Table of Contents

CHAPTER 2: HYDROLOGY

BACKGROUND

United States Geological Survey (USGS) flow records for the San Juan River begin in 1911, but are not consistent or complete until about 1929. By this time substantial irrigation development had occurred. While the pre-Navajo Dam hydrology is natural in shape, it is depleted in volume by about 16 percent from natural conditions due to this irrigation development, with most of the depletion coming during the summer months. Since the depletion prior to Navajo Dam was relatively small and the flow was not regulated by major storage reservoirs, the conditions during the pre-dam period (1929-1961) are used to judge effects of later development and the value of future modification of the hydrology for the benefit of the endangered fishes.

Daily flow data recorded by the USGS (Hydrosphere 1998) from 1929 through the present are available for the key points on the San Juan River. These data have been used to analyze the changes in hydrology with time. The San Juan River's hydrology was very different before regulation by Navajo Dam beginning in 1962. Hydrology is discussed separately for the two periods (pre- and post-dam eras) to contrast the change.

Pre-Navajo Dam (1929 to 1961)

Characterized by large spring snowmelt peak flow, lower summer and winter base flows, and punctuated by high-magnitude, short-duration summer and fall storm events, the San Juan River is typical of dynamic rivers in the Southwestern United States. In addition, this system has a characteristically high sediment load, especially in the lower reaches. For the period 1929 to 1961 at the USGS gaging station near Bluff, Utah, approximately 73 percent of the total annual discharge occurred during spring runoff between March 1 and July 31. The median daily peak discharge (peak daily mean discharge as recorded by USGS does not represent instantaneous peak flow) during spring runoff was 10,500 cfs, with a range of 3,810 to 33,800 cfs. The average pre-dam hydrograph (average of all daily flows from 1929 to 1961) for the San Juan River near Bluff is shown in Figure 2.1.

While the spring runoff produces the largest total volume of water, about 30 percent of the time the yearly peak flow does not occur during spring. Furthermore, the maximum daily average discharge for the period during spring is 33,800 cfs, while the maximum daily average discharge annually is 42,500 cfs. This difference is due to summer and fall storm events. These summer and fall storm events have a small impact on the total water supply, but due to the heavy sediment load, they substantially influence habitat formation and maintenance.

The magnitude of summer and fall storm events in the San Juan River Basin is higher in relation to the mean flow than those noted in the Colorado and Green river basins. In the San Juan River, 97 percent of the years between 1929 and 1961 had at least one storm event during the period of August

next
return to Main Menu

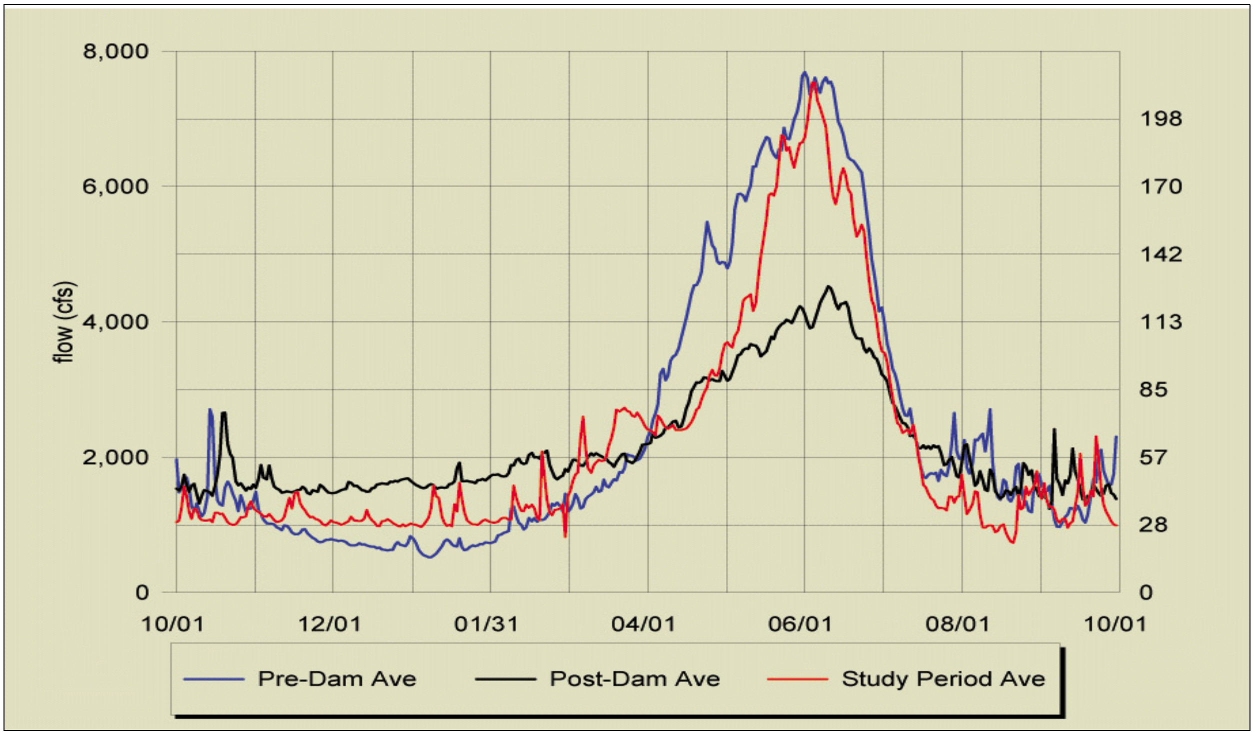

Figure 2.1. San Juan River near Bluff, Utah, average hydrographs for pre-dam, post-dam and 1992-1998 study period.

through November resulting in flows three or more times the average monthly flow for that; 55 percent of the time, the resultant discharge was eight or more times the mean monthly flow, with a maximum daily mean peak to average flow ratio of nearly 13. In comparison, neither the Green River gage nor the Colorado River gage has ever recorded a storm event with a daily mean peak greater than five times the average monthly flow.

The frequency of summer and fall storm events is also higher in the San Juan River Basin. For the period 1929 to 1961, the San Juan River Basin had nearly five times as many days per month with storm events above two times the average base flow, compared with the Green or Colorado rivers. The higher frequency and magnitude of storm events in the San Juan River Basin compared with the Green and Colorado river basins result from the late summer monsoonal influence of the southwestern desert climate. The comparison of average monthly ratios of maximum mean daily flow to daily average flow for the month for the three rivers, along with the average duration of flows above two times the mean monthly flows for the three rivers, appears in Table 2.1.

Annual discharge variability is also a characteristic of the San Juan River. The annual discharge near Bluff for the pre-dam period ranged from 618,000 acre-feet (af) to 4,242,000 af with a median of 1,620,000 af. The maximum flow is 285% of the median while the minimum flow is 41% of the median. This variation in flow is more extreme on the high flow end than the Green or Colorado rivers. For the Green river, the maximum flow is 165% of the median and the minimum 31%. The

Table of Contents

maximum discharge in the Colorado is 182% of the median and the minimum 47%. Furthermore, the hydrology appears to follow cyclic patterns of multiple years of high flow followed by multiple years of low flow where up to four sequential years may have total discharge less than 1,000,000 af. This pattern is characteristic of drought/flood desert climate cycles.

Although the pre-dam era is considered relatively natural, irrigation and other water development depletions have occurred annually since the settlement of the San Juan River Basin. As a result, the pre-dam hydrology was not pristine. Summer and winter base flows during the pre-dam period were low but variable. Typically, summer flows were lowest due to irrigation depletions, and periods of near zero flow were not uncommon. Flows of less than 50 cfs have a recurrence frequency of 29 percent, with an average duration of 11 days. Monthly mean flows were as low as 65 cfs.

Table 2.1. Comparison of storm magnitude and frequency for the Colorado River at Cisco gage, Green River at Green River gage, and San Juan River near Bluff gage, 1929-1961.

	RATIO AVE MAX DAILY /AVG MONTHLY DISCHARGE			AVG NO. OF DAYS FLOW EXCEEDED 2 TIMES AVE MONTHLY FLOW		
Month	Colorado R. at Cisco	Green R. at Green R.	San Juan R. near Bluff	Colorado R. at Cisco	Green R. at Green R.	San Juan R. near Bluff
Oct	1.59	1.46	3.08	0.18	0.06	1.67
Nov	1.24	1.24	1.87	0.00	0.06	0.45
Dec	1.26	1.39	1.75	0.03	0.00	0.33
Jan	1.22	1.25	1.83	0.00	0.00	0.42
Feb	1.24	1.34	1.96	0.00	0.03	1.00
Mar	1.41	1.80	1.91	0.03	1.09	0.70
Apr	1.89	1.74	1.81	1.00	0.48	0.58
May	1.72	1.60	1.78	0.48	0.15	0.52
June	1.54	1.42	1.75	0.09	0.00	0.42
July	1.87	1.90	2.70	0.55	0.79	2.09
Aug	1.75	1.62	3.52	0.42	0.12	2.79
Sep	1.84	1.66	3.78	0.39	0.18	2.52
Ave	1.55	1.54	2.31	0.26	0.25	1.12
Mean annual flow - cfs				7,089	5,557	2,420
Mean base flow (August - January) - cfs				3,153	2,265	1,171
Ratio, base flow to mean annual flow				0.44	0.41	0.48

previous
next
return to Main Menu

Post-Dam Period (1962 to 1991)

Completion of Navajo Dam and subsequent dam operation substantially altered the natural hydrograph of the San Juan River below the dam. Although the Animas River ameliorated some effects of the dam and maintained an elevated spring runoff, the system overall experienced an appreciable reduction in magnitude and change in timing of the annual spring peak. In years of high runoff, dam releases began early to allow space in the reservoir to store the runoff. In the wettest years, releases continued through the peak season (May and June), but during many years, dam releases in May and June were close to the average base release of about 600 cfs. The peak discharge during the post-dam period averaged 54 percent of the spring peak during the pre-dam period.

Base flows were substantially elevated in the post-dam compared with the pre-dam period. The median monthly flow for the base-flow months of August through February averaged 168 percent of the pre-dam period. Minimum flows were also elevated. The near-zero flow periods were eliminated, with a minimum monthly flow during base-flow periods of 250 cfs compared with 65 cfs for the pre-dam period. Summer storm runoff was not directly affected by the dam, especially in terms of high sediment input, because these events can be generated below the influence of the dam. The average post-dam hydrograph (average of daily flows for 1962 to 1991) is shown in Figure 2.1, allowing comparison with the average pre-dam hydrograph.

OBJECTIVES

Since the outset of the SJRIP, mimicry of a natural hydrograph has been hypothesized as necessary to meet the biological and habitat needs of the fish (SJRIP Biology Committee, 1995). The seven-year research program was designed to test the response of the fish and their habitat to a range of hydrologic conditions to provide the data necessary to quantify the required mimicry in the San Juan River. With this need, the following objectives were established:

- Provide a range of flows in the habitat area that would represent wet and dry conditions with a naturally shaped hydrograph.
- Define release hydrographs that would allow testing shape and magnitude in relation to available water supply.
- Define the relationship of the resulting flows to historic conditions, both pre- and post-Navajo Dam.
- Analyze the effect of Navajo Dam and research period test releases on water temperatures downstream in the San Juan River.

METHODS

Beginning in 1991, Navajo Dam release requests were developed by the research group (Biology Committee beginning in 1993), based on information from the Bureau of Reclamation (Burec) on the available water supply. The release hydrographs were defined in terms of the shape of the ascending limb, magnitude and duration of the peak flow and the shape of the descending limb. Both wet years

Table of Contents

and dry years were tested. Due to operating constraints at Navajo Dam, not all requests could be precisely met, but most years the release was close to the requested release. In wet years, extra releases prior to the normal runoff season were necessary to prevent reservoir spills.

USGS gage records were used to assess the resulting hydrograph at Archuleta, Farmington, Shiprock, Four Corners and Bluff. Comparisons of the long term gage record near Bluff, UT to that of the research period were completed to assess the degree of mimicry attained during the research period and allow definition of long term operating criteria.

USGS water temperature data recorded at the San Juan River gages at Archuleta and Shipriock, NM and at the Animas River Gage at Farmington were compared for pre-dam and post-dam conditions to explore the effect of Navajo dam on downstream water temperatures.

Table 2.2. Water temperature monitoring locations and period of record.

Location	RM	Period of Record
Archuleta - San Juan at USGS Gage Location	218.6	7/23/92 to 9/22/98
Blanco - San Juan at US-64 Bridge	207.1	8/7/92 to 2/28/95 (missing 11/21 - 12/9/92)
Bloomfield - San Juan at Highway 44 Bridge	195.6	2/27/93 to 7/17/98
Lee Acres - San Juan at Lee Acres Bridge	188.9	8/8/92 to 12/2/92, 2/26/93 to 4/15/93, 5/27/93 to 9/6/94, 3/9/95 to 10/10/95
Farmington - San Juan at USGS Gage Location	180.1	8/5/92 to 1/16/96
Four Corners - San Juan at USGS Gage Location	119.4	10/7/94 to 3/11/96 *
Montezuma Creek - San Juan at Montezuma Creek Bridge	93.6	8/9/92 to 1/11/93, 2/25 to 3/14/93, 4/14 to 5/10/93, 5/28/93 to 9/21/98
Cedar Hill - Animas at USGS Gage nr Cedar Hill	n/a	8/7/92 to 9/22/98
Farmington - Animas at USGS Gage Location	n/a	8/5/92 to 4/14/97, 5/7/97 to 8/26/97, 10/15/97 to 6/4/98
USGS Data - San Juan at Archuleta	218.6	10/1/50 - 9/30/68 with some missing data
USGS Data - San Juan at Shiprock	148.0	10/1/51 - 9/30/86,9/7/91 - 3/3/93 with some missing data
USGS Data - Animas	n/a	10/1/52 - 9/30/90 with some missing data

Note all locations missing October 1992 data
* installed 8/10/92 but bad data was logged until thermistor was changed in October 1994. Prior to this time is was thought sediment accumulation was causing the warmer readings instead of bad thermistor.

previous next
return to Main Menu

Nine temperature recorders were installed in the San Juan and Animas rivers in July and August of 1992 at the locations shown in Table 2.2. Each station consists of a temperature sensor, lead wires and an OMNIDATA DP-230 data pod. The temperature is sampled every 10 minutes and stored every 24 hours as a maximum, minimum and mean temperature for the day. Also shown in Table 2.2 are the periods of record at each site. Equipment problems impacted the available data.

The USGS has maintained temperature monitoring at Shiprock and Bluff. However, equipment malfunctions have limited the usefulness of these data in recent years and the record at Shiprock terminated in 1992. Shiprock has the best historic record, so having an extended record for this station through the research period was important to the trend analysis. Since the USGS data were incomplete, a Shiprock temperature record was computed from our recorded data based on a linear regression with temperature data at Montezuma Creek and Farmington.

RESULTS

Research releases from Navajo Dam were made every year from 1992 through 1998 (1991 was a control year with no modification to the release) to augment the unregulated flows from the Animas River and provide peak spring runoff flows mimicking a natural hydrograph in the San Juan River below Farmington, NM. Table 2.3 describes the nature of the release each year. The volume of water released in excess of an assumed base release of 600 cfs normally required to meet downstream demands is also shown.

The reservoir release pattern for each year was determined in anticipation of certain flow conditions in the critical habitat range (Farmington to Lake Powell) resulting from the release. However, the flow patterns from the Animas River and other downstream tributaries are not predictable in terms of shape or timing. Therefore, the results anticipated were not always realized. Table 2.4 summarizes the anticipated and actual effects of these releases on downstream hydrology.

The hydrographs at Four Corners for these years appear in Figures 2.2 and 2.3. The flow statistics that apply to these hydrographs appear in Table 2.5. The Four Corners gage is considered the most representative gage for the habitat range and is used in all correlations reported here. However, to do long term statistical comparisons, it is necessary to use the Bluff gage, since the Four Corners gage does not have a long period of record. The statistical comparisons for the Bluff gage are presented in Table 2.6, showing the statistics for the research period with a comparison to the pre-dam (1929-1961) period. The comparison shows that the mean peak flow for the pre-dam period was never reached in any single year during the research period, although the mean runoff volume was exceeded three times. This reflects the limited discharge capacity of the dam and its effect on peak discharge in the river below. Although there are some limitations in the ability of the system to meet the magnitude of pre-dam peak flows, the ability of the system to be managed to produce a more natural hydrograph has been demonstrated. Examination of the statistics for the individual years shows that a reasonable range of conditions were tested to provide a basis for establishing flow recommendations. Ascending limb, descending limb, breadth and magnitude of peak and total volume of runoff were all varied to provide different hydrologic conditions in each year of the study. Wet, dry and intermediate years were also represented in rough proportion to their natural occurrence.

Table 2.3. Summary of Navajo Dam release hydrograph characteristics during the research period, 1992 to 1998.

YEAR	ASCENDING LIMB	PEAK	DESCENDING LIMB	MATCHED ANIMAS RIVER PEAK	VOLUME ABOVE 600 CFS BASE - AF
1992	6 weeks starting April 13	2 weeks at 4,500 cfs	4 weeks ending July 15	Yes	409,740
1993	Starting March 1, rapid increase to 4,500 (compare with 1987)	split peak, 45 days at 4,500 cfs, 7 days at 4,500 cfs	4 weeks ending July 13	No	773,820
1994	4 weeks starting April 23	3 weeks at 4,500 cfs	6 weeks ending July 28	Yes	486,620
1995	3 weeks at 2,000 cfs in March, ramp to 4,500 over 6 weeks starting April 1	3 weeks at 5,000 cfs	4 weeks ending July 14 (summer flow increased by 200 cfs)	Yes	675,810
1996	1 week starting May 27	3 weeks at 2,500 cfs	1 week ending June 29	No	100,320
1997	3 weeks at 2,000 cfs in March, return to 600-cfs base for 31 days, 10 days starting May 12	2 weeks at 5,000 cfs	6 weeks ending July 16	Yes	433,580
1998	30 days starting April 23	3 weeks at 5,000 cfs	1 week ending June 18	Yes	340,850

Table of Contents

Table 2.4. Anticipated and Actual flow conditions achieved in the San Juan River below Farmington as a result of designed releases at Navajo Dam.

YEAR	ANTICIPATED CONDITION	ACTUAL CONDITION
1992	Gradual ascending and moderate descending limbs with a large peak centered near the historical mean	Relatively steep ascending and descending limbs with moderately large peak centered near the historical mean
1993	Long ascending limb, moderate descending limb and large peak centered near the historical mean	Long ascending limb, relatively steep descending limb with moderately large peak centered near the historical mean
1994	Moderate ascending limb, gradual descending limb and large peak centered near the historical mean	Moderate ascending limb, sharp descending limb with earlier reduced magnitude peak
1995	Gradual ascending limb, moderate descending limb and large peak centered near the historical mean	Gradual ascending limb, moderate descending limb and large peak centered later than the historic mean
1996	Sharp ascending and descending limb and low, extended peak designed late to extend the runoff period in this dry year	Sharp ascending and descending limb with low extended, split peak
1997	Sharp ascending limb, gradual descending limb and high, short duration early peak	Sharp ascending and descending limbs and high, split peak centered near the historical mean
1998	First year of applying the proposed flow recommendation with a moderate ascending limb, steep descending limb and high, moderate duration peak centered near the historical mean	Moderate ascending limb, steep descending limb and moderate peak centered near the historical mean.

The hydrograph statistics for the average pre-dam, post-dam and research period conditions are presented in Table 2.7 and the three average hydrographs are plotted in Figure 2.1. Comparison of the statistics in the table and the three graphs demonstrates the more natural like hydrograph that has resulted from re-operation of Navajo Dam during the research period. While the statistics are not directly comparable due to the much shorter time during the research period, some general observations can be made. The apparent decrease in total annual runoff during the research period compared to the pre-dam period is due entirely to increased depletions from the river resulting primarily from the Navajo Indian Irrigation Project (NIIP), the San Juan-Chama Project, and other contracts out of Navajo Dam. With the adjustment for depletions made (Table 2.6), the runoff for this period was actually greater by about 6%.

previous next
return to Main Menu

Table of Contents

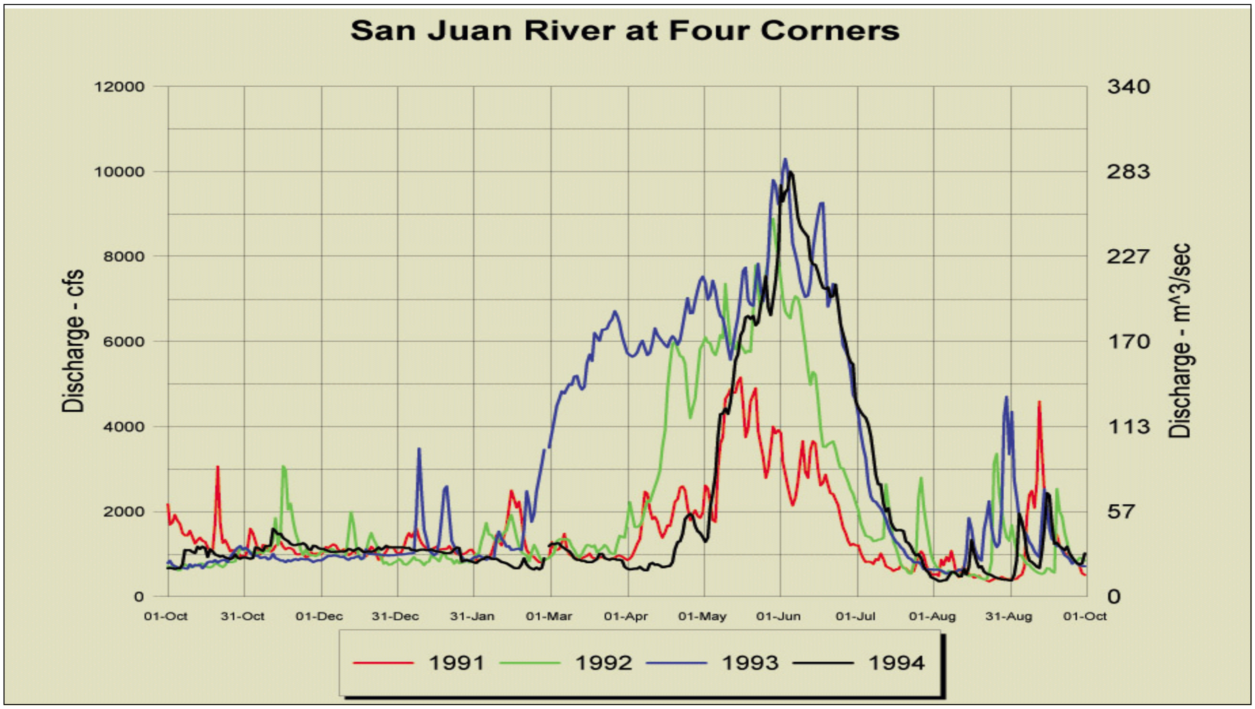

Figure 2.2. **Hydrographs for the San Juan River at Four Corners for 1991 - 1994.**

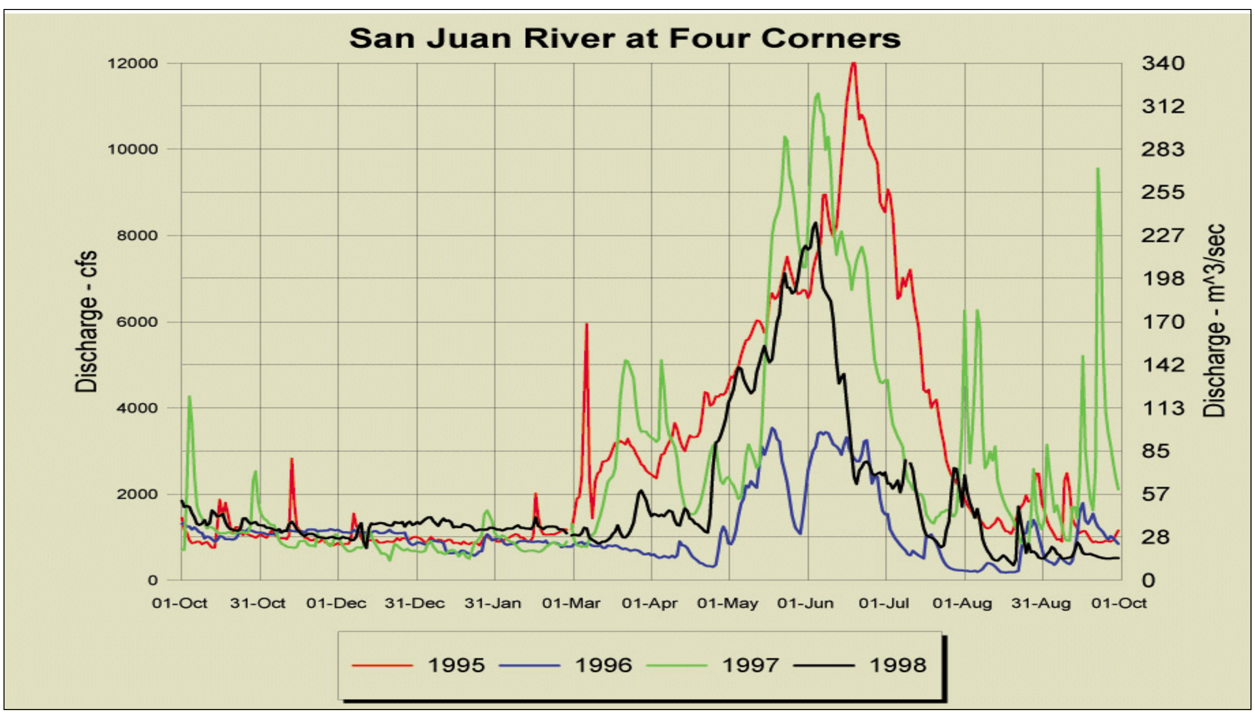

Figure 2.3. **Hydrographs for the San Juan River at Four Corners for 1995 - 1998.**

previous
next
return to Main Menu

Table 2.5. Summary of research flows for the research period, San Juan River at Four Corners, New Mexico.

	1991	1992	1993	1994	1995	1996	1997	1998
San Juan River at Four Corners, New Mexico								
Peak Runoff-cfs	5,160	8,900	10,300	10,000	12,100	3,540	11,900	8,300
Runoff(Mar-Jul)-af	599,459	1,074,795	1,714,328	1,039,601	1,624,927	431,913	1,338,539	855,320
Runoff(total annual)-af	1,086,676	1,512,795	2,216,819	1,448,893	2,102,228	815,795	1,844,019	1,374,229
Peak Date	16-May	29-May	03-Jun	05-Jun	19-Jun	18-May	04-Jun	04-Jun
Days>10,000	0	0	1	0	11	0	10	0
Days>8,000	0	3	16	13	27	0	33	2
Days>5,000	2	54	109	49	72	0	50	31
Days>2,500	46	81	128	67	135	36	100	67
Ave. Daily Flow for month								
October	1,449	769	827	941	1,109	1,091	1,276	1,410
November	1,127	1,356	911	1,210	1,077	1,139	883	1,126
December	1,080	1,088	957	1,105	960	1,088	702	1,191
January	1,173	859	1,358	1,050	918	785	789	1,292
February	1,289	1,298	1,511	781	1,076	899	690	1,211
March	995	1,173	5,463	967	2,782	766	2,255	1,207
April	1,810	3,723	6,188	1,028	3,478	607	2,529	1,801
May	3,739	6,634	7,298	5,251	6,119	2,150	6,000	5,632
June	2,580	4,844	7,701	7,836	9,367	2,925	8,514	4,666
July	801	1,444	1,776	2,170	5,187	715	2,904	1,732
August	556	927	1,348	552	1,564	492	2,310	931
September	1,441	997		1,142	1,193	891	2,365	594

An examination of Figure 2.1 reveals an apparent match of mean peak discharge for the pre-dam and research period. This is somewhat misleading, in that the timing of the peak varied more greatly during the pre-dam period, resulting in a more averaged peak than for the research period. When the peak runoff is averaged without regard to timing, then the difference is apparent (Table 2.7). Both Table 2.7 and Figure 2.1 show the decrease in runoff during the March to July period that occurred primarily on the ascending limb of the hydrograph. The base flow during the fall and winter were closer to pre-dam conditions, although still somewhat elevated.

Table of Contents

Table 2.6. Summary of research flows for the pre-dam and research periods, San Juan River near Bluff, Utah.

	1929-61	1991	1992	1993	1994	1995	1996	1997	1998
San Juan River near Bluff, Utah									
Peak Runoff-cfs	12,409	4,530	8,510	9,650	8,290	11,600	3,280	11,300	7,960
Runoff (Mar-Jul)-af	1,263,890	573,863	1,025,622	1,681,192	887,252	1,503,533	421,001	1,278,795	855,320
(total annual)-af	1,750,643	1,084,540	1,504,916	2,271,912	1,289,521	2,011,415	797,821	1,893,403	1,374,229
Peak Date	31-May	16-May	29-May	30-May	06-Jun	19-Jun	16-Jun	05-Jun	04-Jun
Days>10,000	14	0	0	0	0	6	0	8	0
Days>8,000	23	0	4	13	1	19	0	22	0
Days>5,000	46	0	44	109	41	68	0	46	28
Days>2,500	82	42	79	128	64	137	37	95	56
Ave Daily Flow for month-cfs									
October	2,863	1,628	716	885	1,054	1,145	1,123	1,521	1,639
November	1,858	1,173	1,479	1,013	1,160	1,123	1,181	982	1,213
December	1,405	1,009	1,187	995	1,066	1,033	1,065	769	1,212
January	1,336	1,053	860	2,053	1,047	1,007	739	832	1,391
February	2,115	1,541	1,517	2,256	838	1,175	819	807	1,352
March	3,250	1,179	1,205	5,741	1,081	2,970	739	2,552	1,321
April	7,881	1,684	3,296	6,369	928	3,298	599	2,676	1,686
May	12,484	3,357	6,278	6,840	4,680	5,753	1,974	5,629	5,424
June	13,078	2,474	4,590	7,136	6,055	8,749	2,874	8,000	4,159
July	4,825	807	1,624	1,787	1,961	4,158	798	2,358	1,559
August	3,548	650	1,020	1,195	529	1,581	476	2,497	1,096
September	2,844	1,470	1,219	1,456	976	1,349	860	2,756	708
Frequency of exceedence - annual		67%	52%	36%	58%	39%	91%	39%	58%
Frequency of exceedence - runoff		88%	55%	39%	55%	39%	94%	42%	58%
Frequency of exceedence - peak		94%	61%	58%	61%	41%	100%	45%	67%
Uniqueness		Control	early ave.	early ascent	late ave.	late peak	dry	narrow runoff	early ave.
			storm @ spawn					storm @ spawn	storm @ spawn

previous
next
return to Main Menu

Table of Contents

Table 2.7. Comparison of hydrograph statistics for pre-dam (1929-1961), post-dam (1962-1991) and research period (1992-1998) for the San Juan River near Bluff, Utah.

PARAMETER	1929-1961 PRE-DAM PERIOD			1962-1991 POST-DAM PERIOD			1992-1998 POST-DAM PERIOD		
	Average	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**
Peak Runoff - cfs	12,409	3,810	33,800	6,749	2,660	15,200	8,656	3,280	11,600
Runoff (Mar-Jul) - af	1,263,890	352,551	3,361,882	891,712	177,190	2,458,190	1,093,245	421,001	1,681,192
Runoff (total ann) - af	1,750,643	618,101	4,241,998	1,587,242	611,196	3,266,017	1,591,888	797,821	2,271,912
Runoff (total ann) - af, adjusted for pre-dam depletions							1,862,000	1,068,000	2,542,000
	Years	**Total Yrs**	**Frequency**	**Years**	**Total Yrs**	**Frequency**	**Years**	**Total Yrs**	**Frequency**
Peak>10,000 cfs	18	33	55%	6	30	20%	2	7	29%
Peak>8,000 cfs	22	33	67%	11	30	37%	5	7	71%
Peak>5,000 cfs	30	33	91%	16	30	53%	6	7	86%
Peak>2,500 cfs	33	33	100%	27	30	90%	7	7	100%
AF>1,000,000	18	33	55%	12	30	40%	4	7	57%
AF>750,000	22	33	67%	14	30	47%	6	7	86%
AF>500,000	30	33	91%	20	30	67%	6	7	86%
	Ave. Date	**Std Dev.**		**Ave. Date**	**Std Dev.**		**Ave. Date**	**Std Dev.**	
Peak Date	31-May	23		01-Jun	35		06-Jun	7	
Flow Duration	**Avg all yrs**	**Avg flow yrs**	**Maximum**	**Avg all yrs**	**Avg flow yrs**	**Maximum**	**Avg all yrs**	**Avg flow yrs**	**Maximum**
Days>10,000 cfs	14	27	76	3	15	48	2	7	8
Days>8,000 cfs	23	34	81	8	22	84	8	12	22
Days>5,000 cfs	46	51	108	28	52	124	48	56	109
Days>2,500 cfs	82	82	140	67	74	150	85	85	137
Base Flow	**Median**	**High 10%**	**Low 10%**	**Median**	**High 10%**	**Low 10%**	**Median**	**High 10%**	**Low 10%**
August	1,156	4,782	300	1,566	3,242	407	1,096	2,497	476
September	1,033	3,383	201	1,174	3,279	478	1,221	2,760	708
October	1,000	2,551	400	1,608	3,317	635	1,123	1,639	716
November	752	1,387	497	1,199	3,205	765	1,160	1,479	982
December	667	1,325	434	1,288	3,389	711	1,065	1,212	769
January	609	1,267	471	1,440	3,226	582	1,007	2,053	739
February	872	2,265	572	1,661	3,188	823	1,175	2,256	807

previous
next
return to Main Menu

Table of
Contents

Storm Influence

The San Juan River is heavily influenced by high intensity summer and fall advective storms. These storms produce short duration flow increases that are heavily sediment laden and have been associated with deterioration of habitat quality in the San Juan River (See Chapters 3, 6 and 7). In the flow recommendation report (Holden, 1999), the conditions that impacted habitat quality were described, based on calibration to observed impacts from storm events. A storm-event day was defined in that study as a day in which the daily gain in flow between Farmington, New Mexico and Bluff, Utah, and the daily flow at Bluff, Utah, were each more than 150 cfs greater than the preceding 5-day average. A storm-event day was given a weight of 2 if the gain in flow was 3,000 cfs or more. In the flow/habitat model presented in that report, a year in which there were more than 12 storm-event days during August through December was determined to be a year in which the backwater habitats were filled with sediment (perturbated) to the point that flushing was required to restore them. Figure 2.4 shows the frequency distribution of storm-event days for the period 1931 - 1998 for the San Juan River at Farmington, New Mexico and near Bluff, Utah. This figure shows that at Bluff, Utah, the number of storm-event days exceeded the 12-day threshold about 50% of the time. Field observations of river substrate condition through the summer suggested that these perturbating conditions occur more frequently and with greater severity at downstream locations. The plot of storm-event days for Farmington confirm this observation. Figure 2.4 shows that at Farmington, New Mexico, the 12-day threshold was exceeded only about 10% of the time. The shorter gage record and Shiprock and Four Corners, New Mexico did not allow full comparison, but indicate for the shorter period that most of the increase in storm-event frequency occurs below Four Corners, although some increase in frequency over Farmington is likely.

The obvious conclusion is that spawning bars and backwater habitats would be less disrupted and more easily maintained in the upper reaches of the river, particularly between Farmington and Four Corners.

Water Temperature

The average daily temperature for the San Juan River at Archuleta and at Shiprock are plotted on Figure 2.5. The averages plotted for Archuleta are 1951 - 1961 (pre-dam) and 1964 - 1968 (post-dam). The Shiprock Averages are for the period 1951 - 1961 and 1964 - 1986. Also shown on the plot are the data for Shiprock, averaged over the research period, 1992 - 1998. From March 13, 1993 to September 30, 1998, the Shiprock data is synthesized from a linear regression equation that predicts San Juan at Shiprock temperature from San Juan at Farmington and San Juan at Montezuma Creek temperature based on the following equation developed utilizing 127 values of coincident temperature record from the fall of 1992 through March 13, 1993.:

$$WT_{\text{Shiprock}} = 0.4342 * WT_{\text{Farmington}} + 0.618\ WT_{\text{Montezuma Cr.}} - 0.654\ (R^2 = .997,\ p < .001)$$

Where WT = water temperature in °C.

previous
next
return to
Main Menu

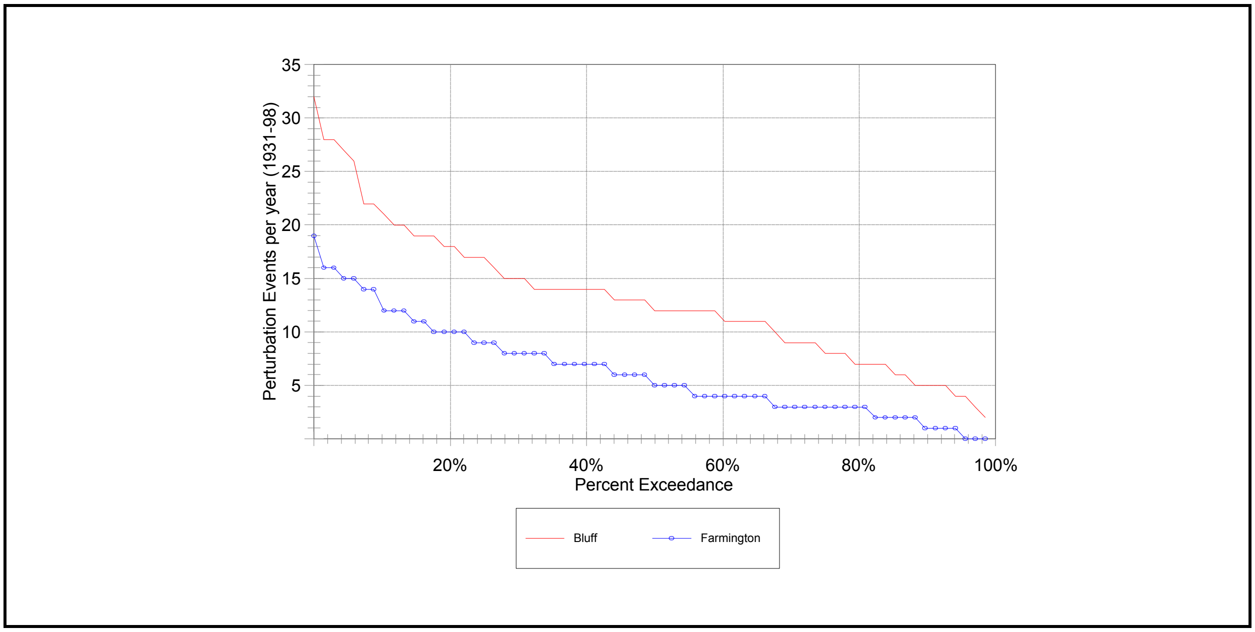

Figure 2.4. Frequency distribution of storm-event days for the San Juan River at Farmington, New Mexico and near Bluff, Utah, 1931-1998.

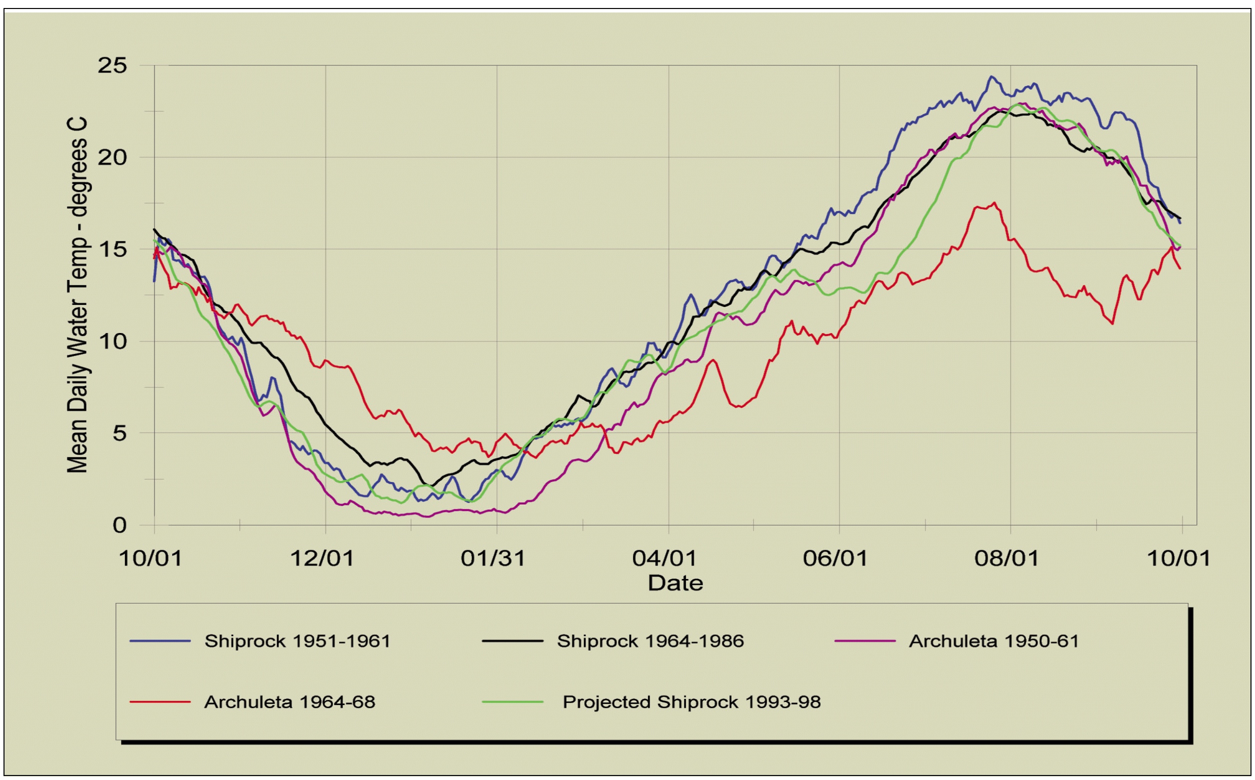

Figure 2.5. Seven-day running mean daily water temperature for the San Juan River at Archuleta, New Mexico, and at Shiprock, New Mexico during pre-dam, post-dam and research flow periods.

previous
next
return to Main Menu

Comparing the Archuleta pre- and post-dam temperature profiles, the effect of Navajo Dam is obvious. The monthly average temperature is as much as 9 °C cooler in the summer and as much as 6°C warmer in the winter since regulation by Navajo Dam began when comparing the two time periods. Since the second time period is rather short, a check on Animas River temperatures for the same two periods was made. It was found that the 1964 - 1968 period was about 0.75 °C warmer than the 1951-1961 period. Therefore, the impact of Navajo Dam on water temperature at Archuleta is at least as great as that shown. The effect of Navajo Dam at Shiprock is less pronounced due to solar heating in this intervening 70 miles of river and the effects of Animas River inflow. Though less pronounced than the effect at Archuleta, the effect is similar. The 1964 - 1986 period is about 2 °C cooler in the spring and summer and as much as 2.5 °C warmer in the winter.

By comparing the 1993 - 1998 period to the earlier periods the incremental effect of re-operation of Navajo dam on temperatures downstream can be determined. The plot shows a temperature depression during runoff (May and June) that is attributable in part to cooler temperatures in the Animas during this period compared to the 1964-86 period. However, the cooler Animas water accounts for only about ½ of the temperature difference between the 1964-86 and the 1992-1998 Shiprock temperature. The impact of the increased release of the cool reservoir water is a suppression in temperature of about 1.5° C during runoff.

With a threshold spawning temperature of 20 °C for Colorado pikeminnow, the effect of Navajo Dam without reoperation is a delay in reaching the threshold temperature of about 15 days. With re-operation and the resulting release of cool water during spring runoff, the date the threshold is reached was extended about 7 more days.

Prior to dam construction, this threshold temperature was reached at Archuleta about11 days earlier than the present date at Shiprock. After dam completion, Archuleta has not reached the threshold temperature of 20 °C. This cooling condition could have the effect of both delaying spawning and moving it further down river.

DISCUSSION

Review of the pre-dam and post-dam hydrograph and flow statistics demonstrate the substantial impact imposed on the hydrology of the San Juan River by the operation of Navajo dam. The spring peak was materially reduced, while the winter base flow was substantially increased, leading to less variability in the flow and an appreciable departure from the pre-dam hydrograph.

The test flow period clearly demonstrated the ability to operate Navajo dam in a manner that would mimic a natural hydrograph and ameliorate some of the impact of the dam on hydrology. This is especially true for the present level of depletions, but applies for additional levels of depletion as well. Figure 2.1 shows that much of the hydrograph shape can be restored. Comparison of the winter flows, however, indicates the importance of being able to reduce winter releases from Navajo dam below the minimum of 500 cfs maintained during the test flows. Winter flows were maintained higher

Table of Contents

than during pre-dam conditions, reducing the availability of that volume of water for spring releases and improved mimicry during both periods of time.

While, on average, it appears that the potential exists for adequate mimicry, there are extreme conditions that cannot be met. With the present release capacity of Navajo Dam at 5,000 cfs, the ability to produce large spring floods below Farmington has been diminished. The impact of this reduction will be discussed more fully in Chapter 3. Further, historic minimum summer through winter base flows would likely not be matched, both as a result of restrictions on minimum releases and a desire to maintain more flow in the river to benefit the fish during these times.

Not only were flows impacted, but the temperature regime in the river was altered. The post-dam water temperatures in the summer at Shiprock are now cooler than pre-dam at Archuleta. With re-operation and increased releases during spring runoff, the depressed temperatures will extend further down river. The net result is a further loss in range for temperature critical activities of over 140 km. While the program has the goal of expanding range, the opportunity may be limited by temperature suppression. Further studies are needed to determine if this temperature suppression is limiting range in otherwise suitable habitat and the options available to correct it if it is found to be a problem

CONCLUSIONS

- Navajo Dam Operation from 1962-1991 substantially altered the hydrograph of the San Juan River to its confluence with Lake Powell.
- The hydrology of the San Juan River is subject to more variation in the summer and fall due to storm activity than the Green or upper Colorado rivers.
- Mimicry of the natural hydrograph is possible with restoration of a more natural spring peak and reduced winter base flow.
- The test flows achieved during the 7-year research period represented a range of wet and dry years as well as a range of hydrograph shapes suitable for testing response of conditions that might be expected under a new operation scheme.
- While storm events effect habitat quality in the entire San Juan River, the frequency of habitat-perturbating events at Farmington, New Mexico is only about 1/2 that at Bluff, Utah. Further, the conditions requiring habitat flushing only occur about 1/5 as frequently at Farmington as at Bluff.
- Navajo dam has modified the temperature regime in the San Juan River by lowering summer and raising winter water temperatures. The net effect is a further shortening of potential range of the native fish during the summer. This temperature modification is increased by releasing water in a pattern required to mimic a natural hydrograph.

return to Main Menu

previous