

**Assessment of Water Use with the Established
Protected Instream Flows**

Souhegan River Instream Flow Project

**Prepared by
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August 26, 2009

Souhegan River Task 8 Analysis

The purpose of Task 8 is to identify the reaches of the Souhegan Designated River and the times when the protected flows may not be met under three-year wet, average, and dry conditions as well as during the previous five and 30 year periods. The three different conditions selected (wet, average and dry) represent a broad range of hydrologic conditions, while the two time periods (last five and 30 years) provide both a short and long term time perspective for assessing if the protected flows would be met during these hydrologic conditions and periods of time. These examples will guide development of the water management plans to ensure that the management activities identified are sufficient and appropriate to effectively address flow problem areas and times.

Much of this assessment is found in Part II of the Souhegan Protected Instream Flow Report (NHDES 2008). Part II described the occurrence when stream flow is not sufficient to meet the needs of each protected entity (or IPUOCR) as well as the recommended protected instream flows described in Tables 34 through 36 of the report (NHDES 2008).

Withdrawals of Concern

In order to reduce the number of specific withdrawals and their locations upon which, ultimately, NH DES would be continually assessing the meeting of the PISF in the future, it was discussed and decided that withdrawals that represented 15 percent or less than the *lowest recommended PISF* did not have to be considered separately. For the Upper Souhegan (sites SR 6, 12, 16, and 18), this PISF was 0.08 cfs (cubic feet per second per square mile) in the month of June. For the Lower Souhegan (sites SR 31, 34, 50, 56), this PISF was 0.1 cfs from June through September. The withdrawal comparisons to the flow duration curve at the location of the withdrawal may be found in Figures 1 through 4. The result of this winnowing is that the withdrawal for the fish hatchery by NHF&G is a withdrawal that could lead to not meeting the PISF between where the withdrawal is made and their return flows.

In Figures 1 through 4, the vertical axis is flow per watershed area (cfs) and the horizontal axis is the probability that a flow is exceeded. So for example, the lowest flow ever recorded, say 0.04 cfs is exceeded 100 percent of the time. For larger flows, they are exceeded fewer and fewer times. The horizontal axis was cropped to just the highest 10 percent exceedence values in order to magnify the low flow conditions. The blue curve (identified in the legends as “Today”) is the flow duration curve developed for that stretch of the river from the USGS Merrimack gage and the concurrent flow regressions. These are the flows as measured on the river today. The USGS Merrimack gage data, modified to remove the effects of withdrawals and return flows, (dashed red curve) is also plotted and labeled as “Naturalized”. These two curves are very nearly the same due to minimal amount of storage management in the watershed as well as the very small net withdrawals from the system. The solid blue horizontal lines are the registered water withdrawals that came from the NHDES database. Each of these is identified in

the figures. For groundwater withdrawals, the Task 2 report computed the amount of induced recharge from each well, and it was the induced recharge amount that is used for the comparisons in these figures. The induced recharge is the flow that can be reasonably managed at times of low flow on the Souhegan River. The dashed green line is the lowest PISF in the respective stretch of river.

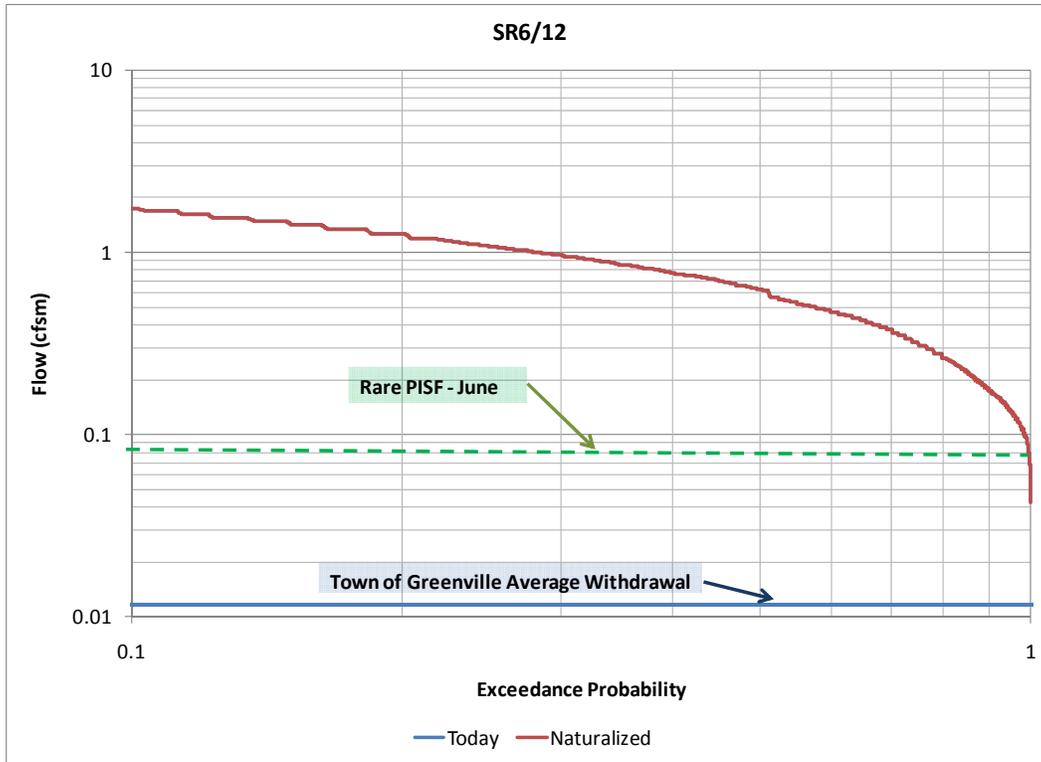


Figure 1. Comparison of withdrawals in the Upper Souhegan headwater section.

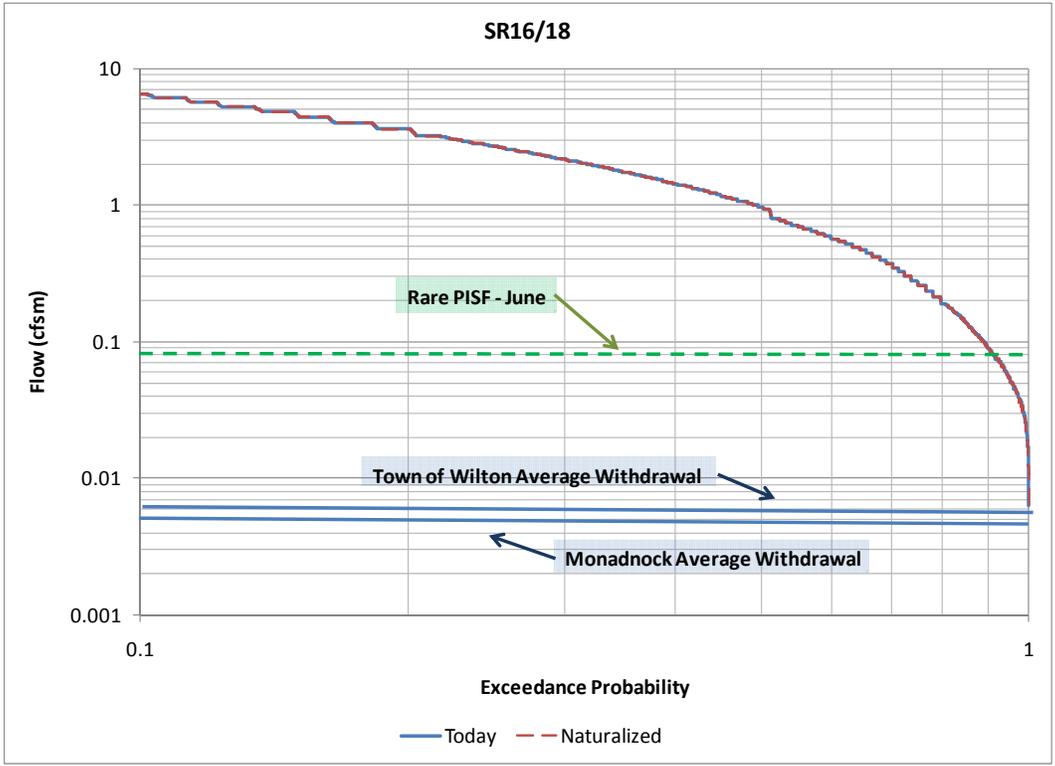


Figure 2. Comparison of withdrawals in the Upper Souhegan downstream section.

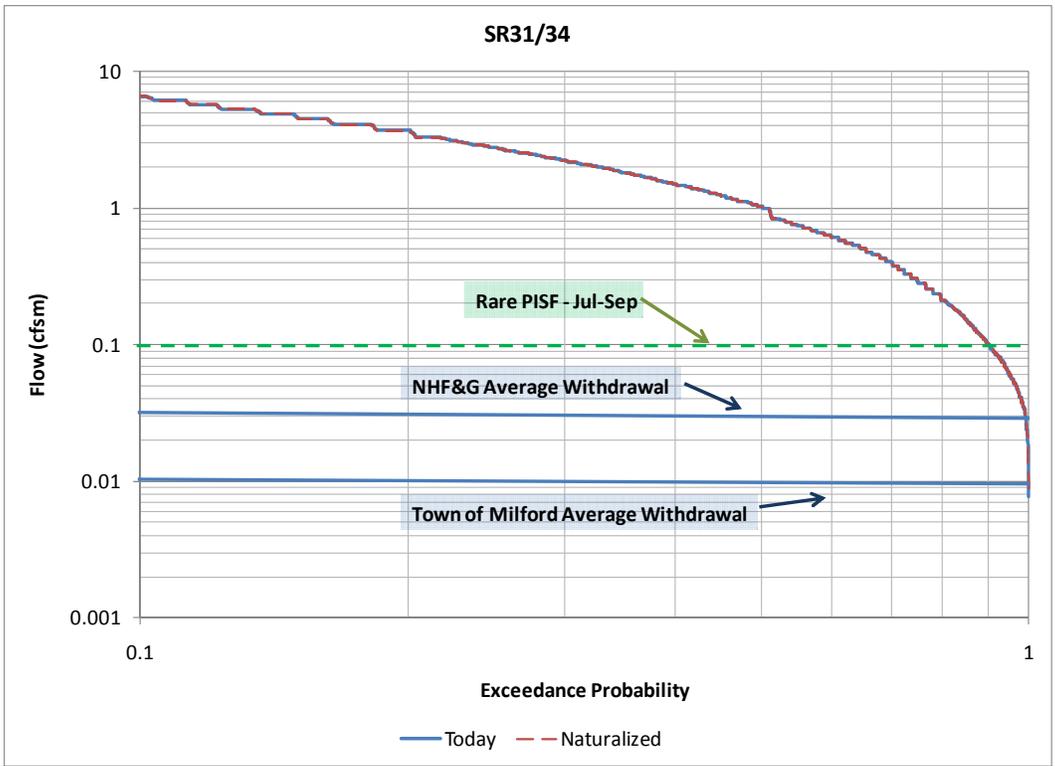


Figure 3. Comparison of withdrawals in the Lower Souhegan headwater section.

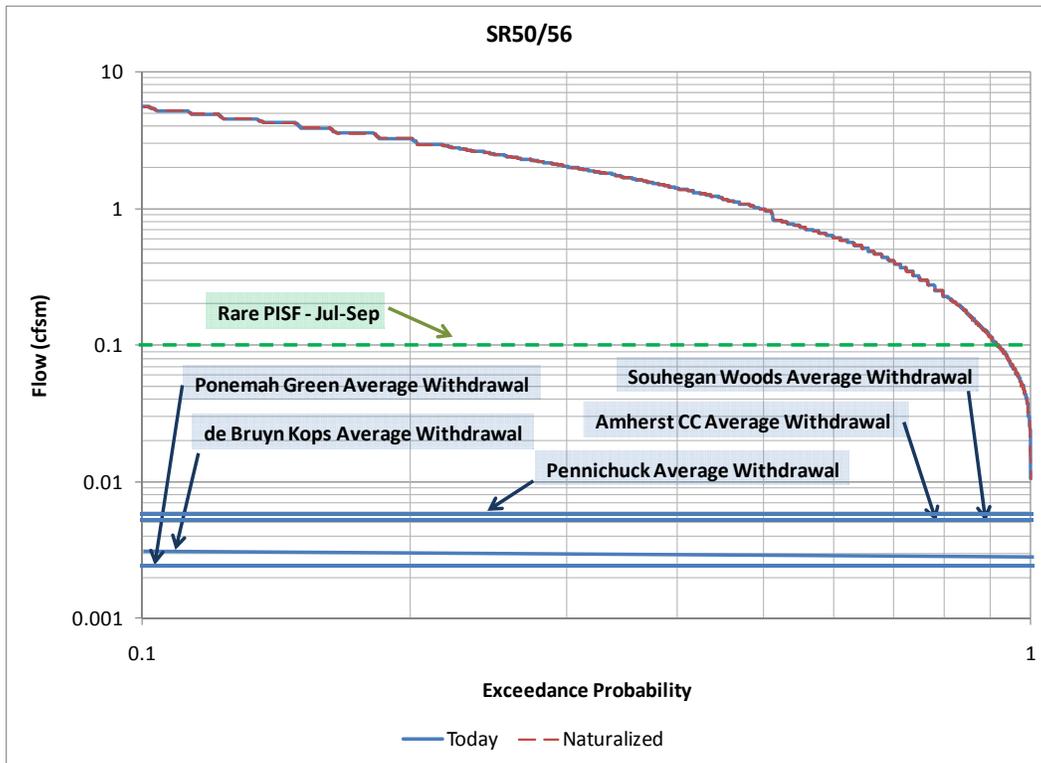


Figure 4. Comparison of withdrawals in the Lower Souhegan downstream section.

When Are the Recommended PISF Not Met?

The assessment of how frequently the recommended PISF are met may be found in Section II of the Final Souhegan River PISF Report (NHDES 2008). Since it was identified that the NHF&G withdrawal could lead to not meeting the PISF from the location of this withdrawal until the return flows from the facility rejoin the Souhegan River, a subsequent analysis was performed to delineate the changes in the PISF failure frequencies from those in the Final PISF Report. This was accomplished by comparing the recommended PISF for Upper and Lower Souhegan River, for each bioperiod, to the naturalized and modern flows of the following hydrographs: Last 30 Years, Last 5 Years, High 3 Years, Average 3 Years, and Low 3 Years. These hydrographs, and how they were selected, were previously described in the Final PISF Report. The results of these comparisons appear in Tables 1 through 4. In these tables, the column labeled “Lower” is the flow series from SR31/34, and this is the hydrograph downstream of the NHF&G return flow. The column labeled “Middle” is the hydrograph located just downstream of the NHF&G withdrawal.

Note: The values in the tables represent “Violations”: the number and percentages of times that the PISF are not met, for both allowable and catastrophic durations.

		Rearing & Growth				Salmon Spawning				
		Today's Flows		Naturalized Flows		Today's Flows		Naturalized Flows		
		Violation	Lower	Middle	Lower	Middle	Lower	Middle	Lower	Middle
Last 30	Common	Flow (days)	2038	2054	2038	2054	824	833	824	833
		Flow (%)	87.09%	87.78%	87.09%	87.78%	61.04%	61.70%	61.04%	61.70%
		Allowable	37	38	37	38	9	10	9	10
		Catastrophic	16	17	16	17	3	3	3	3
	Critical	Flow (days)	1221	1368	1221	1368	639	656	639	656
		Flow (%)	52.18%	58.46%	52.18%	58.46%	47.33%	48.59%	47.33%	48.59%
		Allowable	22	26	22	26	15	16	15	16
		Catastrophic	15	17	15	17	2	2	2	2
	Rare	Flow (days)	871	1107	871	1107	439	461	439	461
		Flow (%)	37.22%	47.31%	37.22%	47.31%	32.52%	34.15%	32.52%	34.15%
		Allowable	45	59	45	59	28	28	28	28
		Catastrophic	26	30	26	30	10	13	10	13
Last 5	Common	Flow (days)	346	349	346	349	187	188	187	188
		Flow (%)	88.72%	89.49%	88.72%	89.49%	83.11%	83.56%	83.11%	83.56%
		Allowable	5	6	5	6	2	2	2	2
		Catastrophic	3	3	3	3	2	2	2	2
	Critical	Flow (days)	234	260	234	260	156	161	156	161
		Flow (%)	60.00%	66.67%	60.00%	66.67%	69.33%	71.56%	69.33%	71.56%
		Allowable	5	7	5	7	4	5	4	5
		Catastrophic	3	4	3	4	1	1	1	1
	Rare	Flow (days)	158	214	158	214	112	116	112	116
		Flow (%)	40.51%	54.87%	40.51%	54.87%	49.78%	51.56%	49.78%	51.56%
		Allowable	7	11	7	11	7	7	7	7
		Catastrophic	6	5	6	5	2	2	2	2
High 3	Common	Flow (days)	187	189	187	189	106	107	106	107
		Flow (%)	79.91%	80.77%	79.91%	80.77%	78.52%	79.26%	78.52%	79.26%
		Allowable	5	5	5	5	2	2	2	2
		Catastrophic	1	1	1	1	2	2	2	2
	Critical	Flow (days)	91	105	88	103	101	101	101	101
		Flow (%)	38.89%	44.87%	37.61%	44.02%	74.81%	74.81%	74.81%	74.81%
		Allowable	1	3	1	3	2	2	2	2
		Catastrophic	1	2	1	2	2	2	2	2
	Rare	Flow (days)	52	80	51	78	96	98	96	98
		Flow (%)	22.22%	34.19%	21.79%	33.33%	71.11%	72.59%	71.11%	72.59%
		Allowable	3	4	3	4	4	3	4	3
		Catastrophic	2	2	2	2	3	2	3	2
Average 3	Common	Flow (days)	173	177	172	177	86	87	86	87
		Flow (%)	73.93%	75.64%	73.50%	75.64%	63.70%	64.44%	63.70%	64.44%
		Allowable	3	3	3	3	1	1	1	1
		Catastrophic	1	1	1	1	1	1	1	1
	Critical	Flow (days)	35	63	39	65	82	82	82	82
		Flow (%)	14.96%	26.92%	16.67%	27.78%	60.74%	60.74%	60.74%	60.74%
		Allowable	1	1	1	1	3	3	3	3
		Catastrophic	0	0	0	1	1	1	1	1
	Rare	Flow (days)	5	24	4	26	72	77	72	77
		Flow (%)	2.14%	10.26%	1.71%	11.11%	53.33%	57.04%	53.33%	57.04%
		Allowable	0	1	0	1	4	5	4	5
		Catastrophic	0	1	0	1	3	3	3	3
Low 3	Common	Flow (days)	234	234	234	234	128	128	128	128
		Flow (%)	100.00%	100.00%	100.00%	100.00%	94.81%	94.81%	94.81%	94.81%
		Allowable	3	3	3	3	3	3	3	3
		Catastrophic	3	3	3	3	2	2	2	2
	Critical	Flow (days)	232	232	232	232	128	128	128	128
		Flow (%)	99.15%	99.15%	99.15%	99.15%	94.81%	94.81%	94.81%	94.81%
		Allowable	3	3	3	3	3	3	3	3
		Catastrophic	3	3	3	3	2	2	2	2
	Rare	Flow (days)	225	232	225	232	128	128	128	128
		Flow (%)	96.15%	99.15%	96.15%	99.15%	94.81%	94.81%	94.81%	94.81%
		Allowable	4	4	4	4	3	3	3	3
		Catastrophic	4	3	4	3	3	3	3	3

Table 1. PISF Comparisons for Rearing & Growth and Salmon Spawning Bioperiods.

		Overwintering				Spring Flood				
		Today's Flows		Naturalized Flows		Today's Flows		Naturalized Flows		
		Violation	Lower	Middle	Lower	Middle	Lower	Middle	Lower	Middle
Last 30	Common	Flow (days)	2084	2103	2084	2103	901	901	901	901
		Flow (%)	65.53%	66.13%	65.53%	66.13%	49.23%	49.23%	49.23%	49.23%
		Allowable	15	15	15	15	1	1	1	1
		Catastrophic	7	7	7	7	1	1	1	1
	Critical	Flow (days)	584	629	584	629	190	204	190	204
		Flow (%)	18.36%	19.78%	18.36%	19.78%	10.38%	11.15%	10.38%	11.15%
		Allowable	11	12	11	12	5	5	5	5
		Catastrophic	6	7	6	7	2	2	2	2
	Rare	Flow (days)	280	313	280	313	132	139	132	139
		Flow (%)	8.81%	9.84%	8.81%	9.84%	7.21%	7.60%	7.21%	7.60%
		Allowable	11	12	11	12	10	10	10	10
		Catastrophic	7	7	7	7	8	8	8	8
Last 5	Common	Flow (days)	378	378	378	378	159	159	159	159
		Flow (%)	71.32%	71.32%	71.32%	71.32%	52.13%	52.13%	52.13%	52.13%
		Allowable	4	4	4	4	0	0	0	0
		Catastrophic	2	2	2	2	0	0	0	0
	Critical	Flow (days)	116	132	116	132	38	39	38	39
		Flow (%)	21.89%	24.91%	21.89%	24.91%	12.46%	12.79%	12.46%	12.79%
		Allowable	3	3	3	3	1	1	1	1
		Catastrophic	1	2	1	2	1	1	1	1
	Rare	Flow (days)	67	70	67	70	16	19	16	19
		Flow (%)	12.64%	13.21%	12.64%	13.21%	5.25%	6.23%	5.25%	6.23%
		Allowable	2	3	2	3	1	1	1	1
		Catastrophic	2	2	2	2	1	1	1	1
High 3	Common	Flow (days)	109	110	109	110	41	41	41	41
		Flow (%)	34.28%	34.59%	34.28%	34.59%	22.40%	22.40%	22.40%	22.40%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	24	25	24	25	0	0	0	0
		Flow (%)	7.55%	7.86%	7.55%	7.86%	0.00%	0.00%	0.00%	0.00%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	19	20	19	20	0	0	0	0
		Flow (%)	5.97%	6.29%	5.97%	6.29%	0.00%	0.00%	0.00%	0.00%
		Allowable	2	2	2	2	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
Average 3	Common	Flow (days)	244	245	244	245	71	71	71	71
		Flow (%)	76.73%	77.04%	76.73%	77.04%	38.80%	38.80%	38.80%	38.80%
		Allowable	2	2	2	2	0	0	0	0
		Catastrophic	1	1	1	1	0	0	0	0
	Critical	Flow (days)	65	67	65	67	7	7	7	7
		Flow (%)	20.44%	21.07%	20.44%	21.07%	3.83%	3.83%	3.83%	3.83%
		Allowable	2	2	2	2	0	0	0	0
		Catastrophic	1	1	1	1	0	0	0	0
	Rare	Flow (days)	34	42	34	42	0	0	0	0
		Flow (%)	10.69%	13.21%	10.69%	13.21%	0.00%	0.00%	0.00%	0.00%
		Allowable	4	4	4	4	0	0	0	0
		Catastrophic	0	1	0	1	0	0	0	0
Low 3	Common	Flow (days)	281	281	281	281	105	105	105	105
		Flow (%)	88.36%	88.36%	88.36%	88.36%	57.38%	57.38%	57.38%	57.38%
		Allowable	4	4	4	4	2	2	2	2
		Catastrophic	2	2	2	2	0	0	0	0
	Critical	Flow (days)	167	172	167	172	18	19	18	19
		Flow (%)	52.52%	54.09%	52.52%	54.09%	9.84%	10.38%	9.84%	10.38%
		Allowable	4	4	4	4	0	0	0	0
		Catastrophic	2	2	2	2	0	0	0	0
	Rare	Flow (days)	137	148	137	148	0	1	0	1
		Flow (%)	43.08%	46.54%	43.08%	46.54%	0.00%	0.55%	0.00%	0.55%
		Allowable	6	6	6	6	0	0	0	0
		Catastrophic	6	6	6	6	0	0	0	0

Table 2. PISF Comparisons for Overwintering and Spring Flood Bioperiods.

		Shad Spawning Min				Shad Spawning Max				
		Today's Flows		Naturalized Flows		Today's Flows		Naturalized Flows		
		Violation	Lower	Middle	Lower	Middle	Lower	Middle	Lower	Middle
Last 30	Common	Flow (days)	409	420	409	420	0	0	0	0
		Flow (%)	30.30%	31.11%	30.30%	31.11%				
		Allowable	7	9	7	9	0	0	0	0
		Catastrophic	1	1	1	1	0	0	0	0
	Critical	Flow (days)	218	234	218	234	0	0	0	0
		Flow (%)	16.15%	17.33%	16.15%	17.33%				
		Allowable	12	14	12	14	0	0	0	0
		Catastrophic	5	5	5	5	0	0	0	0
	Rare	Flow (days)	145	170	145	170	0	0	0	0
		Flow (%)	10.74%	12.59%	10.74%	12.59%				
		Allowable	9	11	9	11	0	0	0	0
		Catastrophic	3	3	3	3	0	0	0	0
Last 5	Common	Flow (days)	24	27	24	27	0	0	0	0
		Flow (%)	10.67%	12.00%	10.67%	12.00%				
		Allowable	1	1	1	1	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	11	12	11	12	0	0	0	0
		Flow (%)	4.89%	5.33%	4.89%	5.33%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	5	6	5	6	0	0	0	0
		Flow (%)	2.22%	2.67%	2.22%	2.67%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
High 3	Common	Flow (days)	29	33	29	33	0	0	0	0
		Flow (%)	21.48%	24.44%	21.48%	24.44%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	14	17	14	17	0	0	0	0
		Flow (%)	10.37%	12.59%	10.37%	12.59%				
		Allowable	0	1	0	1	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	8	10	8	10	0	0	0	0
		Flow (%)	5.93%	7.41%	5.93%	7.41%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
Average 3	Common	Flow (days)	4	4	4	4	0	0	0	0
		Flow (%)	2.96%	2.96%	2.96%	2.96%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	0	0	0	0	0	0	0	0
		Flow (%)	0.00%	0.00%	0.00%	0.00%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	0	0	0	0	0	0	0	0
		Flow (%)	0.00%	0.00%	0.00%	0.00%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
Low3	Common	Flow (days)	84	86	84	86	0	0	0	0
		Flow (%)	62.22%	63.70%	62.22%	63.70%				
		Allowable	3	3	3	3	0	0	0	0
		Catastrophic	1	1	1	1	0	0	0	0
	Critical	Flow (days)	57	59	57	59	0	0	0	0
		Flow (%)	42.22%	43.70%	42.22%	43.70%				
		Allowable	4	4	4	4	0	0	0	0
		Catastrophic	3	3	3	3	0	0	0	0
	Rare	Flow (days)	53	54	53	54	0	0	0	0
		Flow (%)	39.26%	40.00%	39.26%	40.00%				
		Allowable	4	4	4	4	0	0	0	0
		Catastrophic	3	3	3	3	0	0	0	0

Table 3. PISF Comparisons for Shad Spawning Bioperiod.

		GRAF Spawning Min				GRAF Spawning Max				
		Today's Flows		Naturalized Flows		Today's Flows		Naturalized Flows		
		Violation	Lower	Middle	Lower	Middle	Lower	Middle	Lower	Middle
Last 30	Common	Flow (days)	314	347	314	347	0	0	0	0
		Flow (%)	34.89%	38.56%	34.89%	38.56%				
		Allowable	3	4	3	4	0	0	0	0
		Catastrophic	0	2	0	2	0	0	0	0
	Critical	Flow (days)	184	229	184	229	129	125	129	125
		Flow (%)	20.44%	25.44%	20.44%	25.44%	14.33%	13.89%	14.33%	13.89%
		Allowable	2	2	2	2	2	2	2	2
		Catastrophic	1	1	1	1	0	0	0	0
	Rare	Flow (days)	92	157	92	157	80	77	80	77
		Flow (%)	10.22%	17.44%	10.22%	17.44%	8.89%	8.56%	8.89%	8.56%
		Allowable	2	3	2	3	2	2	2	2
		Catastrophic	2	3	2	3	2	2	2	2
Last 5	Common	Flow (days)	20	27	20	27	0	0	0	0
		Flow (%)	13.33%	18.00%	13.33%	18.00%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	2	4	2	4	36	33	36	33
		Flow (%)	1.33%	2.67%	1.33%	2.67%	24.00%	22.00%	24.00%	22.00%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	0	1	0	1	20	18	20	18
		Flow (%)	0.00%	0.67%	0.00%	0.67%	13.33%	12.00%	13.33%	12.00%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
High 3	Common	Flow (days)	21	24	21	24	0	0	0	0
		Flow (%)	23.33%	26.67%	23.33%	26.67%				
		Allowable	0	1	0	1	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	10	15	10	15	10	9	10	9
		Flow (%)	11.11%	16.67%	11.11%	16.67%	11.11%	10.00%	11.11%	10.00%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	4	8	4	8	7	7	7	7
		Flow (%)	4.44%	8.89%	4.44%	8.89%	7.78%	7.78%	7.78%	7.78%
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
Average 3	Common	Flow (days)	6	10	10	14	0	0	0	0
		Flow (%)	6.67%	11.11%	11.11%	15.56%				
		Allowable	0	0	0	0	0	0	0	0
		Catastrophic	0	0	0	0	0	0	0	0
	Critical	Flow (days)	0	3	0	4	19	19	19	19
		Flow (%)	0.00%	3.33%	0.00%	4.44%	21.11%	21.11%	21.11%	21.11%
		Allowable	0	0	0	0	1	1	1	1
		Catastrophic	0	0	0	0	0	0	0	0
	Rare	Flow (days)	0	0	0	0	14	14	14	14
		Flow (%)	0.00%	0.00%	0.00%	0.00%	15.56%	15.56%	15.56%	15.56%
		Allowable	0	0	0	0	1	1	1	1
		Catastrophic	0	0	0	0	1	1	1	1
Low 3	Common	Flow (days)	81	82	81	82	0	0	0	0
		Flow (%)	90.00%	91.11%	90.00%	91.11%				
		Allowable	3	3	3	3	0	0	0	0
		Catastrophic	1	2	1	2	0	0	0	0
	Critical	Flow (days)	72	77	72	77	0	0	0	0
		Flow (%)	80.00%	85.56%	80.00%	85.56%	0.00%	0.00%	0.00%	0.00%
		Allowable	2	3	2	3	0	0	0	0
		Catastrophic	2	2	2	2	0	0	0	0
	Rare	Flow (days)	54	69	55	70	0	0	0	0
		Flow (%)	60.00%	76.67%	61.11%	77.78%	0.00%	0.00%	0.00%	0.00%
		Allowable	3	3	3	3	0	0	0	0
		Catastrophic	3	3	3	3	0	0	0	0

Table 4. PISF Comparisons for GRAF Spawning Bioperiod.

References:

New Hampshire Department of Environmental Services (NHDES) 2008. FINAL Souhegan River Protected Instream Flow Report dated 26 February 2008. Prepared by University of New Hampshire, University of Massachusetts and Normandeau Associates, Inc. NHDES-R-WD-06-50.