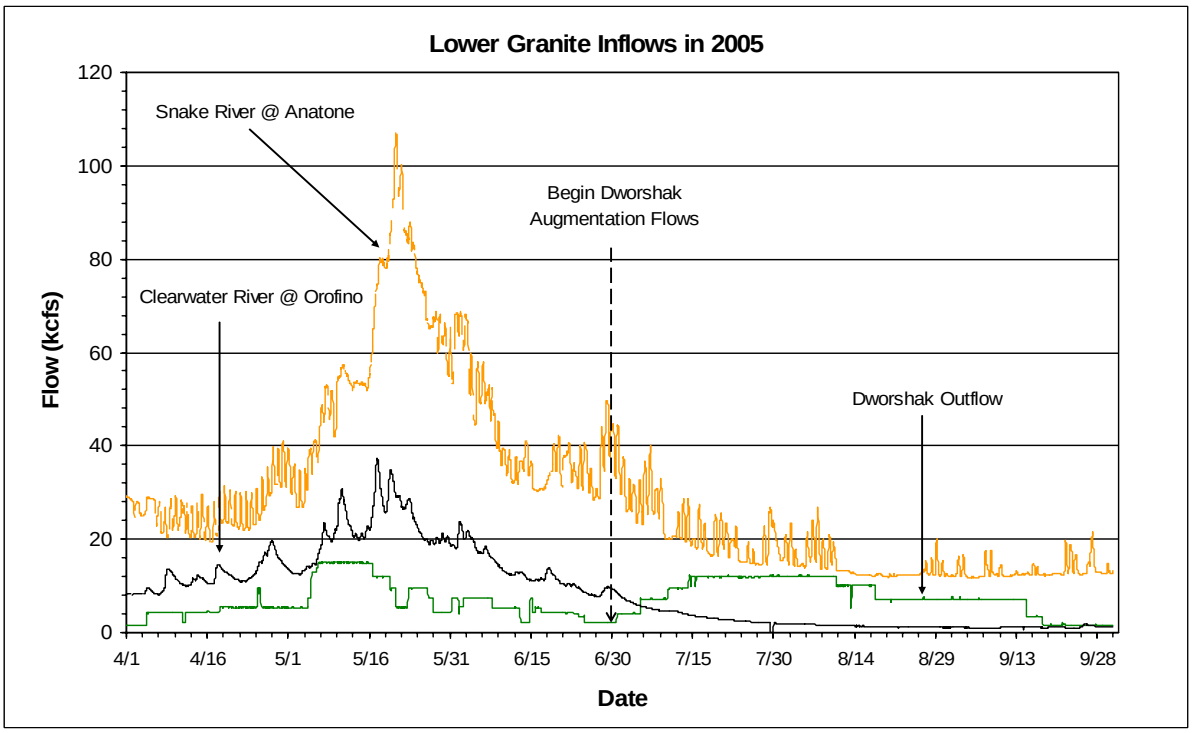

Figure D-9
Dworshak Tailwater Hourly TDG Data
October 2004– September 2005