SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

HYDROLOGY AND WATER TEMPERATURE MONITORING

2009 ANNUAL REPORT

prepared by

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EXECUTIVE SUMMARY

HYDROLOGY

2009 was a dry year in the San Juan Basin, with annual and March-July runoff flows about 59% of the long-term average. The flow recommendation operating guidelines called for a small release from Navajo Reservoir (1 week ramp-up, 1 week at 5,000 cfs, 1 week ramp-down) which was met within operating limitations.

The Animas River peaked early (May 13, 5,320 cfs). The release was implemented per the flow recommendations, missing the Animas peak by over two weeks. This resulted in a split peak with no days above 8,000 or 10,000 cfs. Only the 2,500 cfs criteria were met. If the Animas peak could have been perfectly matched, there would have been 3 days above 10,000 cfs and 11 days above 8,000 cfs.

There were no storm events that created flow spikes after the spring runoff season, resulting in relatively clear, stable flows through the summer and early fall. This is a relatively rare condition. The previous three years all had storm-influenced summer and fall flow events.

The 500 cfs minimum base flow recommendation was not met. The three-gage average was missed for 10 days by as much as 66 cfs.

Long-term trends in hydrology also influence habitat maintenance. Extended droughts do not provide sufficient flushing flows to remove fine sediments that accumulate as a result of summer and fall storm events and can contribute to channel simplification as fine sediments accumulate in low velocity areas and isolate secondary channels (Bliesner, et al., 2008). An examination of 10-year antecedent flow of the San Juan River near Bluff shows that there has been an extended drought period during the 17 years of this study with 2009 being preceded by the driest 10-year average flow on record. There are now seven consecutive years with 10-year antecedent flows below any recorded prior to the monitoring period.

While the high flow criteria were not met this year, the flow recommendations were not violated as the maximum duration between events was not exceeded. The only deviation from the recommendations was during the summer base flow period.

Improving the timing of the Navajo Dam release to better match the Animas peak would increase the number of days of flows above 8,000 and 10,000 cfs. Recent research on the effect of dust deposition on snowpack indicates a strong correlation between albedo of the snow pack and the timing of peak runoff. The possibility of improving the timing of the peak by including reflectance measurements from satellite data and/or the number of dust storm events along with temperature and total snow pack data in a prediction model should be explored.

TEMPERATURE MONITORING

Seven temperature recorders are installed in the San Juan River from Navajo Dam to Mexican Hat, Utah and one is installed on the Animas River at Farmington. They are read twice annually.

The Navajo Dam release started on May 27, 2009 and ended on June 12, 2009. The water temperature at Archuleta responded almost immediately, with a drop of about 3° C. The

combined effect of elevated Animas flows and the Navajo dam release resulted in a temperature drop at Farmington of about 7° C, attributable mostly to the Navajo dam release. The suppression is moderated downstream showing a 5° C suppression at Mexican Hat.

During the summer low flow period increased releases from Navajo Dam again suppressed temperatures at Farmington, keeping the mean temperature below 20° C after July 8. Below Shiprock, the impact is not significant post runoff. In years of low Animas flow like 2009, the temperature suppression effect of the cold Navajo dam release is more substantial than in wetter years. Understanding the impact of this temperature suppression on range expansion of the endangered fishes may be advisable.

CHAPTER 1: INTRODUCTION

Hydrology and water temperature studies of the San Juan River began in 1992 as a part of the San Juan River Basin Recovery Implementation Program (SJRIP). The activities changed from research to monitoring beginning in 1999.

This report summarizes data collected in 2009 as a part of the long-term monitoring program and compares these data to those collected since 1992. Hydrology and water temperature data are summarized here. The data are used to evaluate the impact of Navajo dam operations on the aquatic habitat in the San Juan River below the dam.

SAN JUAN RIVER STUDY AREA

The seven-year research program defined eight geomorphically distinct reaches in the San Juan River (Bliesner and Lamara, 2000; Figure 1.1). Both temperature and hydrology studies cover reaches 2 through 8. The lowest sampling point in both data sets is at Mexican Hat, Utah (USGS gage, San Juan River near Bluff, UT).

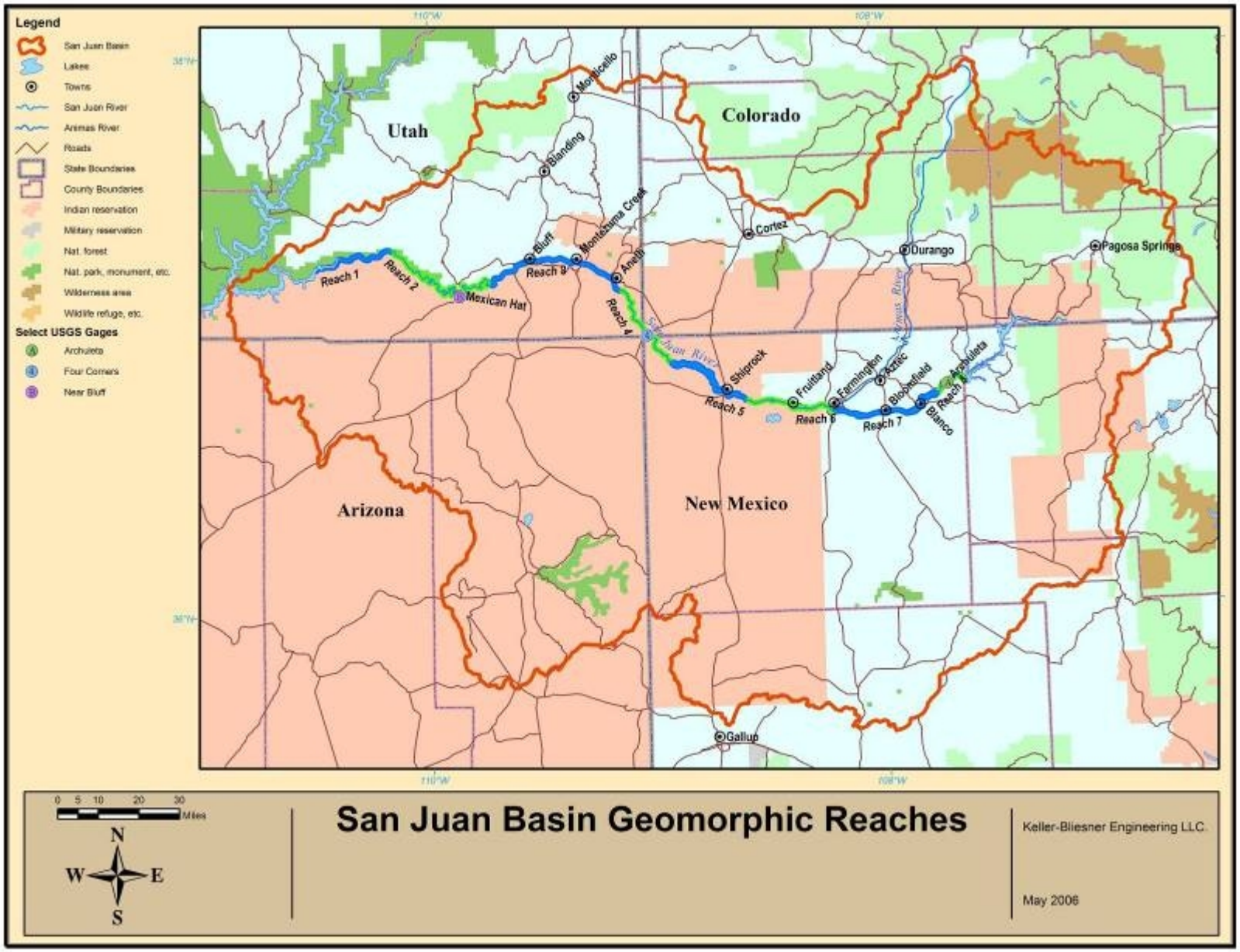

Figure 1.1. San Juan Basin location map showing geomorphic reaches

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 irrigation development, with most of the depletion coming during the summer months. The depletion prior to Navajo Dam was relatively small during the runoff period and the flow was not regulated by major storage reservoirs. Therefore, 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, particularly during the runoff period. The summer low-flow period must be assessed independent of the historical flows as they were much reduced from natural conditions by irrigation and were actually enhanced after reservoir construction.

Between 1993 and 1999 Navajo dam was operated to test a variety of flows during a research period directed toward developing a flow recommendation. The San Juan Recovery implementation program completed the flow recommendation in 1998 (Holden 1999). Since 1999, the operating rules recommended in the Flow Recommendation Report have been employed by Reclamation as far as restrictions would allow[1]. With the completion of the Navajo Dam Operations EIS and the issuance of the Record of Decision in July 2006, the Dam can be operated to meet the flow recommendations as written, subject to the physical limitations of the release works at the dam and the flood control limits between Navajo Dam and Farmington[2].

METHODS

Daily flow data recorded by the USGS from 1929 through the present are available for the key points on the San Juan River. These data have been used to analyze the 2009 hydrology and compare the statistics to previous years. The flow statistics in the SJRIP Flow Recommendation Report (Holden, 1999) are used as the basis for comparison. USGS gage records were used to assess the resulting hydrograph at Archuleta, Farmington, Shiprock, Four Corners, and Bluff.

For each release year, the operating rules are evaluated utilizing the anticipated water supply and the release criteria set. The design release pattern and the actual releases are compared. The statistics of each year are computed and the flow recommendation conditions that were met are indicated.

[1] Prior to completion of the EIS, releases could not go as low as 250 cfs as recommended in the Flow Recommendation Report because the impacts to trout fishery and diverters had not been identified.

[2] Flood control limits do not allow flow in the River to exceed 5,000 cfs. If storm runoff enters any of the tributaries between Navajo Dam and the confluence of the San Juan and Animas Rivers, releases may have to be reduced below 5,000 cfs. Safe operating guidelines on the release works at Navajo Dam may limit magnitude or duration of high flows to accommodate maintenance and inspection requirements and findings.

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. Beginning in 1999, the operating rules presented in the Flow Recommendation Report (Holden, 1999) were implemented.

Water year 2009 was a dry year with annual runoff at Bluff of 937,414 ac-ft and March through July runoff of 606,398ac-ft (both 59% of 1929-2009 average).

The fish release hydrograph resulted in a total volume above base flow (600 cfs) of 111,000 ac-ft (Table 2.1). Table 2.1 also describes the nature of the release each year since 1991 for comparison. Reservoir operating rules called for the smallest release (1 week ramp-up, 1 week at peak, 1 week ramp-down). That release followed the flow recommendations with some minor timing shifts to account for limitations of flow changes on weekends.

The Animas River peaked early (May 13, 5,230 cfs). The release hydrograph missed the peak by over two weeks (Figure 2.1). Only the 2,500 cfs flow recommendation criterion was met (Table 2.2). If the peaks could have matched perfectly, there may have been at most 3 days above 10,000 cfs at Four Corners and 11 days above 8,000 cfs. Days above 5,000 would have reduced to 14 days. While this would have been an improvement in high flow conditions, only the 8,000 and 2,500 cfs criteria in the flow recommendations would have been met.

Base flow conditions of at least 500 cfs (7-day running average) were not met at any gage in 2009 (Table 2.3), although at Farmington it was only missed by 1 cfs. The Shiprock gage was below 500 cfs for 20 days and below 400 cfs for three days. It is the most difficult location to achieve the low flow target since diversions at Hogback occur above the gage and the bulk of the return flow from the Hogback project enters below the gage. Using the three-gage rule, the 500 cfs target was missed for 10 days, with a minimum flow of 434 cfs (Table 2.3).

The 2009 Animas River hydrograph peaked early, with a second small peak in late June (Figure 2.1, Table 2.4). Since the Navajo Dam release was made according to the flow recommendations, it occurred a little over two weeks later, resulting in a split peak in the San Juan River below the Animas River confluence (Figure 2.1). There were no storm events that influenced flow throughout the summer and early fall. The hydrograph is characterized as dry with an early peak (Table 2.4). 2009 is the driest year since 2006 (Figure 2.2).

Long-term trends in hydrology also influence habitat maintenance. Extended droughts do not provide sufficient flushing flows to remove fine sediments that accumulate as a result of summer and fall storm events and can contribute to channel simplification as fine sediments accumulate in low velocity areas and isolate secondary channels (Bliesner, et al., 2008). An examination of 10-year antecedent flow of the San Juan River near Bluff shows that there has been an extended drought period during the 17 years of this study with 2009 being preceded by the driest 10-year average flow on record (Figure 2.3). There are now seven consecutive years with 10-year antecedent flows below any recorded prior to the monitoring period.

While the high flow criteria were not met this year, the flow recommendations were not violated as the maximum duration between events was not exceeded. The only deviation from the recommendations was during the low flow period and that deviation was small (<13% for 10 days).

Table 2.1. Summary of Navajo Dam release hydrograph characteristics since the beginning of the research period, 1992 to 2009

Year	Ascending Limb	Peak	Descending Limb	Matched Animas River Peak	Volume Above 600 cfs Base ac-ft
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 in-creased 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
1999	9 days starting May 24	8 days at 5000 cfs	9 days ending June 18	No	166,189
2000	8 days starting May 30	1 day at 4580	7 days ending June 13	No	61,484
2001	10 days starting May 15	26 days at 4300-5300 cfs	10 days ending June 28	No	265,527
2002	none	None	none	N/A	-
2003	none	None	none	N/A	-
2004	none	None	none	N/A	-
2005	April 28 – May 19	28 days at 4300-4670 cfs	9 days ending June 24	Yes	327,074
2006	9 days starting May 25	6 days at 4900 cfs	9 days ending June 16	No	113,583
2007	5 days starting April 30	13 days at 5,270 cfs	7 days ending 23 May	Yes	171,233
2008[3]	11 days starting May 19	21 days at 5080 cfs	7 days ending June 26	No	262,900
2009	8 days starting May 26	6 days at 5280 cfs	6 days ending June 13	No	111,000

[3] Releases began in February based on high predicted inflow. The flow did not materialize, so the release was terminated in early May with the fish release starting as shown.

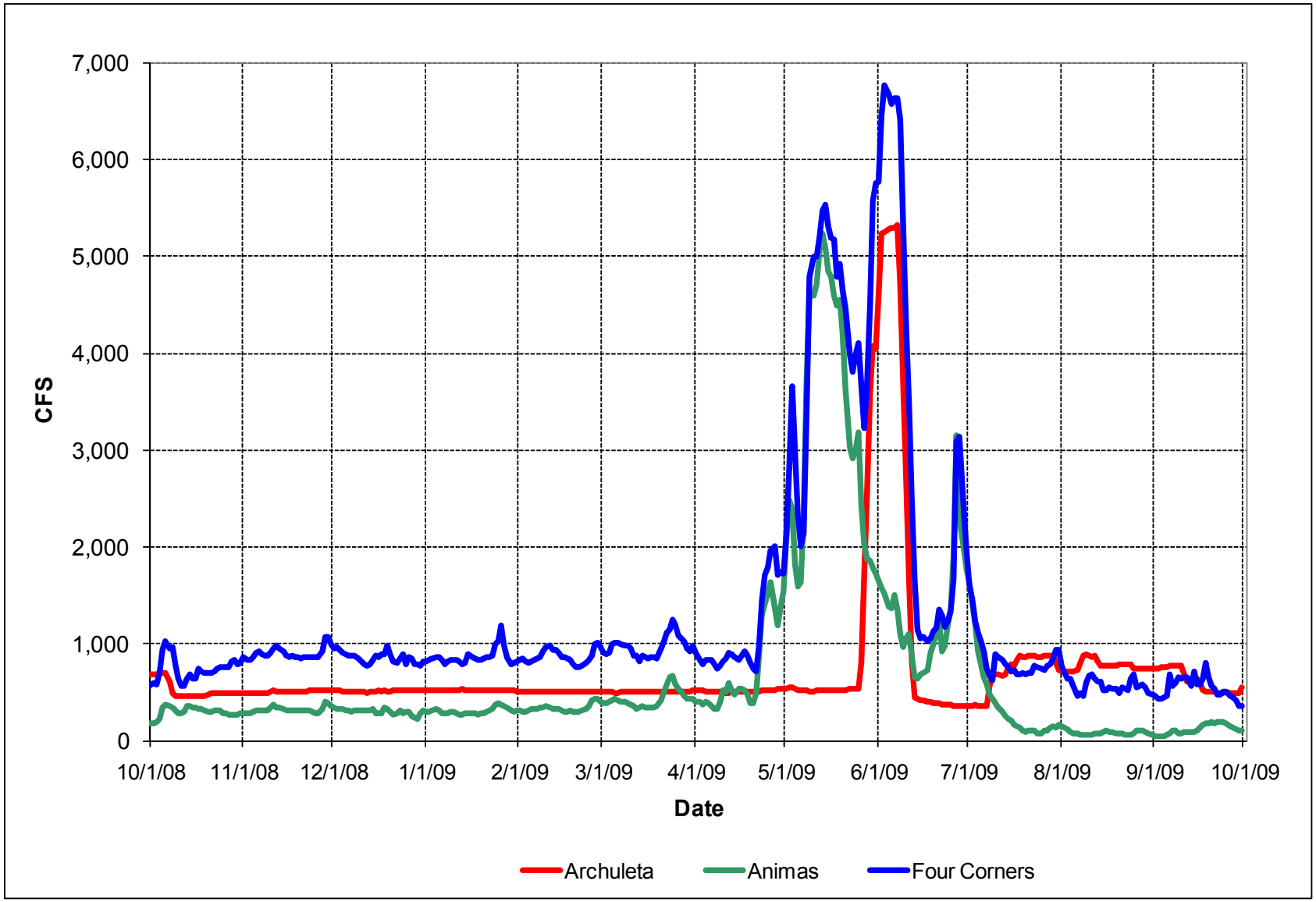

Figure 2.1. San Juan River near Archuleta, and Four Corners and Animas River near Farmington, 2009

Table 2.2. Flow statistics met in each year from 1992 through 2009

Condition (cfs)	Std	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09
10,000 or more	5	0	1	0	**11**	0	**10**	0	0	0	0	0	0	0	**9**	0	0	4	0
8,000 or more	10	0	**16**	9	**27**	0	**33**	2	0	0	1	0	0	0	**18**	0	2	**25**	0
5,000 or more	21	2	**109**	**49**	**72**	0	**51**	**34**	**29**	3	**33**	0	0	1	**50**	7	**21**	**58**	17
2,500 or more	10	**46**	**126**	**68**	**135**	**36**	**103**	**65**	**72**	**37**	**55**	0	**13**	**23**	**84**	**25**	**54**	**118**	**41**
Years w/o meeting 10,000	10	6	7	8	0	1	0	1	2	3	4	5	6	7	0	1	2	3	4
Years w/o meeting 8,000	6	0	0	1	0	1	0	1	2	3	4	5	6	7	0	1	2	0	1
Years w/o meeting 5,000	4	0	0	0	0	1	0	0	0	1	0	1	2	3	0	1	0	0	1
Years w/o meeting 2,500	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Note: Values in **BOLD** are those that meet or exceed the minimum standard

Table 2.3. 2009 base flow statistics using a 7-day running average

Gage	Minimum 7-Day Average Flow	Days below Given Flow Rate		
		500 cfs	400 cfs	300 cfs
Farmington	499	1	0	0
Shiprock	374	20	3	0
Four Corners	435	9	0	0
Bluff	493	2	0	0
3-gage	434	10	0	0

DISCUSSION

The lack of summer and autumn storm events exhibited in 2009 is unusual in the San Juan River. This is the only year there have been no storm flows during the period July through September that elevated the flow at Four Corners above 1,000 cfs. To add to the uniqueness of base flow conditions, the October 2008 through April 2009 period was also very stable with a maximum flow of 1,250 cfs prior to runoff. In association with the stable flows, turbidity was lower. The stable flows and reduced turbidity may have influenced sampling efficiency either positively or negatively depending on sampling method and should be considered when interpreting the results.

The Animas runoff was unusually early in 2009. New research by Tom Painter, director of the Snow Optics Laboratory at the University of Utah, and other scientists indicates that this early runoff was influenced by high dust content in the snow which decreases reflectance and increases the rate of snowmelt (Earth Today, 2009). The winter of 2008-2009 had 12 dust events resulting in reduced reflectance (browner snow) than in the spring of 2008 (Figure 2.3). By using MODIS satellite imagery and/or dust storm event data in combination with temperature and snow pack information, it may be possible to improve the prediction of the Animas River runoff peak. This would allow a better match between the Animas peak and the peak of any

Table 2.4. Summary of flows for San Juan River at Four Corners, New Mexico, 1992-2009

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Peak Runoff-cfs	8,900	10,300	9,090	12,100	3,540	11,900	8,580	7,970	5,210	8,340	926	3,900	5,110	13,500	6,200	8,530	11,600	6,760
Runoff - af (Mar - Jul)	1,076,680	1,717,333	1,004,047	1,627,775	432,670	1,340,886	931,107	876,847	548,424	848,626	174,282	294,401	475,970	1,205,506	433,755	769,371	1,418,697	622,372
Runoff - af (Tot. Ann.)	1,512,795	2,216,820	1,410,706	2,102,229	815,796	1,884,020	1,401,536	1,901,804	928,808	1,288,346	534,643	627,396	739,950	1,575,554	838,114	1,328,930	1,992,026	942,819
Peak Date	29-May	3-Jun	5-Jun	19-Jun	18-May	4-Jun	4-Jun	3-Jun	6-Jun	29-May	23-May	30-May	5-Apr	27-May	7-Jun	17-May	4-Jun	3-Jun
Days >10,000	0	1	0	11	0	10	0	0	0	0	0	0	0	9	0	0	4	0
Days >.8,000	3	16	9	27	0	33	2	0	0	1	0	0	0	18	0	2	25	0
Days >5,000	54	109	49	72	0	51	34	29	3	33	0	0	1	50	7	21	58	17
Days >2,500	81	126	68	135	36	103	65	72	37	55	0	13	23	84	25	54	118	41
Average Daily Flow for Month																		
October	767	826	919	1,107	1,089	1,273	1,404	1,533	1,141	1,273	829	720	633	873	1,351	2,676	1,252	734
November	1,354	909	1,202	1,076	1,137	881	1,175	1,494	910	1,154	836	744	612	796	908	979	1,086	901
December	1,086	955	1,129	958	1,087	700	1,154	1,031	940	966	848	657	517	689	790	887	1,261	858
January	858	1,356	1,056	916	783	788	1,208	947	935	915	835	569	524	838	740	837	1,251	863
February	1,263	1,522	852	1,084	874	695	1,239	976	931	1,039	732	574	578	1,295	583	989	3,141	867
March	1,171	5,454	948	2,777	765	2,251	1,267	969	1,186	1,329	663	698	1,016	1,285	583	1,278	4,799	970
April	3,716	6,178	984	3,472	606	2,524	1,910	1,174	2,263	1,680	582	580	2,020	3,082	861	1,318	4,111	1,083
May	6,622	7,285	5,255	6,108	2,146	5,990	5,831	3,439	2,995	5,146	713	1,619	2,485	7,694	1,974	5,787	5,185	4,170
June	4,835	7,688	7,212	9,351	2,920	8,499	4,542	5,986	2,293	4,984	501	1,371	1,754	6,382	2,721	3,174	7,779	3,184
July	1,442	1,773	2,195	5,178	714	2,899	1,802	2,925	330	877	411	583	586	1,468	1,031	1,101	1,583	852
August	925	1,346	534	1,561	491	2,306	1,073	6,135	708	1,315	482	672	440	940	1,266	1,614	818	576
September	997	1,432	1,078	1,193	891	2,361	574	4,852	733	646	1,443	1,611	1,100	762	1,058	1,287	883	543
Uniqueness	Early Ave.	Early	Late Ave.	Late Peak	Dry	Narrow Runoff	Early Ave.	Large Summer Release	Dry	Early Ave.	Record Dry	Very Dry	Dry	Classic Hydro-graph	Dry	early average	High Spring Flows	Dry, early peak
	Storm @ Spawn					Storm @ Spawn	Storm @ Spawn	Storm @ Spawn				Sep. Peak > 10,000			Storm @ Spawn	Storm @ Spawn, 8,000 peak Oct	Storm @ Spawn	

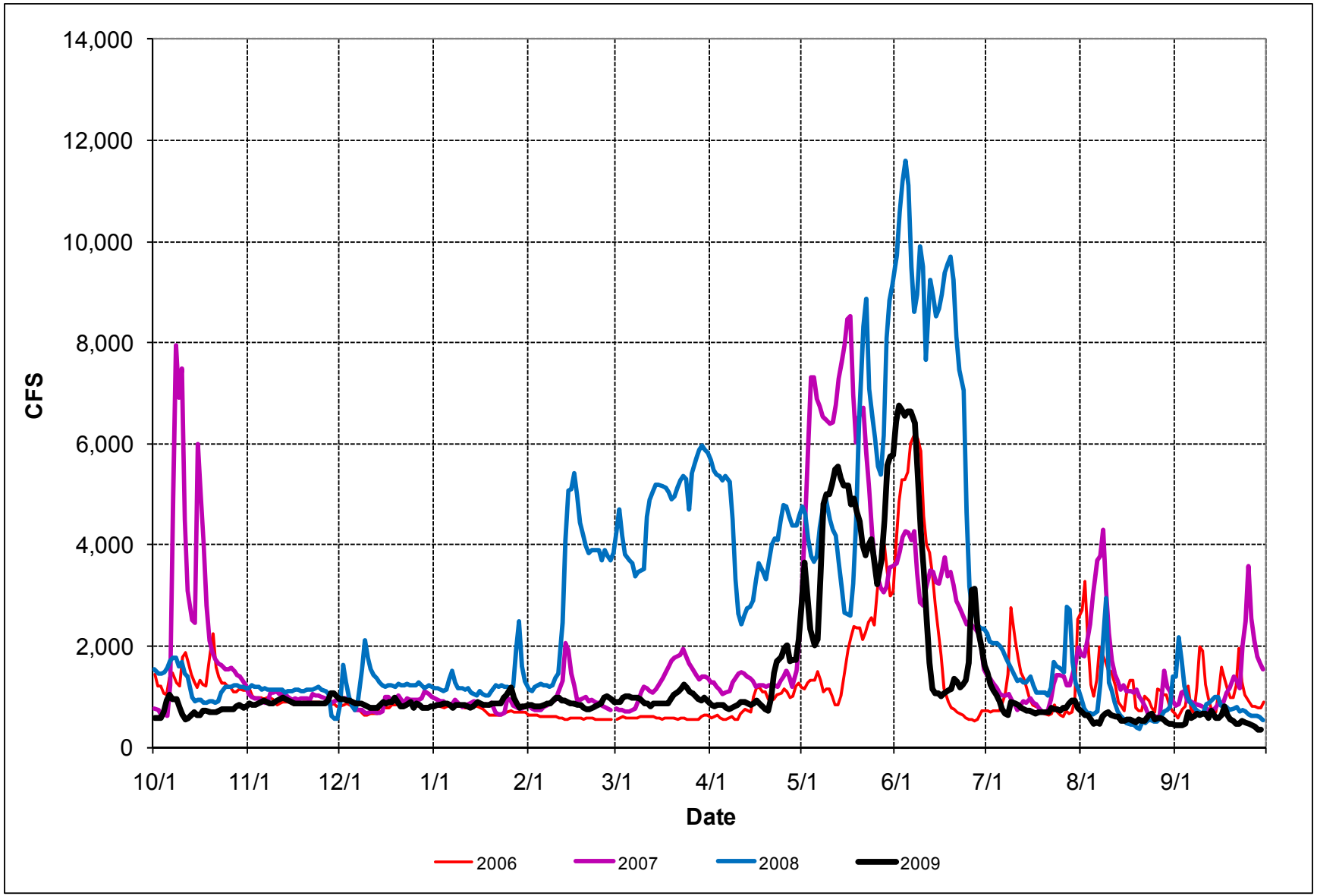

Figure 2.2. San Juan River at Four Corners, 2006-2009

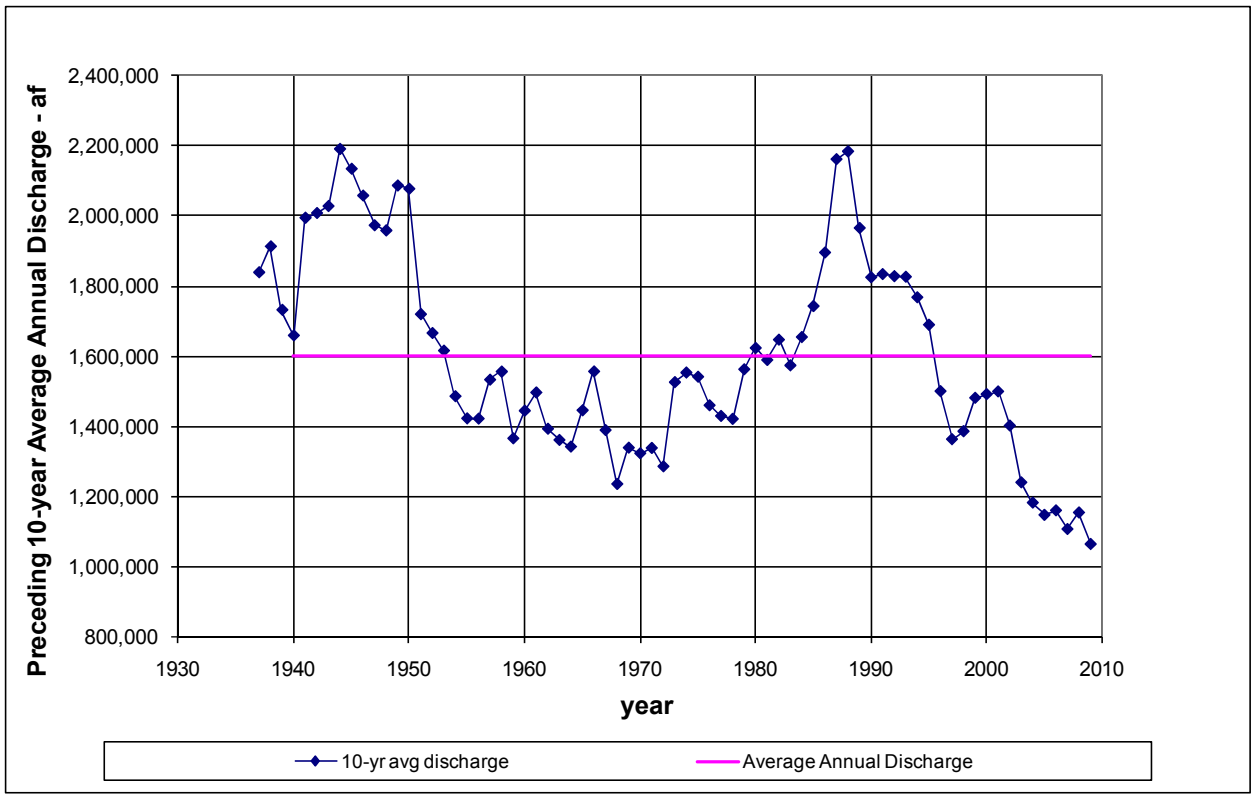

Figure 2.3. 10-year average antecedent flow in the San Juan River near Bluff, Utah 1937-2009

Navajo dam release, providing an increase in the number of days of high flows in the San Juan River. It is recommended that a runoff timing prediction approach that includes snow reflectance or dust storm events be evaluated for the potential to improve timing of the Navajo Dam release.

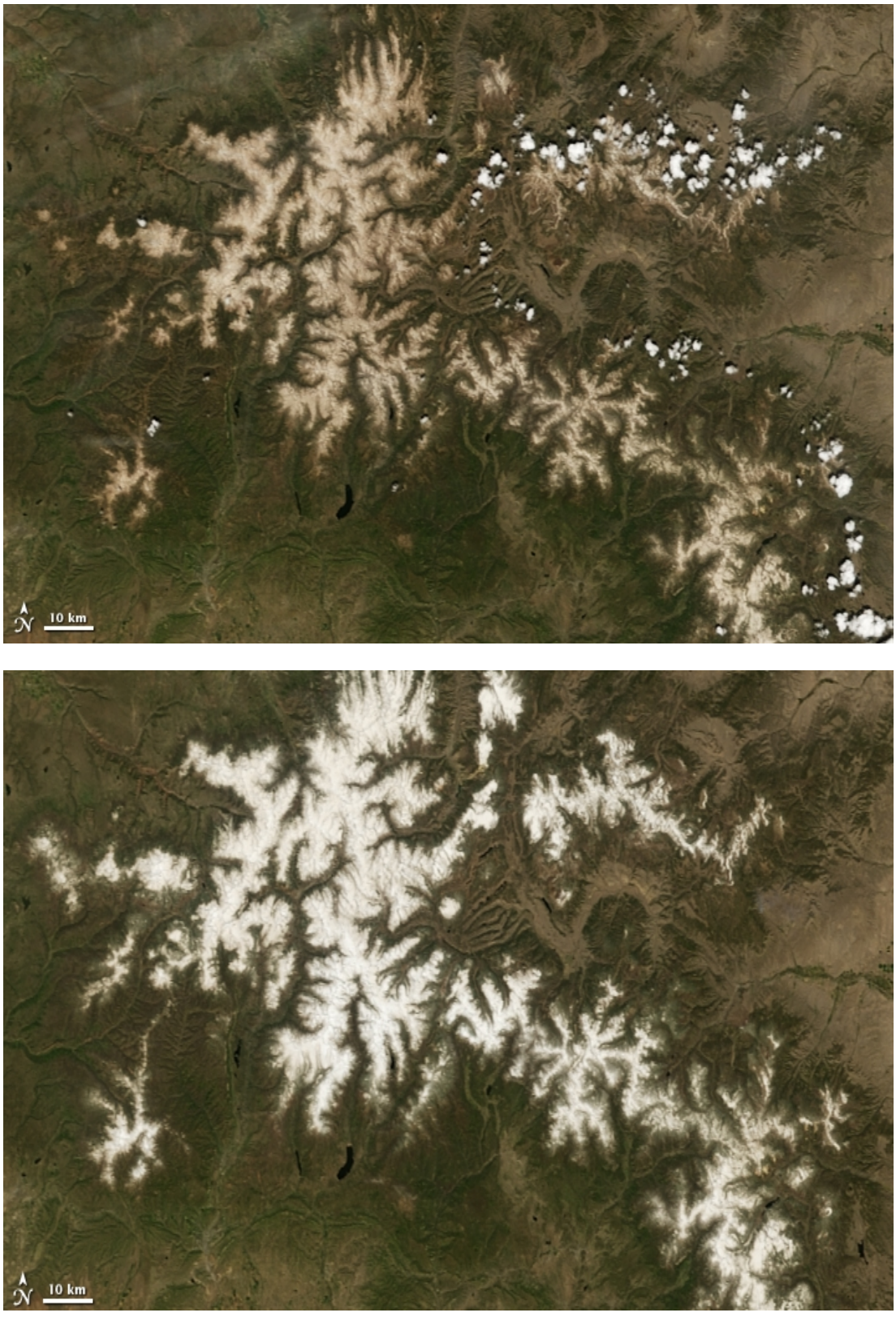

Figure 2.3. Comparison of snow reflectance May 2009 (top photo) to May 2008 (bottom photo) showing influence of dust events.

CHAPTER 3: WATER TEMPERATURE

METHODS

Eight temperature recorders are presently installed in the San Juan and Animas rivers and have been in place since summer of 1992 at the locations shown in Table 3.1. Optic StowAway temperature loggers from Onset Corporation were utilized from 1999-2006. In 2006, these recorders were replaced with Onset Corporation HOBO Water Temp Pro loggers. Both loggers record water temperature every 15-minutes. Table 3.1 also shows the periods of record at each site for this 15-minute data. The missing data were caused by equipment problems or vandalism. The recorders are inspected and read twice each year, once in the spring and once in the fall. Battery condition is monitored and loggers changed out when the battery life falls below that required to continue until the next reading point.

From 1992-1999, OMNIDATA DP-230 data pod loggers sampled water temperature every 10 minutes and stored maximum, minimum and mean temperature for each day. The period of record for these data appear in Table 3.2. All temperature records for both data sets are maintained in a Microsoft Access Database.

OMNIDATA DP-230 loggers were also installed in a few additional sites for a period of time (Table 3.2). These records are not in the database, but have been archived, along with some earlier USGS data as indicated in Table 3.2.

RESULTS

The temperature profiles plotted with the hydrograph at the Four Corners (4C) and Archuleta gage flows illustrate the negative correlation between flow and water temperature (Figure 3.1). The Navajo Dam release started on May 27, 2009 and ended on June 12, 2009. The water temperature at Archuleta responded almost immediately, with a drop of about 3° C. The combined effect of elevated Animas flows and the Navajo dam release resulted in a temperature drop at Farmington of about 7° C, attributable mostly to the Navajo dam release. The suppression is moderated downstream with a 5° C suppression at Mexican Hat.

During the summer low flow period increased releases from Navajo Dam again suppressed temperatures at Farmington, keeping the mean temperature below 20° C after July 8. Below Shiprock, the impact is not significant post runoff.

In years of low Animas flow like 2009, the temperature suppression effect of the cold Navajo dam release is more substantial than in wetter years.

DISCUSSION

The temperature suppression of the San Juan River at Farmington is evidenced each year there is a peak release from Navajo Dam. The suppression is short lived and in less obvious in high flow years than in low flow years like 2009. In 2009, and other years when the Animas flow is low, the temperature suppression in the San Juan River above Shiprock is substantial in both magnitude and duration. It may be advisable to examine the impact of this cooler water on the desired range expansion of the endangered Colorado pikeminnow and razorback sucker.

Table 3.1. Water temperature monitoring locations and period of record for active monitoring sites[4]

Location	River Mile	Notes	Latitude	Longitude	Start Date	End Date	Missing Data
Navajo Dam	225	Base of Navajo Dam on river left immediately downstream of outlet	36.80484	-107.6148	11/17/1999	10/05/2009	9/16/06 - 10/11/06
Archuleta	218.6	Located at the Archuleta USGS gage	36.80278	-107.6990	07/09/1999	10/05/2009	9/16/06 - 10/11/06
Farmington	180.1	Located at the Farmington USGS gage	36.72221	-108.2251	07/08/1999	09/29/2009	11/5/01 - 10/2/02, 9/16/06-10/10/06
Shiprock	148	Located at the Shiprock USGS gage	36.78100	-108.6899	07/08/1999	10/05/2009	9/15/06-10/10/06
Four Corners	119.4	Located at the Four Corners USGS gage	37.00195	-109.0311	07/09/1999	09/21/2009	9/16/06 - 10/11/06
Montezuma Creek	93.6	Located left bank at sheet piling upstream side of the Mont. Creek bridge	37.25790	-109.3096	07/09/1999	09/21/2009	3/12/05 - 10/30/05, 9/16/06 - 10/11/06, 10/6/08 – 4/29/2009
Mexican Hat	52.1	Located right bank near the USGS mini-monitor enclosure upstream of Mex Hat bridge	37.15059	-109.8669	07/09/1999	09/21/2009	3/26/02 – 10/28/02, 8/1/06 - 10/11/06
Animas at Farmington	n/a	Located at the Animas at Farmington USGS gage	36.72154	-108.2017	07/08/1999	09/29/2009	9/16/06 - 4/25/07, 10/11/08 – 4/4/08, 10/10/08-4/23/09

[4] Period of record is for 15-minute data from Onset loggers. Earlier data listed in Table 3.2.

Table 3.2 Temperature data for other periods and locations in the database

Location	River Mile	Notes	Latitude	Longitude	Start Date	End Date	Missing Data
Daily Maximum, Minimum and Average Temperature Data Collected Before 1999 at the Active Monitoring Sites							
Archuleta	218.6	Located at the Archuleta USGS gage	36.80278	-107.6990	07/23/1992	05/19/1999	10/2/92-10/29/92
Farmington	180.1	Located at the Farmington USGS gage	36.72221	-108.2251	08/05/1992	01/16/1996	10/2/92-10/29/92
Four Corners	119.4	Located at the Four Corners USGS gage	37.00195	-109.0311	10/07/1994	7/19/1998	data sporadic 1996-98
Montezuma Creek	93.6	Located left bank at sheet piling upstream side of the Mont. Creek bridge	37.25790	-109.3096	08/09/1992	05/19/1999	10/2/92-10/30/92 1/12/93 - 2/25/93, 3/15/93 - 4/14/93, 5/11/93-5/27-93
Animas at Farmington	n/a	Located an the Animas at Farmington USGS gage	36.72154	-108.2017	08/05/1992	06/04/1998	10/2/92-10/29/92 4/15/97 - 5/6/97, 8/27/97 - 10/14/97
Maximum, Minimum and Average Daily Temperature Records Archived from other Sites							
Blanco	207.1	San Juan R. at US 64 bridge	n/a	n/a	7/7/1992	2/27/1995	10/2/92-10/29/92, 11/21/92 - 12/9/92
Bloomfield	195.6	San Juan R. at Highway 44 bridge	n/a	n/a	2/27/1993	7/17/1998	
Lee Acres	188.9	San Juan R. at Lee Acres bridge	n/a	n/a	02/26/1993	10/10/1995	4/16/93 - 5/26/93, 9/07/94 - 3/08/95
Cedar Hill	188.9	Animas at USGS gage near Cedar Hill, NM	n/a	n/a	08/07/1992	9/22/1998	10/2/92-10/29/92, 1/30/98-4/23/98
USGS Data Archived							
Archuleta	218.6	Located at the Archuleta USGS gage	36.80278	-107.6990	10/01/1950	09/30/1968	Some missing data
Shiprock	148	Located at the Shiprock USGS gage	36.78100	-108.6899	10/01/1951	09/07/1991	10/1/86 - 9/6/91
Animas at Farmington	n/a	Located an the Animas at Farmington USGS gage	36.72154	-108.2017	10/01/1952	09/30/1990	Some missing data

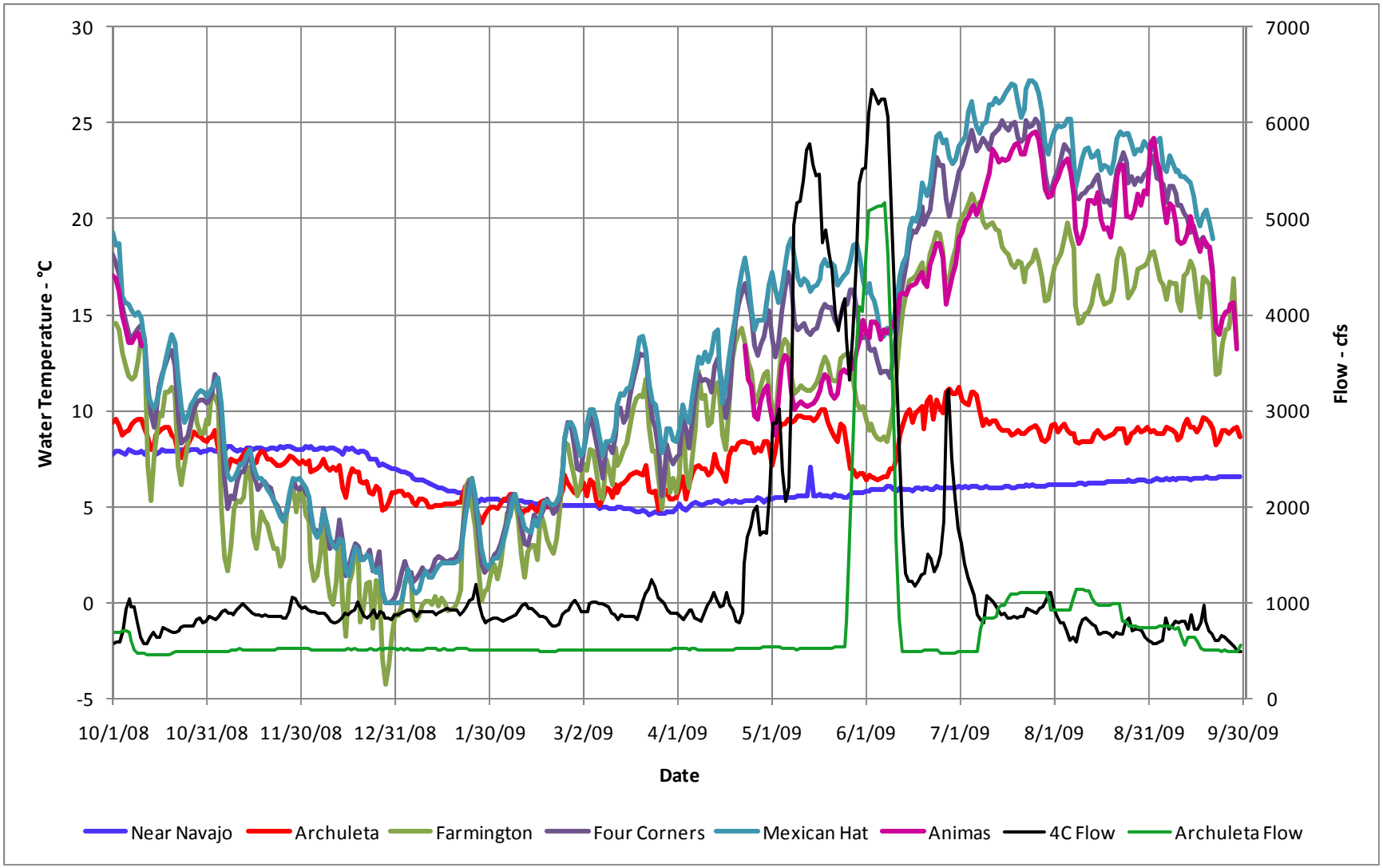

Figure 3.1. San Juan Basin Average Water Temperature Data, 2009

REFERENCES

Bliesner, R., and V. Lamarra, 2000. San Juan River Basin Recovery Implementation Plan Hydrology, Geomorphology and Habitat Studies. 1992 - 1998 Final Report. Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Bliesner, R., de la Hoz, E.A., P. Holden., and V. Lamarra. 2008. Hydrology, geomorphology, and habitat studies. 2007 annual report. San Juan River Basin Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 97p.

Earth Today.net, July 7, 2009 - Dust Accelerates Snow Melt in San Juan Mountains. url: http://www.spaceref.com/news/picture_of_the_day?pid=752

Holden, 1999. Flow Recommendations for the San Juan River. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.