SAN JUAN RIVER BASIN
RECOVERY IMPLEMENTATION PROGRAM

HYDROLOGY, GEOMORPHOLOGY AND HABITAT STUDIES

2007 ANNUAL REPORT

prepared by

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EXECUTIVE SUMMARY

HYDROLOGY

The 2007 flow in the San Juan River near Bluff, Utah was only 85% of the 1929-2007 average, but the March through July flow was only 69% of average. The flow recommendation operating rules called for an intermediate release (1 week ramp up, 2 weeks at peak, 1 week ramp down) which was met. However, a very full reservoir required an early release to prevent an uncontrolled spill. The peak release was centered on May 11 rather than June 4 as recommended. This shift in the peak did match an early peak on the Animas and caught part of a later peak, resulting in about the same high-flow conditions as would have resulted from a later release. The early release reduced potential downstream flooding and provided about the same conditions for habitat maintenance as the recommended release would have provided. The 2,500 and 5,000 flow criteria were met and there were two days at 8,000 cfs or above. The peak flow at Four Corners was 8,530 cfs.

One large storm event (7,940 cfs peak, 130,000 acre-foot total) occurred pre-runoff in October 2006. Two storm runoff events with peak discharge greater than 3,000 cfs occurred post-runoff (August 8 – 4,310 cfs and September 25 - 3,580 cfs). These events are typically sediment laden and increase turbidity and sediment deposition through the fall months. While late summer and fall storm events are common, July and early August storm events that could affect pikeminnow hatching success only occur about 30% of the time. The August event falls within that time window.

DETAILED REACH STUDIES

Detailed reaches established at RM 82 and RM 137 in 2005 were surveyed again in 2007 to assess channel change with flow and update the River2D models developed in 2005. Water's edge surveys were also completed in August during an intermediately high flow event. Standard and detailed habitat mapping were completed in November 2007. A two-pass fish survey was completed in both reaches in August 2007. Detailed mapping was completed coincident with the fish survey. Colorado pikeminnow capture data from the small-bodied monitoring and non-native removal programs were included in habitat selection and association studies. The River2D model results were used to generate velocity and depth data throughout the detailed reaches over a range of flows from 700 to 8,000 cfs. These results were used to examine coarse sediment transport, relationships of mean velocity and wetted area with flow and identification of the characteristics and extent of shore-run habitat, which has not been specifically mapped.

The following findings were reached:

Channel Change

- DR 82 demonstrated about 8 cm of net deposition between August 2006 and August 2007, with both scour and deposition within the reach. Both cobble/gravel and sand increased in the reach in 2007, compared to a net decrease for both in 2006. 86% of the net increase was sand, likely as a result of a large storm event a few days before the survey.

- DR 137 demonstrated nearly 5 cm of net deposition during the same time period with both scour and deposition within the reach. There was a net loss of cobble/gravel and a net import of sand. Two thirds of the total deposition was sand, much of it likely as a result of the storm event discussed above.
- The change in bed elevation is statistically significant for both cobble and sand.

River2D Model

- River2D models have been developed and operated for DR 82 and 137 that cover ranges in flow from about 700 cfs to around 8,000 cfs.
- The models provide sufficiently reliable results to forecast depth, velocity and wetted area over a range of flows.
- At high flows, continuity of wetted area remains a problem in the model representation of the shallow channels across the islands. Additional survey break lines will be needed to improve the visual representation of wetted area at high flow.
- Model results indicate that DR 82 reaches maximum average flow velocity at about 6,000 cfs and bank-full conditions at 7,000 – 8,000 cfs.
- For DR 137, maximum average flow velocity is reached at about 5,000 cfs and bank-full conditions occur at between 6,000 and 7,000 cfs.

Coarse Sediment Transport

- Boundary shear stress is adequate in both reaches to mobilize cobble into the reaches at flows near bank-full (6,000 – 8,000 cfs).
- Localized shear stress analysis indicates locations within the detailed reaches that scour at low flow and deposit at high flow and vice versa.
- The analysis within the detailed reaches confirms conclusions in the flow recommendation report for cobble transport: 1. cobble on some portions of bars moves at low flow and on other portions at high flow. 2. Bank-full flow (8,000 cfs) is adequate for the cobble transport necessary to maintain spawning bars.
- Providing survey data upstream and downstream of the detailed reaches is recommended to allow computation of boundary shear stress in the inlet and outlet areas of the detailed reach

Detailed Reach Habitat

- Detailed mapping identifies from 2 to 3 times as many habitat polygons as standard mapping overall. For important low velocity habitats, the increase in resolution is much higher.
- Habitat grouping was changed as a result of habitat classification review to include run-riffles in the riffle rather than run category.
- Extrapolation of detailed mapping results to the river-wide data set will require at least one more year of data before regressions can be attempted. All though the original study plan anticipated 5 years of data, we will assess the quality of the relationships and determine the additional data requirement in 2008.

Model and Habitat Data Integration

- Availability of shore-run habitat was determined by applying depth/velocity criteria to establish a typical distance from shore as the break between shore-run and mid-channel run habitat types. 2.5 m was found to best represent the transition between the two habitats based on data from the detailed reaches.
- Application of the 2.5 m offset for the detailed reaches resulted in about 10% of the run habitat being classified as shore-run.
- Shoreline discrimination for selection of appropriate edge conditions should be included in future definitions.
- Shore-run habitat definition should be refined after receiving input from the Biology Committee.

Fish Survey

- During the August 2007 survey, 18 age 1 Colorado pikeminnow were captured in the two detailed reaches (5 in DR 82 and 14 in DR137).
- The density of Colorado Pikeminnow in both the detailed reach and small bodied monitoring programs was less than that typically recommended for reliable Chi-square analysis, so conclusions should be considered tentative, pending additional years of data.
- Age 1 Colorado pikeminnow selected for eddy and cobble shoal habitat in the detailed reaches.
- The native fish assemblage selected for isolated pool and riffle plunge and against cobble shoal and run
- The non-native fish assemblage selected for backwater, isolated pool, pool and sand shoal and against cobble shoal, eddy, run, riffle and slackwater
- No Colorado pikeminnow were captured in velocities greater than 0.6 m/sec in the detailed reaches.
- Age 1 Colorado pikeminnow selected for coarse (cobble/gravel) substrate and against fine (sand/silt) habitat.
- The small-bodied fall monitoring program captured 23 age 0 and 31 age 1 Colorado pikeminnow.
- In the small-bodied monitoring program, age 1 Colorado pikeminnow selected for riffle-eddy, pool and debris pile habitats while age 0 Colorado pikeminnow selected for backwater, slackwater and overhanging vegetation habitats.
- Occurrences of combinations of cobble shoals with slackwater, runs with cobble shoals and runs with cobble shoals and slackwater within 5 m of the sampling location were significantly higher for sites where Colorado pikeminnow were captured.
- GPS data for Colorado pikeminnow capture locations by the non-native removal program indicate greater habitat diversity or richness in locations of Colorado pikeminnow capture compared to sites without Colorado pikeminnow. Low velocity habitats, bars and to a lesser extent islands, occurred more frequently in these locations. Greater habitat richness and the presence of bars and low velocity habitat are higher in complex channel areas, underscoring the importance of complex channel areas to age 1+ Colorado pikeminnow.
- Coordinated habitat mapping and fish sampling has provided additional data to be used in refinement of habitat descriptions.

- Detailed reach fish survey efforts undertaken in 2008 that include both spring and summer sampling, coupled with results of other sampling programs, will allow us to contrast habitat use between times of the year, between years, and for younger fish than in 2007. The data will strengthen our assertions regarding habitat availability and use by young Colorado pikeminnow.
- An agreed-upon set of habitat descriptions should be used by all studies and a training program should be instituted to assure that all field personnel with responsibility for determining habitat type have the same training.
- Effort should continue to be placed on identifying the suitability of low velocity habitat along channel margins for endangered fish.
- If this edge habitat is found to be important, a process of mapping it should be developed.

RIVER-WIDE HABITAT MAPPING

Aquatic habitat has been mapped in the San Juan River since 1992. This data set has played a major role in determining and evaluating flow recommendations. Twenty-seven habitat types in seven major categories are mapped annually on digital aerial photography and then processed into GIS coverage. Monitoring protocol established in 1999 specifies that the habitat be mapped at flows between 500 and 1,000 cfs, if possible, in the fall of the year following runoff with the results used to assess response of the habitat to spring runoff. The following conclusions are drawn from the results of the habitat mapping in 2006:

- Relative abundance among habitat categories has not changed during the 15 years of data collection. Runs, riffles and slackwater still dominate.
- Backwater habitat reached a low in 2003 at about 20% of the peak value. The trend started to reverse in 2004 and increased even more in 2005. There was no increase in 2006, a dry year with a small reservoir release.
- The channel is simplifying with time as evidenced by a loss of islands and reduction in total wetted area with time.
- The channel simplification is related to both the extended dry period and encroachment of non-native vegetation along main channel margins and within secondary channels.
- Reach 5 has experienced the greatest loss of islands over time and is continuing to lose island while other reaches seem to have stabilized.
- While Reach 3 lost the greatest amount of backwater habitat over time, it actually gained backwaters, other low velocity habitat and islands in 2006, while Reach 5 lost in all three categories.
- Flow manipulation alone may be inadequate to restore channel complexity and increase backwater and other low velocity area in the river.

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. These recorders log temperature every 15 minutes and store data for about 8 months. They are read twice each year.

The Navajo Dam release made April 30, 2007 to May 23, 2007 caused an average drop of approximately 2 - 4° C over a two week period throughout most of the river system. At high flow, the temperature at Archuleta was suppressed by about 2 degrees, but remained warmer than the release temperature. The temperature of the San Juan at Farmington ranged 1 - 6° C cooler than the Animas at Farmington, depending on the flow in the Animas. By the end of the fish release (May 23), the San Juan and Animas Rivers at Farmington were approximately the same water temperature (12° C). The water temperatures on the San Juan and Animas Rivers at Farmington remained nearly the same until mid-June. After which, the water temperatures on the Animas River was 1 - 4° C warmer than the San Juan throughout the rest of the 20068water year, coinciding with the period after spring runoff on the Animas River.

This temperature suppression in 2007 occurred earlier than in other years as a result of an early reservoir release, but was of similar magnitude for years with similar flows. The temperature suppression was less in 2007 than in 2006, which was a dry year.

CHAPTER 1: INTRODUCTION

Hydrology, geomorphology and habitat 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. Geomorphology monitoring changed in 2005 at the direction of the SJRIP Biology Committee. River cross-section measurement changed from pre- and post-runoff to post-runoff every 5 years with the next measurements in 2009. In 2005, two detailed reach studies were initiated. The reaches were selected and first surveyed in 2005. In 2007, Colorado pikeminnow surveys in the two detailed reaches were added.

This report summarizes data collected in 2007 as a part of the long-term monitoring program and compares these data to those collected since 1992. Data collected in the following areas are summarized here:

- Hydrology
- Detailed Reach Analysis
    - Geomorphology
    - Habitat Mapping
    - Fish Survey
- Aquatic Habitat Mapping from the confluence of the San Juan and Animas Rivers (RM180) to the Clay Hills Crossing (RM 2)
- Water Temperature

All data sets are from the 2007 field season except full-river habitat mapping. Due to the long data analysis time after the late fall data collection, there is a one-year lag in the habitat data.

Methods for each data set that are covered in the Long-Term Monitoring Plan are not described in detail in this annual progress report. The methods for detailed reach analysis are reported here as they are not included in the long-term monitoring plan. This report concentrates on data reporting with a minimum of data analysis, particularly between data sets.

SAN JUAN RIVER STUDY AREA

The seven-year research program defined 8 geomorphically distinct reaches in the San Juan River (Bliesner and Lamara, 2000; Figure 1.1). The bulk of the studies reported here occur within Reaches 1-6, as this encompasses the critical habitat for the endangered Colorado pikeminnow and razorback sucker. Some studies extend outside this range where necessary to define processes that affect the critical habitat. The study area for each data set is described with the summary of that data set.

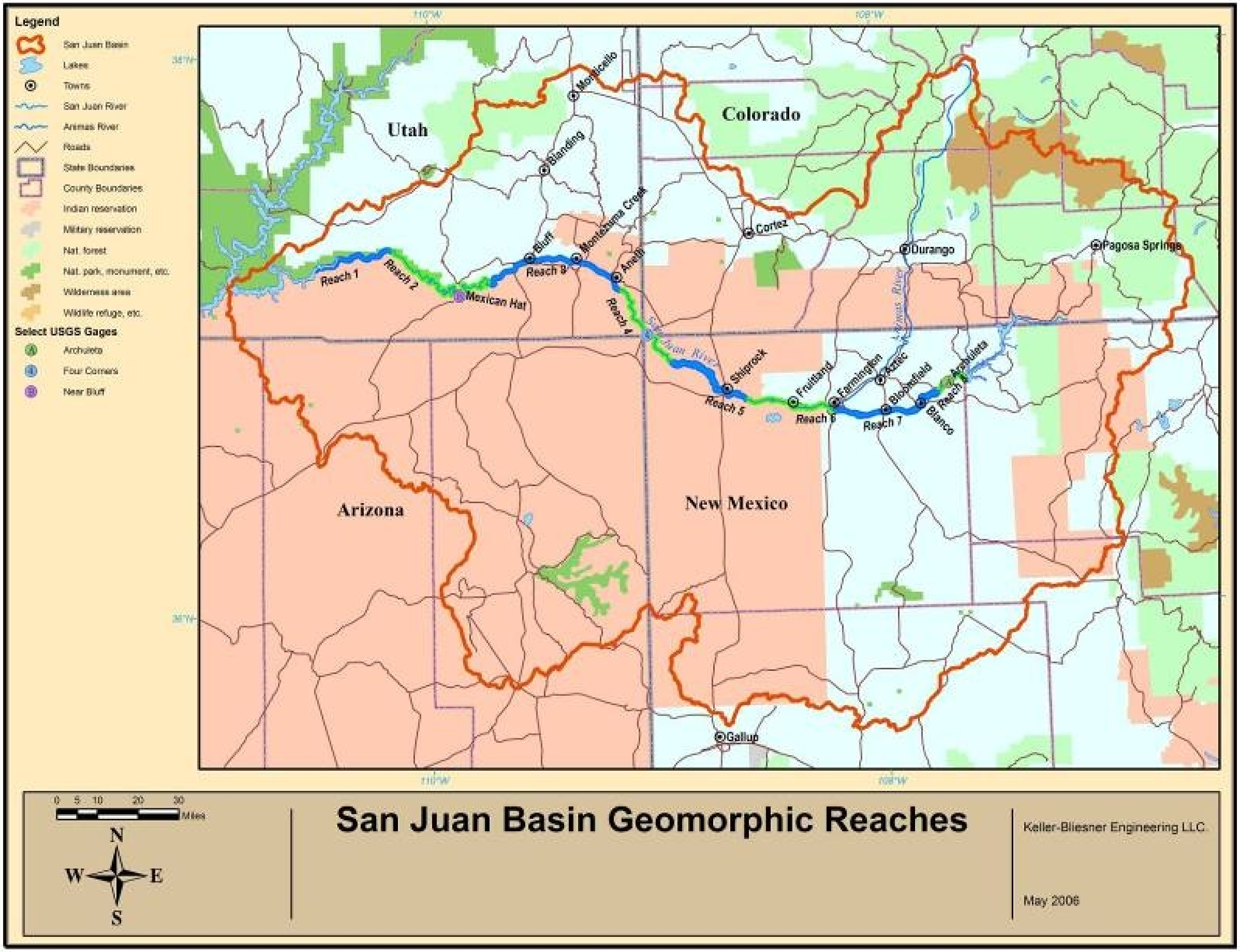

Figure 1.1. San Juan Basin location map showing geomorphic reaches

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 this 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 2007 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.

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[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 were implemented.

Water year 2007 was an average year with annual runoff at Bluff of 1,359,100 ac-ft (85% of the 1929-2007 average). The March through July runoff at Bluff was 715,000 ac-ft (69% of 1929-2006 average). The fish release began April 30 with a 5-day ramp-up, a 13-day peak averaging 5,270 cfs, and a 7-day ramp-down to 1,400 cfs, resulting in a total release of 171,000 ac-ft above base flow (600 cfs) conditions (Table 2.1). This table also describes the nature of the release each year since 1991 for comparison. The 2007 release began earlier than the flow recommendations to avoid spilling the reservoir, as the reservoir content was near full at the beginning of runoff. The early release correlated with an early peak in the Animas, providing nearly the same peak flow condition as the recommended release would have given.

Although there was an extended release from Navajo Dam in 2007, the Animas River peak was not sufficient to produce flows much above 8,000 cfs at Four Corners. Both the 2,500 and 5,000 cfs criteria were met (Table 2.2), but there were only 2 days above 8,000 cfs and none above 10,000 cfs. The base flow conditions were met at each individual gage in 2007 as well as the minimum requirement using the three-gage rule (Table 2.3) as there were no 7-day running averages below 500 cfs.

The 2007 hydrographs for the San Juan River at Archuleta (release hydrograph) and Four Corners and the Animas River at Farmington show the influence of the early release from Navajo dam and the summer storm spikes in August and September (Figure 2.1). The summer storm spikes are typically sediment laden and increase turbidity and sediment deposition in the river. The flow spike in early August is of particular concern as it may have an effect on hatching success of Colorado pikeminnow eggs through sedimentation of the spawning bars.

The effects of the early release hydrograph can be seen in comparison to the dry year and small release in 2004 and 2006 and the relatively large runoff in 2005 in Figure 2.2. The flow statistics that apply to these hydrographs appear in Table 2.4. The Four Corners gage is considered the most representative gage for the habitat range and is used in all correlations reported.

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. 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 16 years of this study with 2007 being preceded by the 10 driest years on record (Figure 2.4).

Table 2.1. Summary of Navajo Dam release hydrograph characteristics since the beginning of the research period, 1992 to 2006

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

Table 2.2. Flow statistics met in each year for 1992 through 2007

Condition	Std	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07
10,000 cfs or more	5	0	1	0	**11**	0	**10**	0	0	0	0	0	0	0	**9**	0	0
8,000 cfs or more	10	3	**16**	9	**27**	0	**33**	2	0	0	1	0	0	0	**18**	0	2
5,000 cfs or more	21	**54**	**109**	**49**	**72**	0	**51**	**34**	**29**	3	**33**	0	0	1	**50**	7	**21**
2,500 cfs or more	10	**81**	**126**	**68**	**135**	**36**	**103**	**65**	**72**	**37**	**55**	0	**13**	**23**	**84**	**25**	**54**
Years w/o meeting 10,000 cfs	10	6	7	8	0	1	0	1	2	3	4	5	6	7	0	1	2
Years w/o meeting 8,000 cfs	6	0	0	1	0	1	0	1	2	3	4	5	6	7	0	1	2
Years w/o meeting 5,000 cfs	4	0	0	0	0	1	0	0	0	1	0	1	2	3	0	1	0
Years w/o meeting 2,500 cfs	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Note: Values in first 4 rows in days. Values in bold meet or exceed the minimum standard

Table 2.3. 2007 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	649	0	0	0
Shiprock	624	0	0	0
Four Corners	685	0	0	0
Bluff	726	0	0	0
3-gage	689	0	0	0

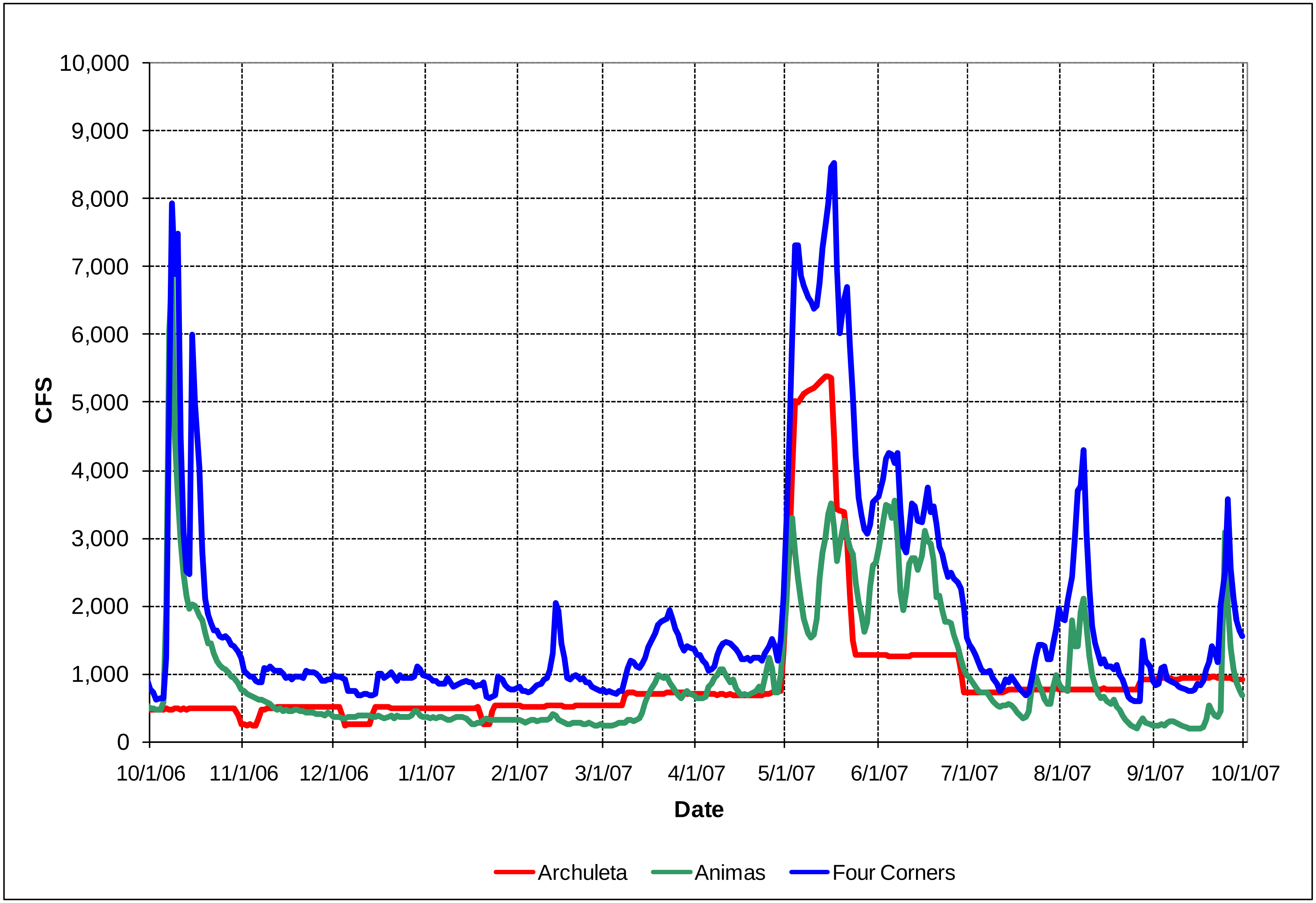

Figure 2.1. San Juan River near Archuleta, and Four Corners and Animas River near Farmington, 2007

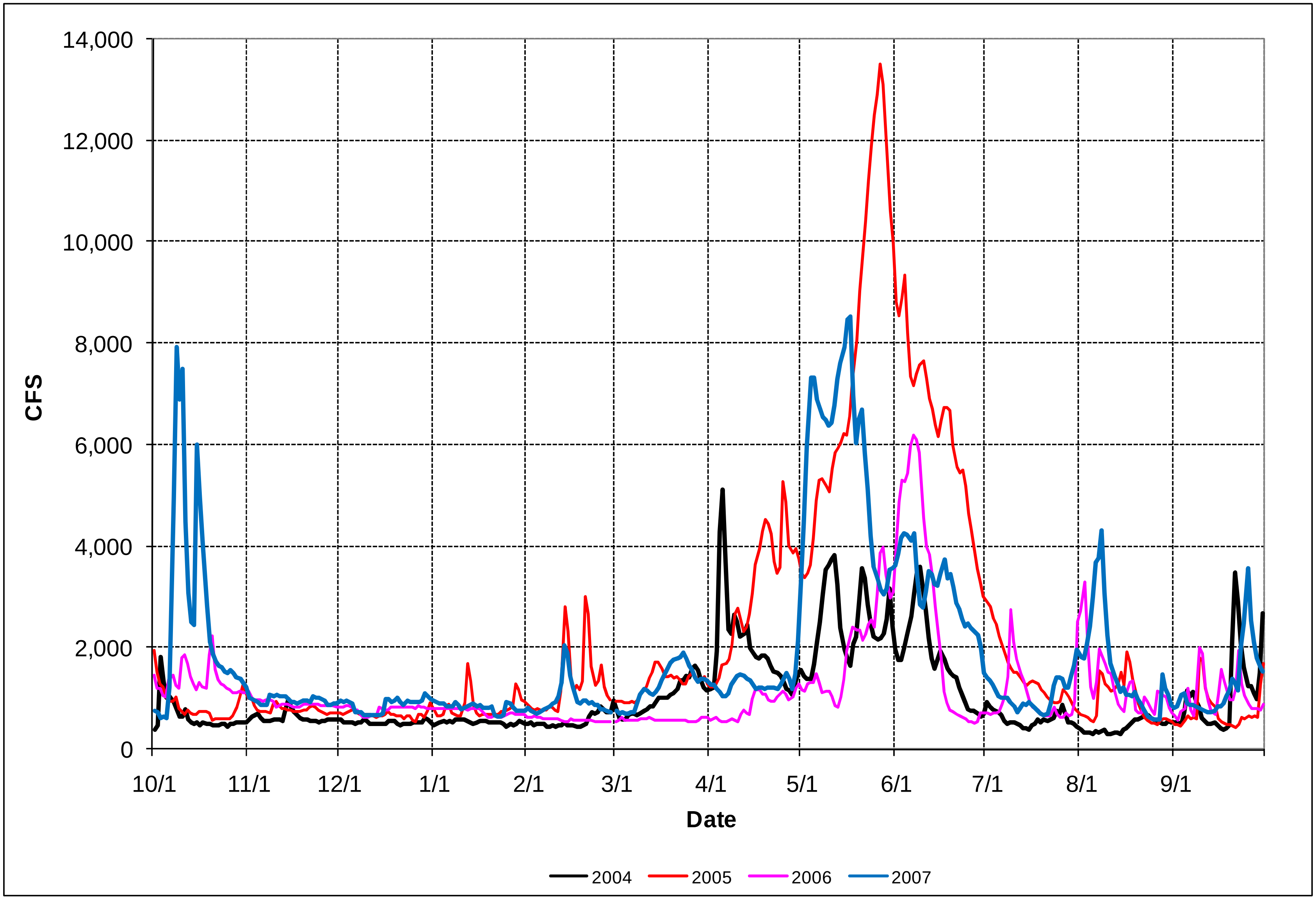

Figure 2.2. San Juan River at Four Corners, 2004-2007

Table 2.4. Summary of flows for the research (1991-1998) and monitoring (1999-2007) periods, San Juan River at Four Corners, New Mexico

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Peak Runoff-cfs	5,160	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
Runoff - af (Mar - Jul)	600,510	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
Runoff - af (Tot. Annual)	1,086,676	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
Peak Date	16-May	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
Days >10,000	0	0	1	0	11	0	10	0	0	0	0	0	0	0	9	0	0
Days >.8,000	0	3	16	9	27	0	33	2	0	0	1	0	0	0	18	0	2
Days >5,000	2	54	109	49	72	0	51	34	29	3	33	0	0	1	50	7	21
Days >2,500	46	81	126	68	135	36	103	65	72	37	55	0	13	23	84	25	54
Average Daily Flow for Month																	
October	1,447	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
November	1,125	1,354	909	1,202	1,076	1,137	881	1,175	1,494	910	1,154	836	744	612	796	908	979
December	1,078	1,086	955	1,129	958	1,087	700	1,154	1,031	940	966	848	657	517	689	790	887
January	1,171	858	1,356	1,056	916	783	788	1,208	947	935	915	835	569	524	838	740	837
February	1,299	1,263	1,522	852	1,084	874	695	1,239	976	931	1,039	732	574	578	1,295	583	989
March	994	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
April	1,807	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
May	3,733	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
June	2,575	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
July	799	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
August	555	925	1,346	534	1,561	491	2,306	1,073	6,135	708	1,315	482	672	440	940	1,266	1,614
September	1,441	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
Uniqueness	Control	Early Ave.	Early	Late Ave.	Late Peak	Dry	Narrow Runoff	Early Ave.	Large Summer Release	Dry	Early Ave.	Record Dry	Very Dry	Dry	Classic Hyrdro-graph	Dry	early average
		Storm @ Spawn					Storm @ Spawn	Storm @ Spawn	Storm @ Spawn				Sep. Peak > 10,000			Storm @ Spawn	Storm @ Spawn

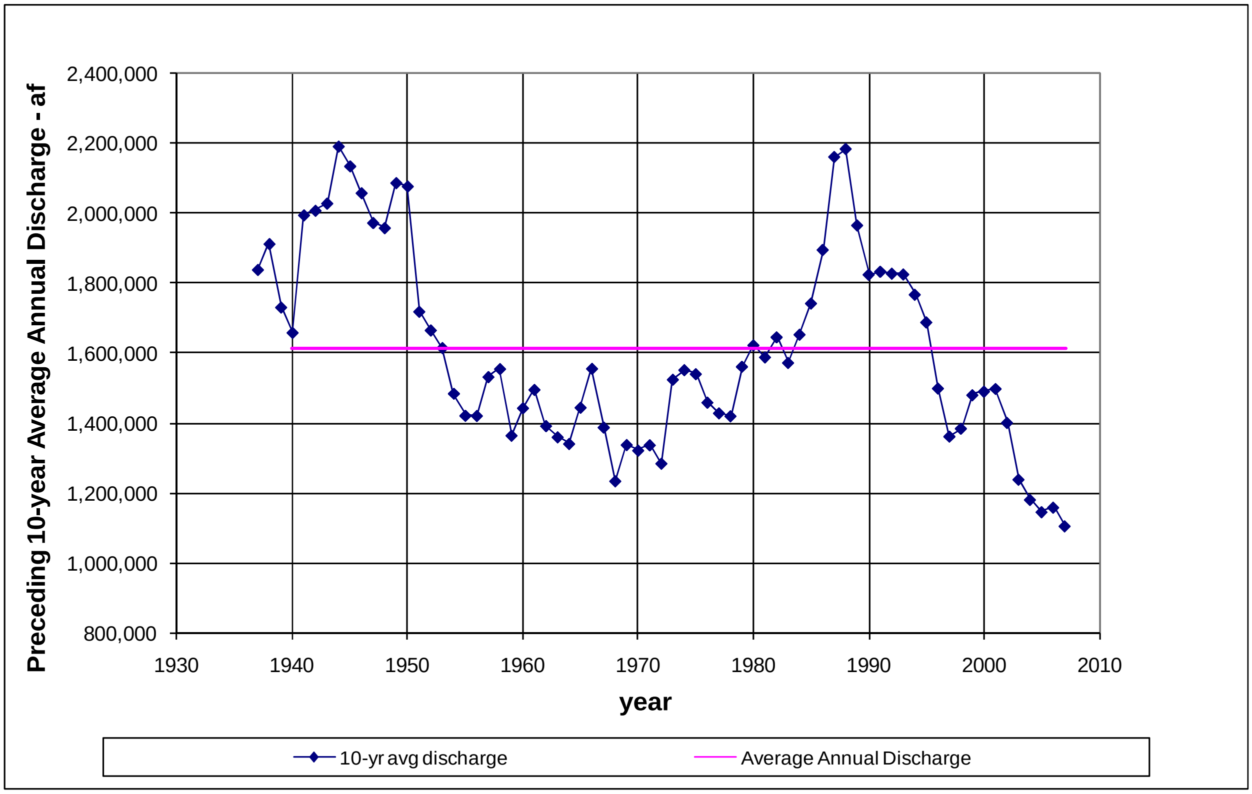

Figure 2.3. 10-year average antecedent flow in the San Juan River near Bluff, Utah 1937-2007

CHAPTER 3: DETAILED REACH GEOMORPHOLOGY AND HABITAT

BACKGROUND

In the process of integrating the 1999-2003 monitoring data for the SJRIP, the Biology Committee determined that the information gained from semi-annual (pre- and post-runoff) surveys of the standard cross-sections in the river was not sufficient to warrant such regular survey. Further, it was determined that a more detailed look at the geomorphology and habitat of shorter reaches that contained elements important to native and endangered fish was warranted. The change was made to better understand the mechanisms at work that maintain backwater and other low velocity habitats and channel complexity and to assess habitat in more detail related to actual captures of endangered fish.

To address these issues, detailed reaches were established in 2005 at RM 82 and RM 137 as described in the 2005 annual report. They have been designated DR 82 and DR 137. Habitat surveys were completed in 2005, 2006 and 2007 at standard and detailed levels and the data correlated to fish utilization where fish data were available. Two-dimensional modeling of the flow in these reaches was completed for fall survey flows in 2005 and 2006 and the model used to predict habitat availability at different flows.

In 2007, characterization of the coarse sediment and analysis of coarse sediment transport in each reach was added to assess conditions necessary to move cobble within these reaches. The habitat mapping, combined with detailed channel topology measurements, hydraulic modeling and coarse sediment transport analysis, is intended provide insight into the mechanism or process for creation and maintenance of these complex reaches and provide a better understanding of the loss or creation of backwater habitats or other low velocity habitats used by the endangered fishes.

OBJECTIVES

The objectives of the detailed reach geomorphology and habitat studies are:

1. Examine the response of the channel morphology and habitat of two typical complex reaches of the San Juan River that have a history of use by endangered fish to hydrology.

2. Identify habitat availability in these complex reaches at a scale compatible with fish sampling efforts to improve linkage of habitat use to habitat availability.

3. Develop methods to extrapolate the detailed mapping in these complex reaches to river-wide mapping.

4. Evaluate mapping protocol and make recommendations for changes that improve integration of fish and habitat data.

METHODS

Reach Survey

Each detailed reach was surveyed with sub-centimeter real time kinematic GPS equipment. Only areas up to the high water mark in 2007 and areas where more detail was needed were surveyed in 2007 to supplement the 2005 and 2006 survey points that were above high water. The surveys were completed with an average point density of about one point per 30 m^2. In areas of complexity, point density was increased as needed to describe the topology. In addition, break lines and waters-edge were surveyed. Water's edge was surveyed in DR 82 at 4,500 cfs and DR 137 at 4,900 cfs for high flow calibration. The flow was changing during this period, so a consistent water mark based on the points taken at the beginning of each survey was used to define the water line at a consistent flow rate.

During each survey, substrate was characterized as fines, gravel/cobble or bedrock. These are qualitative categories based on the material at the point of survey. Water depth prevented reliable assessment between cobble and gravel, so they were lumped.

Wolman pebble counts (Wolman, 1954) were completed at 10 locations DR 82 and 9 in DR 137 to characterize the bed material. The minimum measurement was 1.0 cm. Locations with grain size smaller than 1.0 cm were recorded as <1.0 cm. Size distribution was computed two ways: using all readings and using just the coarse (all measurements above 1 cm) measurements.

Channel Change

Data from the fall 2007 surveys were used to develop the topology of the channel and floodplain using the same boundary conditions that were used for 2005 and 2006. A three-dimensional surface was constructed in AutoCad for 2007, similar to those from 2005 and 2006. Scour and deposition in each detailed reach was determined by subtracting the three-dimensional surface created from the 2006 survey from that created from the 2007 survey. The difference represents average net change in elevation, with a positive difference indicating net deposition and a negative difference indicating net scour. Perspective images were generated showing locations of scour and deposition to identify where change occurred in response to antecedent flow conditions. Only the active channel up to the high water elevation from the June survey is included in the analysis.

The significance of the change in bed elevation was tested by determining the confidence limits around the computation based on 3,000 observations with a standard deviation of 5 cm (estimated accuracy of measurement combined with approximations of computing the surface). For 99% confidence, the deviation about the mean could be as much as ±0.24 cm. If the estimated accuracy is 10 cm, then the deviation would be ±0.47 cm. Since the 5 cm of estimated measurement accuracy is approximate, a value of 10 cm was used as an upper bound. Therefore, change in average elevation greater than ±0.47 cm was taken as significant. This confidence limit is based on the average surfaces. Assessing change at any given point is qualitative, identifying areas of scour or deposition, rather than quantitative due to both elevation and location errors at any point.

River2D Model

The resulting topology of the channel and floodplain in each reach described above was also used for hydrodynamic modeling. The model chosen for analysis is River2D[3]. River2D is a two dimensional depth averaged finite element hydrodynamic model that has been customized for fish habitat evaluation studies. Three of the four modules that are a part of the River2D model suite were used: R2D_Bed, R2D_Mesh and River2D.

The modules were used in succession. A preliminary bed topography file (text) was developed from the field survey data, then edited and refined using R2D_Bed. The resulting bed topography file was used in R2D_Mesh to develop a computational discretization as input to River2D. River2D was then used to solve for the water depths and velocities throughout the discretization. This was an iterative approach at various stages, including modification of the bed topography, for refinement and calibration of the model of the two reaches.

The model was initially calibrated to measured water surface elevations at the time of survey. The roughness was adjusted to calibrate to water surface elevation. The model refinement and calibration was an extensive process whereby the field data points are supplemented with the placement of break lines to best describe the topology and input of roughness height that is judged by the attributes of the bed (fines, gravel, cobble, or vegetation type)[4] collected during survey. Additional calibration was accomplished by measurement of water surface elevation (water's edge) at higher stage flows during spring runoff.

The model was configured using a 2.0 m nominal grid size with refinement in areas where more detail was required to match water surface elevations. This corresponds with the minimum polygon mapped at the detail level (1.7 m^2).

River2D models were calibrated to water surface at survey for each of the detailed reaches at 2007 survey flow. After calibration at survey flow, the model was operated at the high flow waters-edge measurement and recalibrated to provide reasonable results across the range of flows anticipated. Calibration was accomplished by adding break lines or increasing grid resolution in key areas and by adjusting the roughness height both globally and locally. After reviewing the literature for comparable modeling efforts (Bovee, 1982, Pasternack, et al., 2004, Stamp, et al. 2005, Tarbet and Hardy, 1996), the following calibration criteria were set for the difference between modeled and measured water surface elevation as a percent of average elevation for the flow at survey: Mean difference - ±5%, standard deviation – 25%. For high flow calibration the mean difference should not exceed ±10% or the standard deviation 30%. These values are well within the range of the literature reviewed, particularly for complex river reaches. Comparisons were also made between the model results in 2005 and 2006. In 2006 we found that we could not reliably use a model calibrated in a previous year to accurately represent depths and velocities in the current year due to topology change. Therefore, comparisons between years rely on results from the individual models in each year.

[3] Developed by the University of Alberta. www.river2d.ualberta.ca

[4] These general classifications are made at the time of survey. The categories are based on qualitative assessment. No grain size measurements are made. Vegetative type is assessed for areas above normal water surface that are vegetated. These initial roughness heights may be adjusted later during the calibration process.

Coarse Sediment Transport Analysis

Bed sediment size distribution was determined by completing Wolman pebble counts (Wolman, 1954) at 10 locations in each reach. Size distributions were computed for the full sample and then for just the coarse fraction (size > 1 cm). The full set was used to characterize the nature of the fine/coarse distribution. The coarse distribution was used for transport analysis. Sampling locations were limited to those that could be sampled by wading.

The thresholds for incipient and significant motion occur when boundary shear stress (τ_0) is greater than or equal to the critical shear stress of the median bed material diameter (τ_{c50}) thresholds (Equation 1). The average boundary shear stress is calculated using Equation 2.

$$\tau_{c50} = \tau_c^*(\gamma_s - \gamma_w)D_{50} \quad (1)$$

$$\tau_o = \gamma_w \cdot h \cdot S_f \quad (2)$$

Where τ_c^* is the critical dimensionless shear stress, γ_s is the specific weight of sediment, γ_w is the specific weight of water, D_{50} is the median sediment diameter, h is the flow depth, and S_f is the friction slope or energy gradient, calculated using Equation 3. All computations were completed in SI units.

$$S_f = S_o - \frac{u}{g}\frac{du}{dx} - \frac{dh}{dx} \quad (3)$$

Where S_o is the channel bed slope, u is the mean column velocity, and *dx* is the change in distance downstream. There has been much discussion over appropriate values of τ_c^* and the reasons for its variation from river to river. There is evidence that the Colorado River bed material begins to move at τ_c^* = 0.03, however very few particles of any size are moving and bed material transport rates are very low (Pitlick and Van Steeter 1998).

In this analysis, the three conditions of transport were examined using the median sediment diameter (D_{50}) of bed material with incipient motion occurring when τ_c^* is in the range of 0.02 (Andrews 1994) to 0.03 (Parker et al. 1982, Pitlick et al. 1998), average motion when τ_c^* = 0.030 to 0.045, and significant motion when τ_c^* =0.045 to 0.06 (Wilcock and Southard (1989) and Pitlick (1992). These values were used in Equation 1 to determine the flow at which the boundary shear stresses were high enough for incipient, average and significant or full motion.

Model output depth, velocity and bed elevation over a range of flow from 745 to 8,000 cfs were used in sediment transport calculations. Locations were selected based on evidence of either scour or deposition of cobble between 2006 and 2007. Reference points were selected within these areas to extract depth, velocity, and bed elevation data from the model runs. All data within a radius of approximately 4-6 meters depending on the site were extracted at each reference point. The extracted depths and velocities at each reference point were averaged for boundary shear stress calculations. Slopes were determined between reference points. A linear trend analysis was performed to determine the bed slope for entrance and main channel analysis areas. Individual paired-point analysis was used to examine localized transport potential.

Habitat Mapping

Habitat mapping of the detailed reaches was completed in the fall at the same time as the standardized mapping. Each reach is included in the standardized mapping and then each was mapped at a detailed level at the same time by the same mapper. Standard habitat mapping is completed at a scale of approximately 1" = 150 ft. Detailed mapping for the reaches is completed at a scale of 1" = 75 ft. The two data sets were then compared to determine differences in mapping detail. Detailed mapping was also completed at the same time as the fish survey as described in the next section.

Model and Habitat Data Integration

The original study design anticipated overlaying habitat mapping with modeled depth and velocity to characterize the depth and velocity by habitat type, using that correlation to forecast habitat availability at flows other than those mapped. Since the model is based on field survey and the habitat mapping on photo-interpretation, the two maps do not precisely overlay, making it difficult to accurately assess the depth and velocity of habitat types, particularly the small features and those affected by channel margin.

Since this approach did not work, an alternate approach was developed and implemented in 2006. Depth and velocity standards for habitat classifications developed in 1998 (Bliesner & Lamarra, 2000) were used to characterize the main habitat classifications. It was necessary to identify unique bins with non-overlapping depths and velocities to associate model results with habitat (Table 3.1). These categories were then applied to the model results to estimate habitat availability at different flows. The process was developed and demonstrated in 2006, but not repeated in 2007. The intent is to use the 2005-2008 data together in 2008 to finalize the process of extending habitat description to other flows and examining availability of key habitat found to be important to the early life stages of Colorado pikeminnow (and razorback sucker to the extent it can be defined) across a range of flows.

During the fish survey work in August 2007, shore runs were sampled but not separately mapped. Other fish sampling efforts have identified this habitat category (Golden et al. 2006, Robertson and Holden 2007). Shore runs are low velocity habitats along the margin of runs characterized by shallower depths and lower velocities. The break line between shore run and mid-channel run is not easily discernable when mapping and is typically too narrow to map during standard mapping. The model was used in this study to identify a reasonable break point between shore and mid-channel runs based on observed depth and velocity in areas where shore-runs were sampled. Four locations (2 in each reach) representing seven fish samples were used for the analysis. Depth and velocity were plotted with distance from shore and a break point selected based on maximum velocity where Colorado pikeminnow were captured. A distance from shore was then defined for that average condition and the availability of shore run identified by intersecting this offset distance to the edge of all runs that contacted a shore line in the GIS.

Table 3.1. Depth and velocity categories by habitat

Habitat Category	Velocity – cm/sec		Depth - m	
	Min	Max	Min	Max
Backwaters (1,2,22)	0	0.1	0	3+
Low Velocity (3,4,5,6,7,16)	0.1	10	0	3+
Slackwater (20,35)	10	20	0.3	3+
Shoals (8A,8B)	10	43	0	0.3
Runs (9A,9B,10,11,12,13,14)	43	75	0	0.3
Runs (9A,9B,10,11,12,13,14)	20	100	0.3	3+
Riffles (15,17,18,19,30,32)	75	100	0	0.3
Riffles (15,17,18,19,30,32)	100	300+	0	3+
Vegetation (24,34)	n/a			
Other (21,29,33,37,39)	n/a			

Adapted from Hydrology, Geomorphology, Habitat final report, February 2000, pp 5-5 to 5-8

RESULTS

Reach Survey

Each reach was surveyed in the fall of 2007 to compare to fall 2006 surveys and determine deposition and scour for each reach. There are 2,202 points for DR 82 and 2,359 for DR 137, all taken below the 2007 high water line (Figures 3.1 and 3.2). These data points, in conjunction with data points collected above the 2007 high water mark collected in 2005 and 2006, were used to generate the bed elevations used in channel change analysis and for River2D modeling. Water's edge was determined in these surveys at flows of 1,120 cfs for DR 82 and 1,018 cfs for DR 137. Water's edge at high flow was surveyed in August 2007 at a flow of 4,480 cfs (Bluff gage) for DR 82 (213 points) and 4,870 cfs (Shiprock gage) for DR 137 (190 points). The increased surface area and additional flowing secondary channels at high flow are shown in Figures 3.3 and 3.4 for DR 82 and DR 137, respectively, with the fall 2007 water surface overlain. The 2006 high flow water surface was used as the extent of analysis for channel change as it was higher than the 2007 surveyed high flow waters-edge shown in Figures 3.3 and 3.4. Actual high flow in 2007 was over 8,000 cfs, but at that flow, the water is out of the channel and cannot be accurately modeled.

Channel Change Analysis

Figures 3.5 and 3.6 show the channel topology generated from the 2005, 2006 and 2007 surveys for DR 82 and DR 137, respectively. Scour and deposition between 2006 and 2007 surveys have been assessed for each reach by subtracting the 2006 surface from the 2007 surface (Figures 3.7 and 3.8, Table 3.2). Table 3.2 shows substrate makeup from the 2005 and 2006 survey, the volume of scour and deposition and the net change in volume and depth between the two surveys for each detailed reach. Although there are locations of scour and deposition in each reach, DR 82 exhibited nearly 3 cm of net scour and DR 137 experienced about the same amount of deposition. This change is significant at the 99% level.

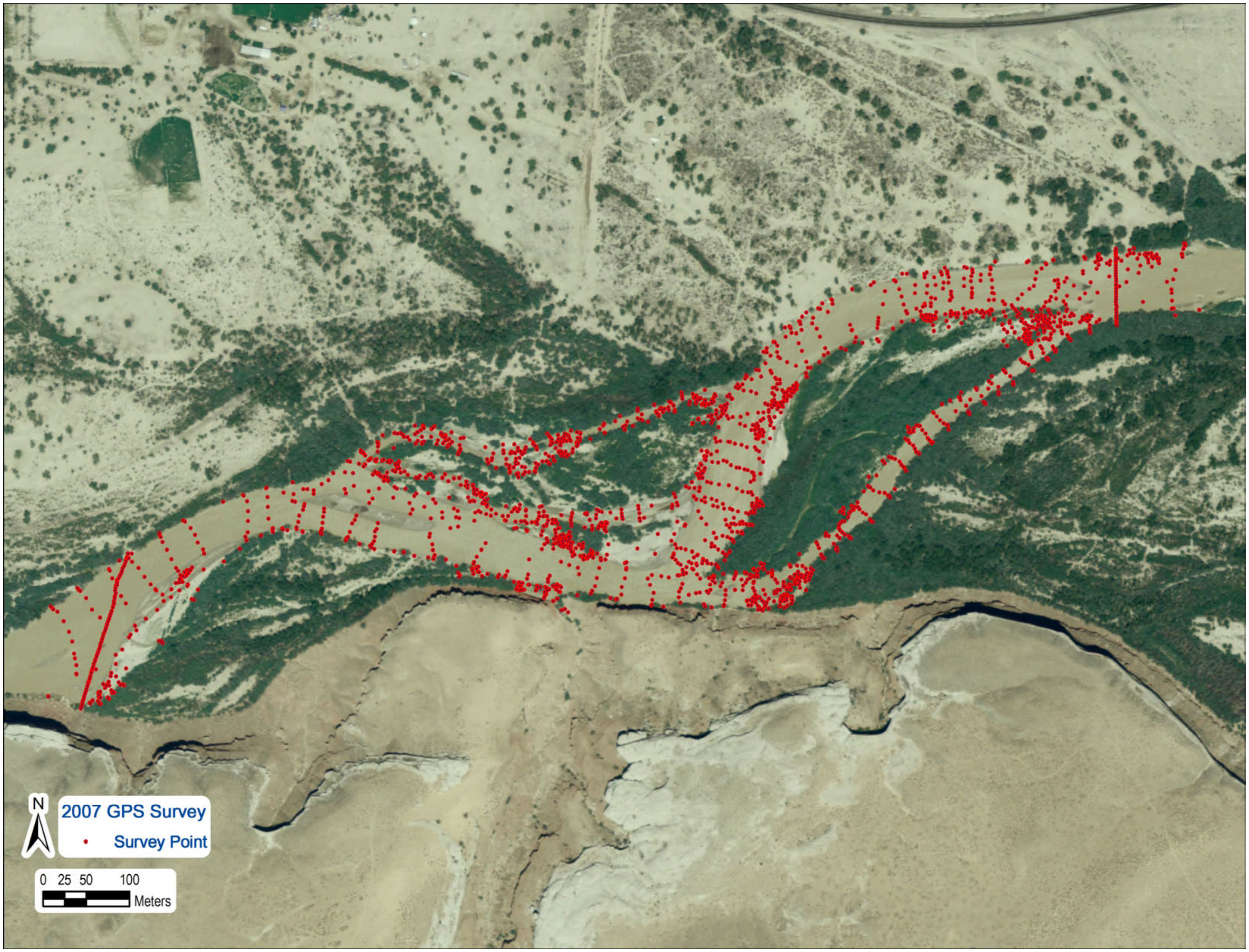

Figure 3.1. Point locations for August 2007 survey at DR 82

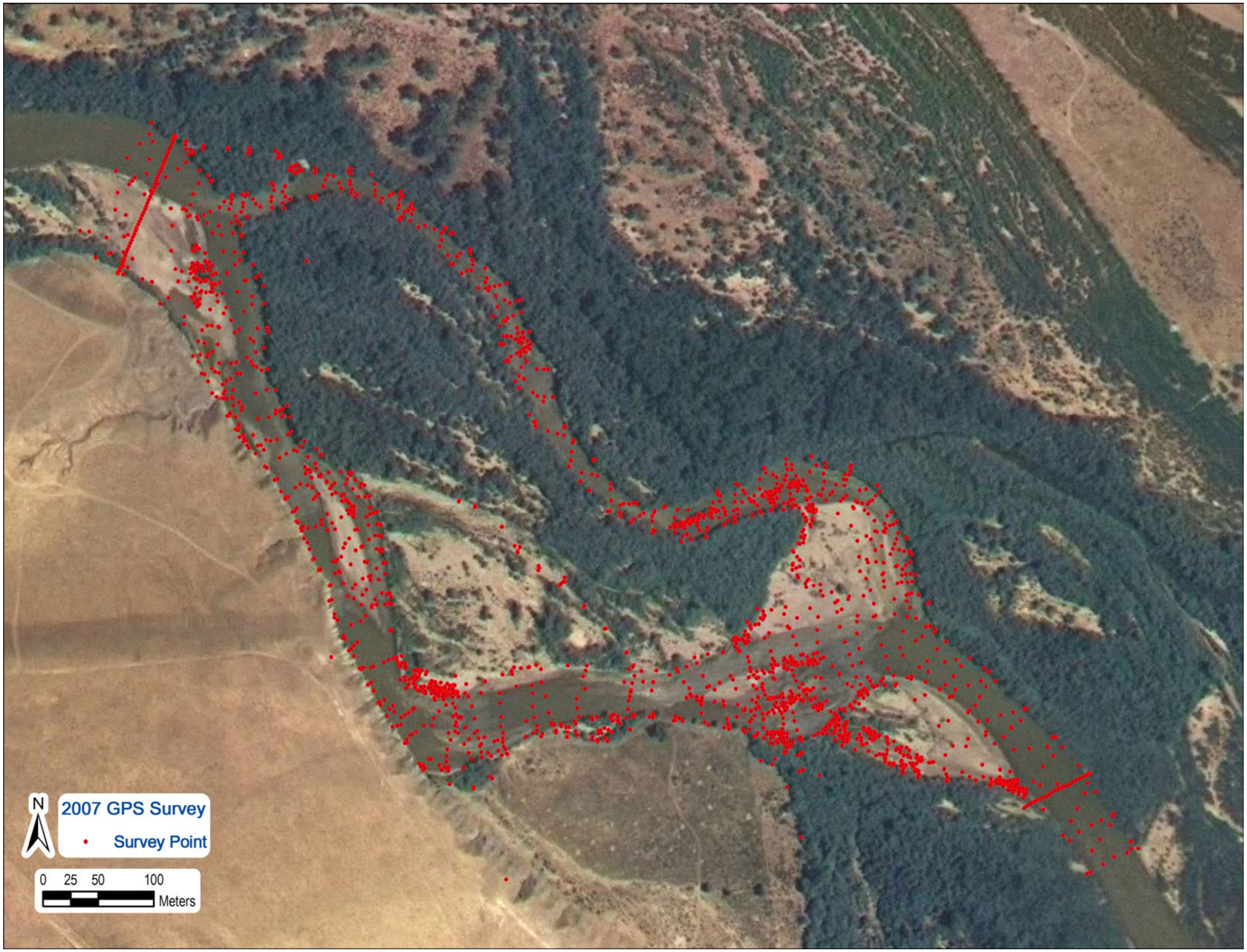

Figure 3.2. Point locations for August 2007 survey at DR 137

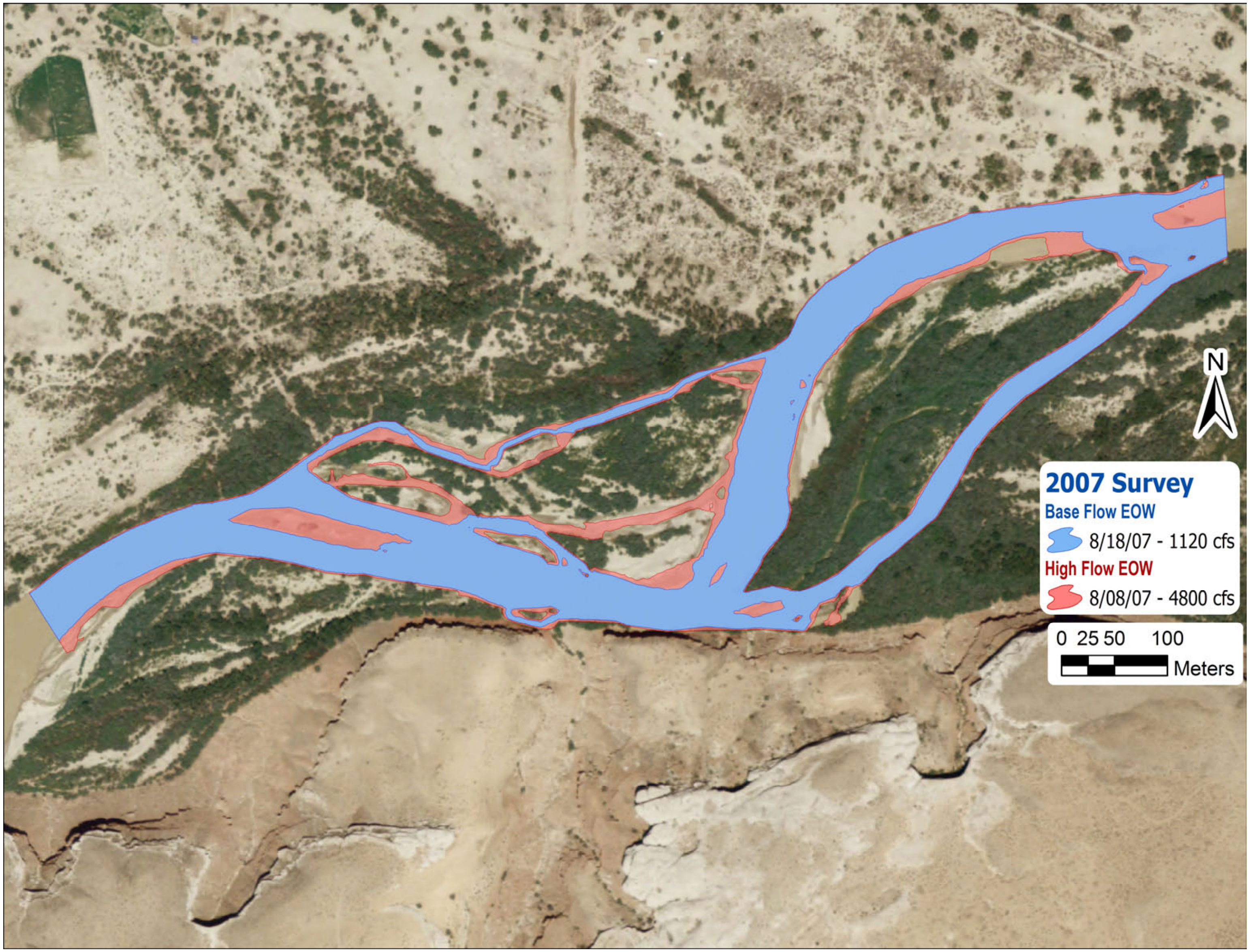

Figure 3.3. DR 82 water surface at 4,800 and 1,120 (August 2007 high and low-flow surveys)

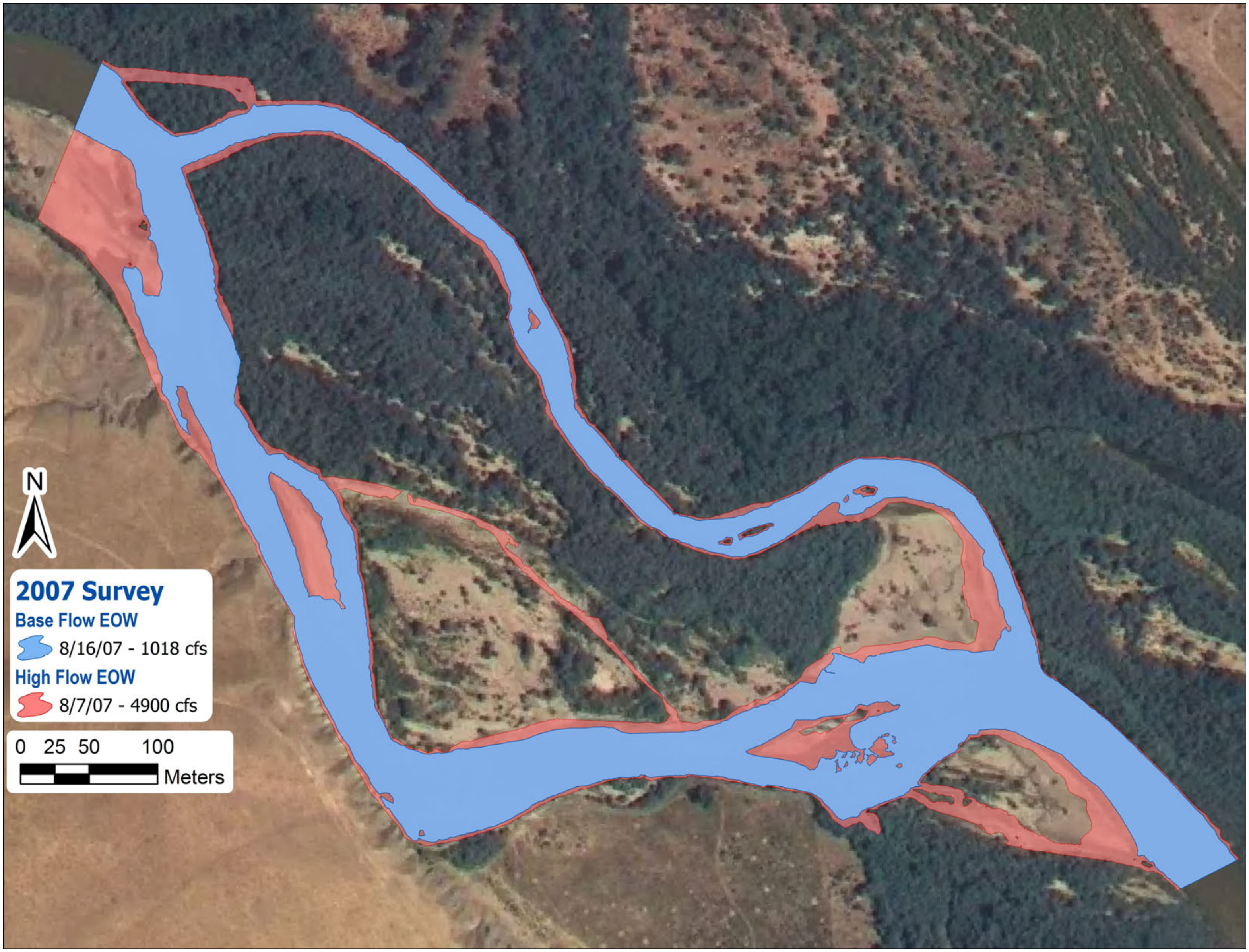

Figure 3.4. DR 137 water surface at 4,900 and 1,018 cfs (August 2007 high and low-flow surveys)

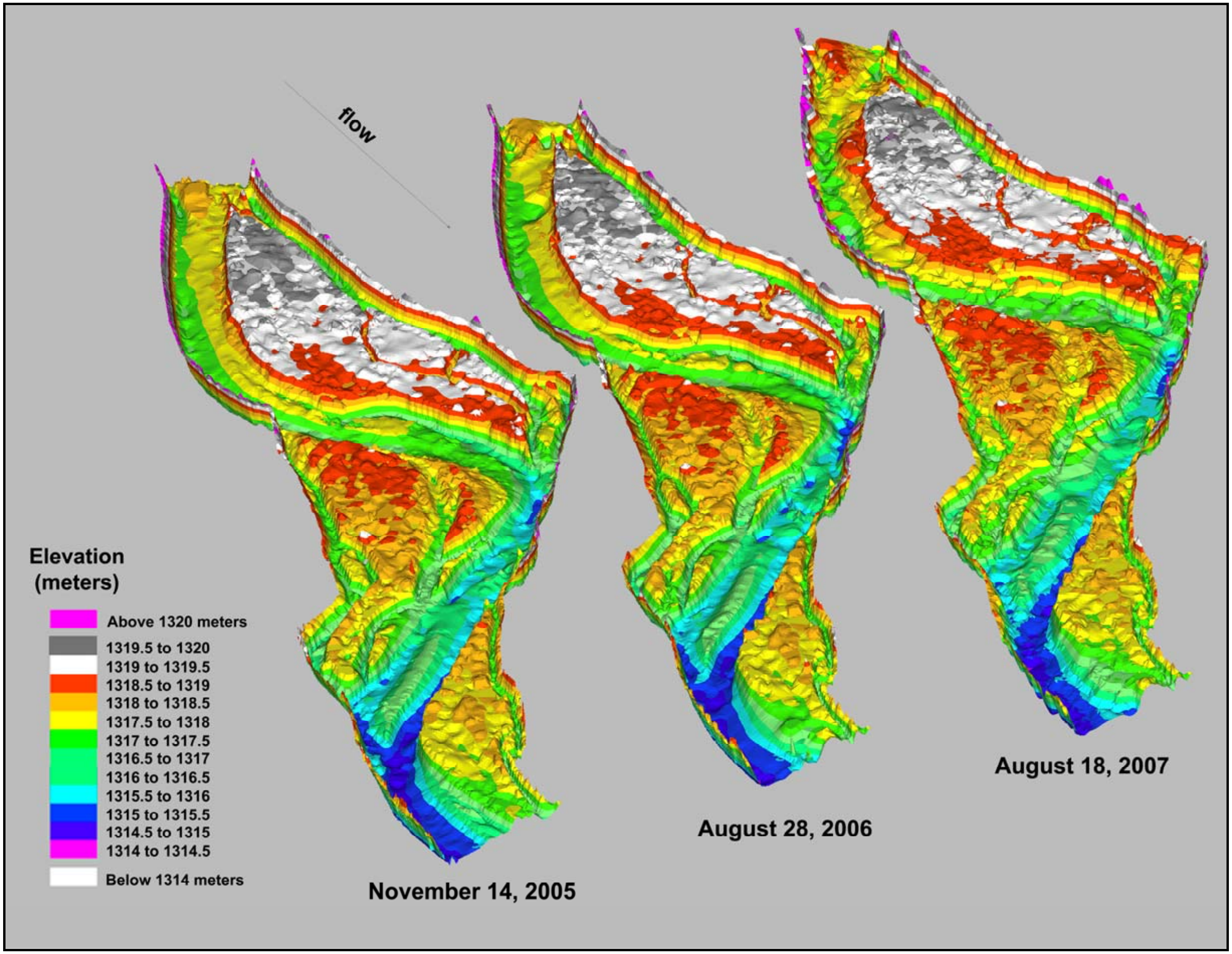

Figure 3.5. 2005, 2006 and 2007 channel topology generated from fall surveys for DR 82

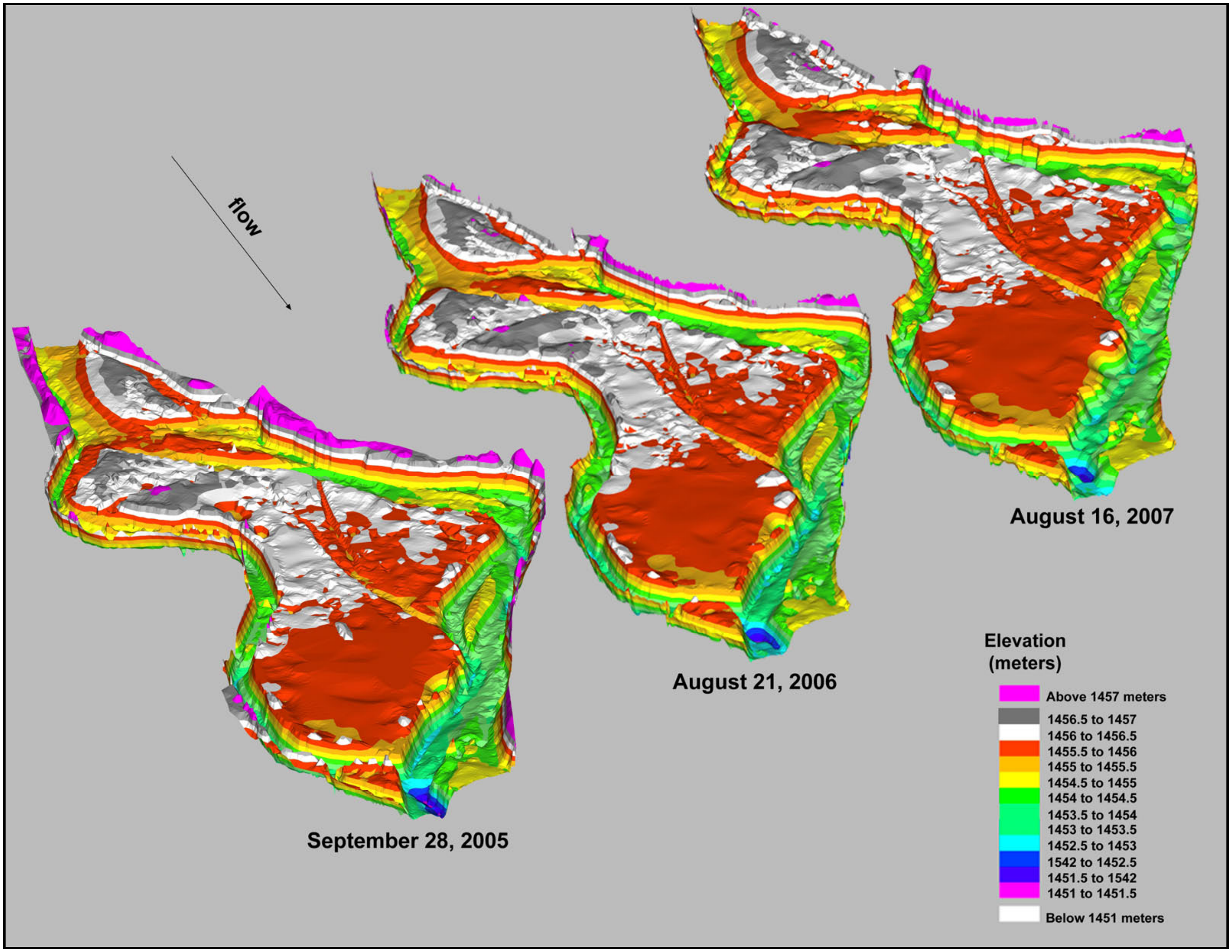

Figure 3.6. **2005, 2006 and 2007 channel topology generated from fall surveys for DR 137**

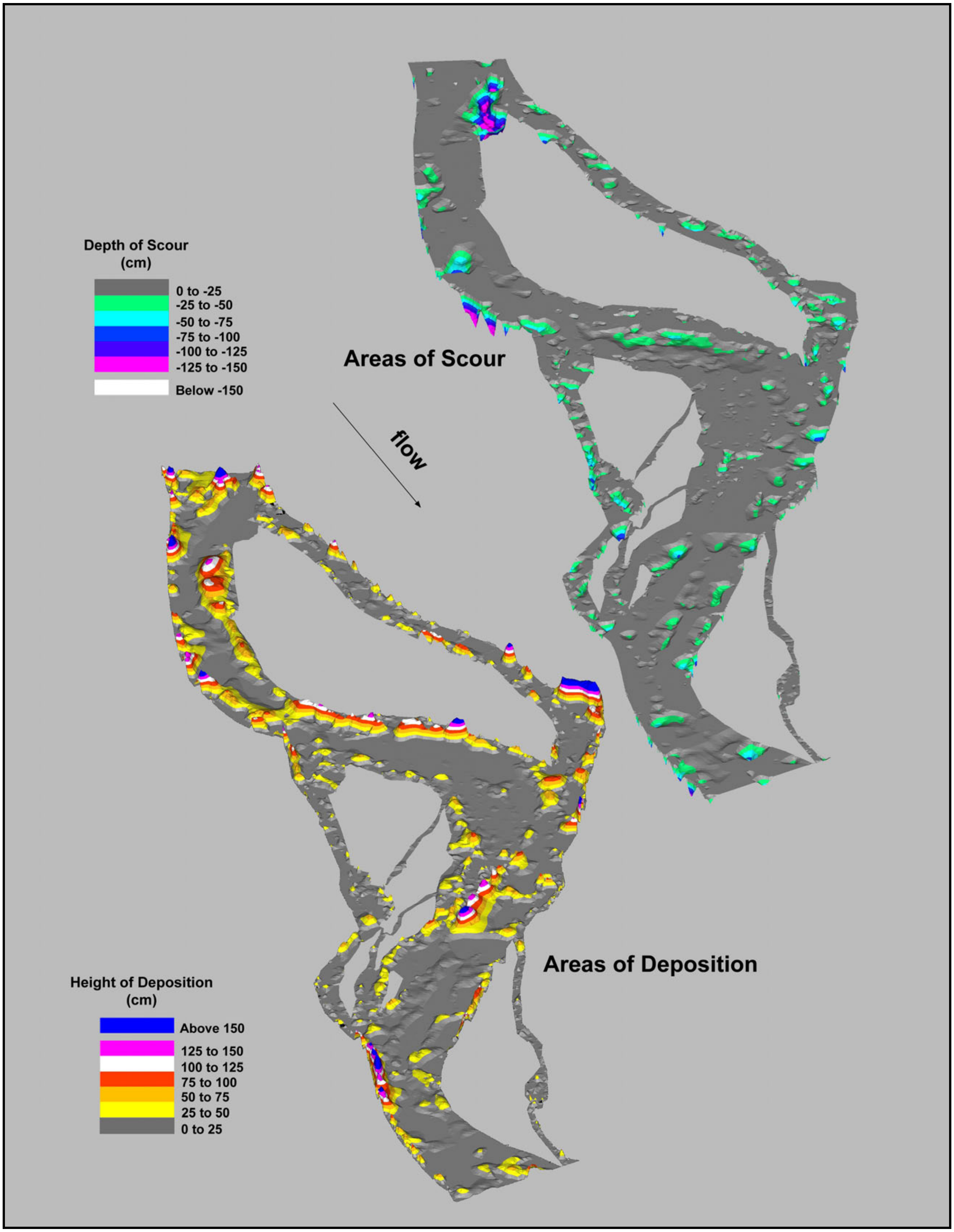

Figure 3.7. Location and depth of scour and deposition between 2006 and 2007 for DR 82

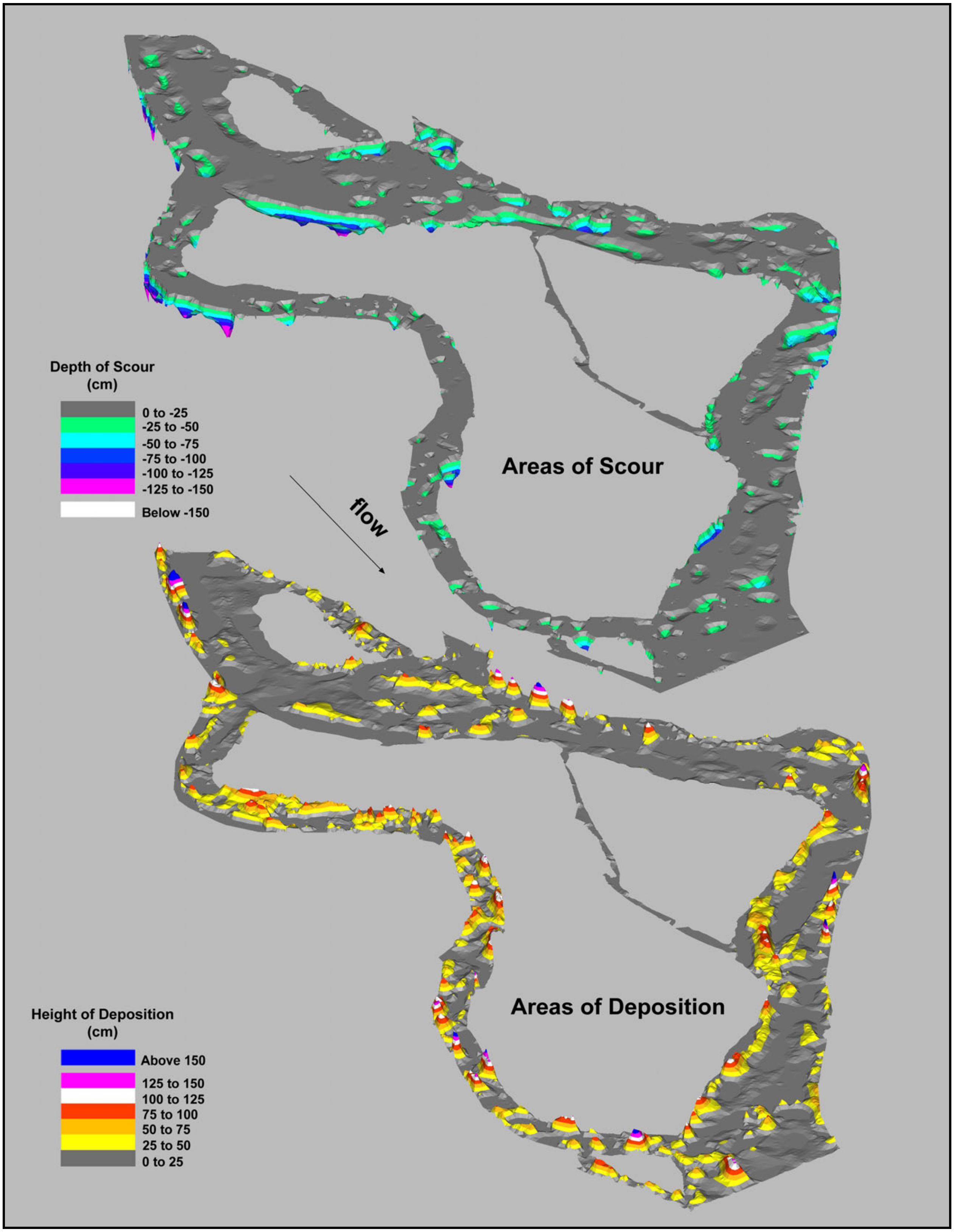

Figure 3.8. Location and depth of scour and deposition between 2006 and 2007 for DR 137

Table 3.2. Volume of scour and deposition between 2005 and 2006 surveys

Parameter	DR 82 2005-06	DR 137 2005-06	DR 82 2006-07	DR 137 2006-07
Volume of scour – m^3	16,612	11,739	13,263	13,607
Volume of deposition - m^3	12,762	15,373	24,643	18,464
Net change (+ = deposition, - = scour) - m^3	-3,850	3,634	11,380	4,858
Net change in depth – cm	-2.95	+2.94	+8.4	+4.7
Volume of cobble/gravel scour - m^3	7,326	4,766	6,269	6,538
Volume of sand scour - m^3	9,286	6,973	6,994	7,068
Volume of cobble/gavel deposition - m^3	5,309	6,580	7,849	6,086
Volume of sand deposition - m^3	7,453	8,793	16,794	12,379

Scour and deposition were also categorized as to bed material (Table 3.2). Only two categories of mobile substrate are categorized: sand and cobble/gravel. The original substrate is used for this characterization of scour, so if cobble or gravel was present under the sand in a scour location, all the scour was considered to be sand. For deposition, the post-runoff (2007 survey) substrate was used to characterize deposition.

25% more cobble/gravel was deposited in DR 82 than was scoured for a net import of cobble/gravel from in 2007. 140% more sand was deposited than scoured, also indicating net import. This is contrasted to observed net scour of both course and fine substrate between 2006 and 2006 (Table 3.2).

About 7% less cobble/gravel was deposited in DR 137 than scoured, indicating a net export of cobble to the reach. 75% more sand was deposited than scoured, indicating net import. Net deposition of both sand and cobble/gravel occurred in 2006 (Table 3.2).

The portion of coarse substrate (cobble/gravel) decreased in 2007 compared to previous years (Table 3.3). Just prior to survey a large storm event (4,300 cfs at Four Corners) deposited large volumes of sand in the reach. Much of the large deposition of sand in both reaches (Table 3.2) likely came during that event. This heavy deposition was beginning to be removed from the reach toward the end of the survey as evidence that is was temporary deposition. It is likely that net deposition occurred prior to this event in DR 82 as cobble and gravel increased. Since cobble and gravel did not increase in DR 137, it is not possible to surmise whether there was net deposition prior to the storm event.

River2D Model

River2D models have been calibrated to water surface at survey for each of the detailed reaches at 2005 and 2006 survey flows (Tables 3.4 and 3.5). The 2007 calibration for DR 82 exceeded calibration standards for both base flow and high flow conditions (Table 3.4) and has consistently been easier to calibrate than DR 137. DR 137 calibration met all the standards in 2007 at both low flow and high flow except for the standard deviation standard (27.2% vs. 25% standard; Table 3.5). This deviation occurred as the model calibration proceeded at high flow in order to stabilize the model at flows above the high flow calibration. While it is possible that the standard deviation could have been met with additional calibration, the time required for the small change in performance together with the excellent average calibration and the possibility that additional work may not result in improvement in a reasonable amount of time, no further calibration was attempted.

The model indicates that the mean velocity in DR 82 reaches maximum at about 6,000 cfs, at the point when the main island begins to flood and the wetted area increases more rapidly with increased flow (Figure 3.9). Model results and field observation indicate that the channel goes over-bank and outside the modeled area between 7,000 and 8,000 cfs. Model results above 8,000 cfs likely over-predict flow depth as the areas that are showing over-bank flow are contained to allow model continuity. Primary channel (portion of the reach that is flowing at 750 cfs) velocity continues to increase, but more slowly as flows exceed 7,000 cfs.

In DR 137, modeled mean velocity peaks at about 5,000 cfs, also corresponding with the initiation of island flooding, although wetted area expands more rapidly between 6,000 and 7,000 cfs (Figure 3.10). Primary channel velocity also flattens at this point. Model results and field observation indicate that the flow begins to go over-bank on the north side of the model reach at around 7,000 cfs, so the 8,000 cfs model results likely over-predict depth somewhat.

Table 3.3 Cobble/gravel substrate percent for DR 82 and DR 137, 2005-2007

Parameter	DR 82	DR 137
Portion of substrate that is cobble/gravel in 2005 - %	52.4	50.3
Portion of substrate that is cobble/gravel in 2006 - %	51.8	55.0
Portion of substrate that is cobble/gravel in 2007 - %	42.9	45.1

Table 3.4. River2D model calibration results for DR 82

Parameter	2005	2006	2006 high flow	2007	2007 high flow
Flow - cfs	1,020	1,140	6,140	1,140	4,500
Average error – cm (% average depth)	.38 (0.74%)	-1.8 (4.9%)	-3.6 (4.5%)	.35 (0.92%)	-5.2 (7.8%)
Standard deviation – cm (%)	7.6 (14.8%)	8.6 (23.8%)	9.2 (11.6%)	7.9 (20.7%)	10.1 (15.2%)
95th percentile range -cm	±12.7	±12.3	±15.7	±13.4	±17.8

Table 3.5. River 2D model calibration results for DR 137

Parameter	2005	2006	2006 high flow	2007	2007 high flow
Flow - cfs	607	799	5,546	1,120	4,900
Average error – cm (% average depth)	1.1 (3.5%)	1.9 (5.4%)	-8.0 (11%)	0.7 (2.0%)	-6.2 (8.9%)
Standard deviation – cm (%)	15.6 (47.7%)	7.8 (22.9%)	11.0 (15.1%)	10.2 (27.2%)	11.2 (16.0%)
95th percentile range-cm	±24.8	±13.4	±17.4	±15.8	±18.7

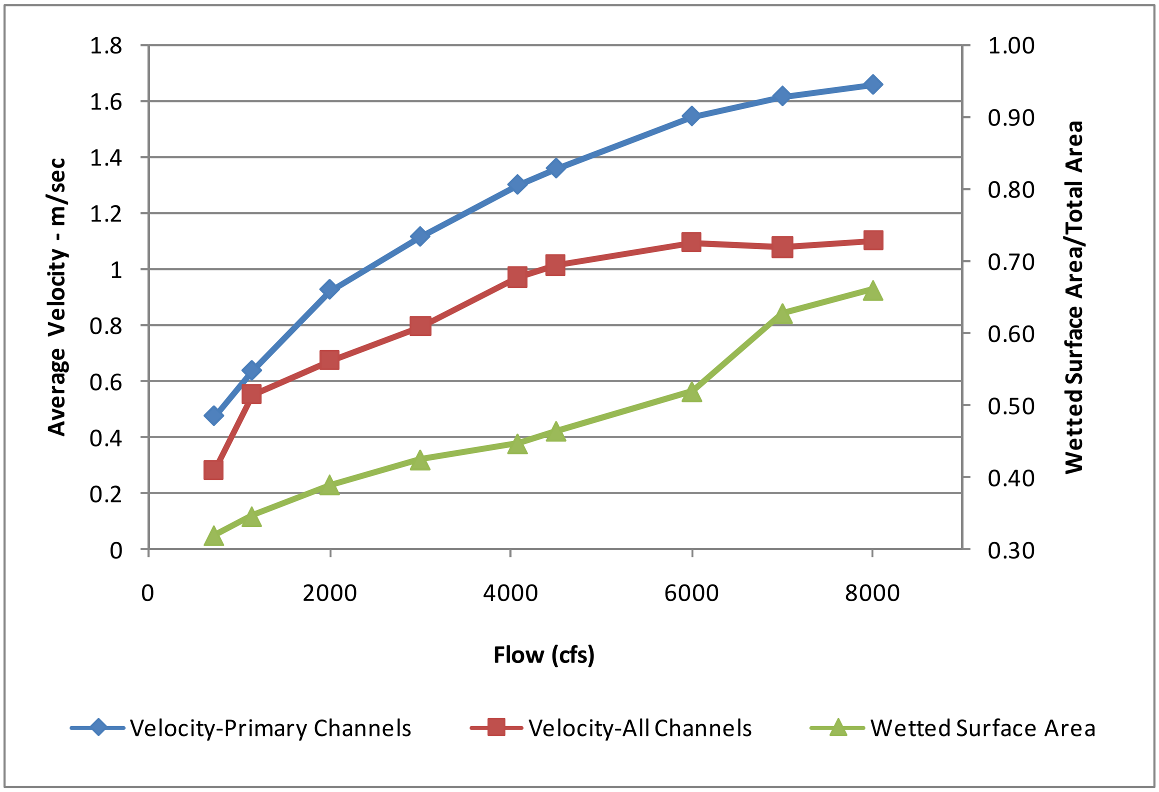

Figure 3.9. DR-82 modeled velocity and wetted surface area, 750 to 8,000 cfs

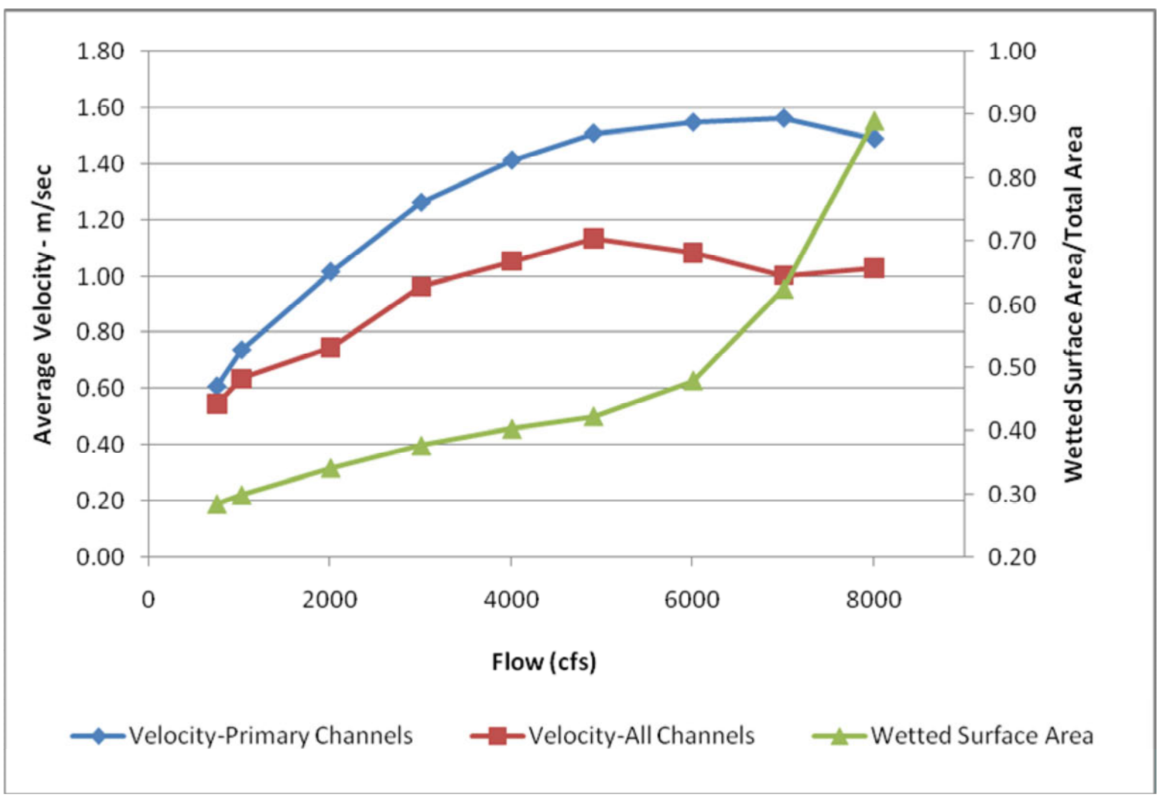

Figure 3.10. DR-137 modeled velocity and wetted surface area, 750-8000 cfs

Coarse Sediment Transport Analysis

Wolman pebble counts were completed at 10 locations in DR 82 and 9 in DR 137 (Figures 3.11 and 3.12). The mean D_{50} for the coarse fraction at DR 82 was 5.77 cm with a range of 3.5 to 7.2 cm (Table 3.6). The mean D50 at DR 137 was 5.57 cm with a range of 3.0 to 8.5 cm (Table 3.6). There is no significant difference between the two reaches ($p=0.997$). Further, the count for individual samples is sufficiently low in some cases once the fine samples were removed that the distribution statistics may not be valid. Channel wide transport calculations were completed using the mean in each reach. Site-specific calculations used only samples with counts greater than 50.

When all samples are included, 60% of the sites in DR 82 and 80% of those in DR 137 had a D_{50} of less than 1 cm (Table 3.7). When analyzed for sediment transport, material smaller than 1 cm was assumed to have a D_{50} of 5 mm. It represents the fine fraction of the bed and is called sand, although the upper end of the range and the D_{50} are in the range of fine gravel.

Boundary shear stress calculations were completed for three general reaches in DR 82 and one general and seven localized reaches in DR 137 (Figures 3.11 and 3.12). Reaches are defined as the area between paired points (Tables 3.8 and 3.9). Calculations were made for modeled conditions from 700 to 7,000 cfs in DR 82 and from 750 to 8,000 cfs in DR 137.

The average Wolman pebble count D_{50} for DR-82 of 5.77 cm was used for all of the shear stress estimates in this reach, since they are all general stream sections. The DR-82 entrance channel (reach 5-6) boundary shear stress reaches incipient motion at approximately 3,000 cfs and average motion at 4,800 cfs (Table 3.8). At the highest modeled flow (7,000 cfs), a backwater condition is created and the cobble material is predicted to be deposited. This is consistent with the formation of a bar at this location, with measured cobble deposition in 2007.

Reach 7-8 of DR-82 cobble shows only marginal sediment transport condition at the highest modeled flow (Table 3.8). Isolated pockets of cobble scour were recorded along the banks between 7 and 8 where bank erosion and localized cobble transport is evident.

Boundary shear stress in reach 9-10 of the main channel is sufficient at flows between 1,000 and 4,000 cfs to have some transport with full motion beginning at about 4,000 cfs, (Table 3.8). The other two reaches did not appear to obtain full motion below 7,000 cfs (Table 3.8). The results of the shear stress analysis are supported by channel survey data that show both cobble scour and deposition in this reach from 2006 to 2007. Localized analyses were not performed in DR 82 to examine site-specific cobble movement.

The average cobble D_{50} for DR 137 of 5.57 cm (Table 3.7) was used to examine the potential for entrance channel cobble transport (Reaches 1-4 and 2-3, Figure 3.12). While the survey did not extend upstream to capture the conditions in the channel approaching the detailed reach, the results for these two reaches indicate initial motion at as low as 1,000 cfs, with full motion at 4,900 cfs and above (Table 3.9). This area is in the deepest part of the channel with recorded scour between 2006 and 2007.

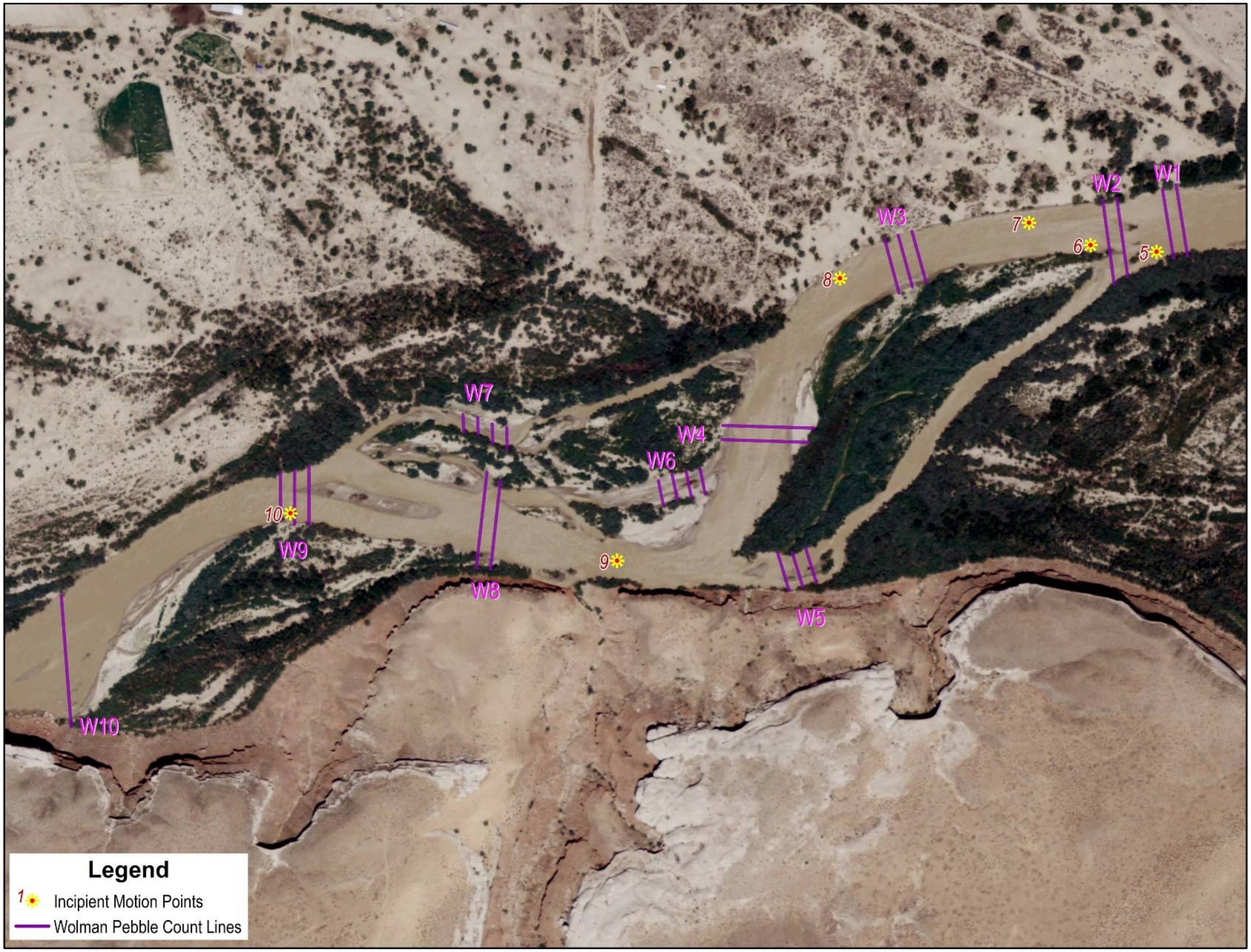

Figure 3.11. Wolman pebble count and shear stress calculation locations – DR 82. Shear stress calculations are for reaches between paired points

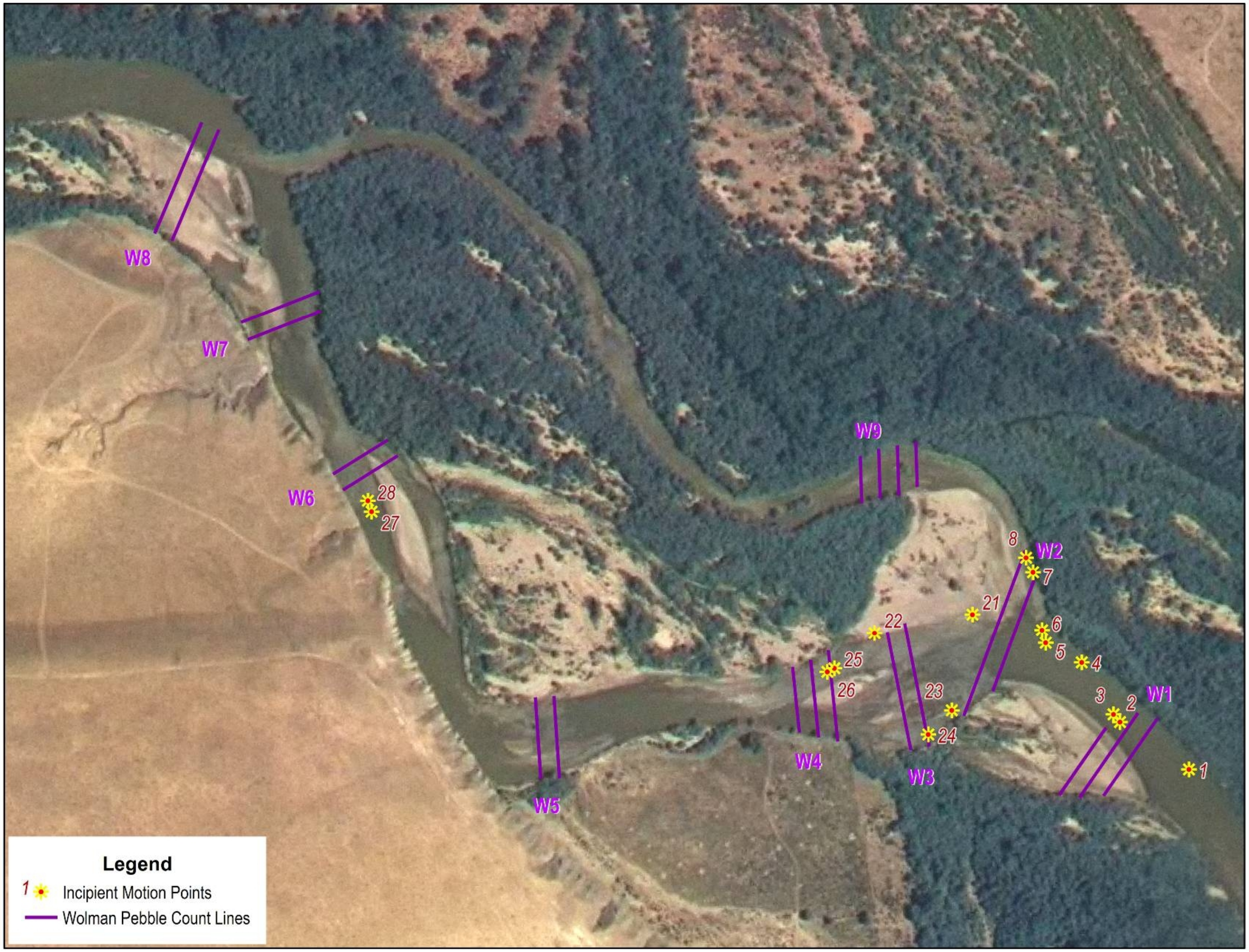

Figure 3.12. Wolman pebble count and shear stress calculation locations – DR 137. Shear stress calculations are for reaches between paired points

Table 3.6. Cumulative sediment size (cm) distribution from Wolman pebble counts for DR82 and DR 137 with data <1 excluded

Location	Date	Sample Size	D84	D75	D50	D25	D16
DR82 W1	8/23/07	59	10.47	9.33	7.22	4.30	3.60
DR82 W2	8/23/07	36	8.85	8.29	6.17	4.04	3.38
DR82 W3	8/23/07	56	10.94	9.46	6.42	3.91	3.27
DR82 W4	8/23/07	40	10.88	8.92	6.13	4.45	3.52
DR82 W5	8/23/07	75	11.77	9.38	6.36	4.25	3.28
DR82 W6	8/23/07	44	9.40	8.19	6.10	4.85	4.04
DR82 W7	8/23/07	38	6.44	5.65	3.50	2.25	1.75
DR82 W8	8/23/07	81	9.97	8.50	5.58	3.75	3.02
DR82 W9	8/23/07	22	8.66	7.63	4.50	2.79	2.45
DR82 W10	8/23/07	55	9.76	8.20	5.50	3.45	2.99
DR82 All	**8/23/07**	**506**	**9.65**	**8.40**	**5.77**	**3.70**	**2.99**
DR137 W1	8/15/07	38	12.88	8.63	5.63	3.48	3.12
DR137 W2	8/16/07	92	11.61	9.75	7.42	4.17	2.74
DR137 W3	8/17/07	107	8.54	6.91	4.53	2.75	1.94
DR137 W4	8/18/07	32	11.58	8.69	5.38	2.56	1.82
DR137 W5	8/19/07	46	9.62	7.81	5.69	2.98	2.55
DR137 W6	8/20/07	47	11.57	10.36	7.10	3.96	3.36
DR137 W7	8/21/07	48	13.26	11.72	8.50	4.65	3.71
DR137 W8	8/22/07	45	6.66	5.70	3.00	1.63	1.28
DR137 W9	8/23/07	4	5.25	4.92	4.50	4.08	3.93
DR137 All	**08/23/07**	**459**	**11.15**	**8.72**	**5.57**	**3.16**	**2.37**

Table 3.7. Cumulative sediment size (cm) distribution from Wolman pebble counts for DR82 and DR 137

Location	Date	Sample Size	D84	D75	D50	D25	D16
DR82 W1	8/23/07	100	9.14	7.75	3.58	<1	<1
DR82 W2	8/23/07	100	6.95	4.46	<1	<1	<1
DR82 W3	8/23/07	100	9.14	6.96	2.90	<1	<1
DR82 W4	8/23/07	100	7.21	5.39	<1	<1	<1
DR82 W5	8/23/07	100	10.44	7.83	4.89	<1	<1
DR82 W6	8/23/07	100	7.31	5.78	<1	<1	<1
DR82 W7	8/23/07	100	3.87	2.82	<1	<1	<1
DR82 W8	8/23/07	100	9.12	7.79	4.77	2.16	<1
DR82 W9	8/23/07	100	2.97	<1	<1	<1	<1
DR82 W10	8/23/07	100	7.34	5.84	2.42	<1	<1
DR137 W1	8/15/07	100	6.46	3.88	<1	<1	<1
DR137 W2	8/16/07	153	9.63	8.11	2.90	<1	<1
DR137 W3	8/17/07	164	6.96	5.58	2.63	<1	<1
DR137 W4	8/18/07	107	5.18	2.00	<1	<1	<1
DR137 W5	8/19/07	101	6.78	5.44	<1	<1	<1
DR137 W6	8/20/07	100	9.25	6.50	<1	<1	<1
DR137 W7	8/21/07	100	10.85	8.39	<1	<1	<1
DR137 W8	8/22/07	109	4.35	2.36	<1	<1	<1
DR137 W9	08/23/07	101	<1	<1	<1	<1	<1

Table 3.8. DR-82 boundary shear stress (τ_0) conditions at various locations and flow rates with the critical shear stresses required according to degree of transport and substrate D_{50}.

									Critical Shear Stress (lb/ft^2)		
Fig ID.	Fig ID.	Flow (cfs)	Mean Vel. (mps)	Change in Vel. (mps)	Change in Depth (m)	Friction Slope	Cobble D_{50} (cm)	τ_0 (lb/ft^2)	Incip. Motion τ_c^*=0.02	Avg. Motion τ_c^*=0.03	Full Motion τ_c^*=0.045
5	6	722	1.04	-0.30	-0.21	0.00096	5.77	0.15	0.39	0.58	0.88
5	6	1,017	1.29	-0.28	-0.22	0.00111	5.77	0.20	0.39	0.58	0.88
5	6	2,000	1.53	-0.56	-0.19	0.00135	5.77	0.31	0.39	0.58	0.88
5	6	3,000	1.69	-0.64	-0.16	0.00133	5.77	0.36	0.39	0.58	0.88
5	6	4,075	1.83	-0.67	-0.17	0.00161	5.77	0.51	**0.39**	0.58	0.88
5	6	4,500	1.83	-0.75	-0.15	0.00166	5.77	0.55	**0.39**	0.58	0.88
5	6	6,000	1.94	-1.15	-0.09	0.00195	5.77	0.72	**0.39**	**0.58**	0.88
5	6	7,000	1.96	-0.43	-0.09	0.00005	5.77	0.02	0.39	0.58	0.88
7	8	722	1.11	-0.21	-0.07	0.00092	5.77	0.10	0.39	0.58	0.88
7	8	1,017	1.35	-0.27	-0.07	0.00100	5.77	0.14	0.39	0.58	0.88
7	8	2,000	1.65	-0.25	-0.10	0.00115	5.77	0.21	0.39	0.58	0.88
7	8	3,000	1.80	-0.17	-0.13	0.00122	5.77	0.28	0.39	0.58	0.88
7	8	4,075	1.93	0.06	-0.19	0.00131	5.77	0.35	0.39	0.58	0.88
7	8	4,500	1.83	0.03	-0.14	0.00115	5.77	0.34	0.39	0.58	0.88
7	8	6,000	2.01	0.40	-0.27	0.00140	5.77	0.46	**0.39**	0.58	0.88
7	8	7,000	1.92	0.24	-0.28	0.00157	5.77	0.63	**0.39**	**0.58**	0.88
9	10	722	0.87	0.32	-0.43	0.00325	5.77	0.55	**0.39**	0.58	0.88
9	10	1,017	1.09	0.34	-0.47	0.00332	5.77	0.66	**0.39**	**0.58**	0.88
9	10	2,000	1.47	0.35	-0.38	0.00304	5.77	0.77	**0.39**	**0.58**	0.88
9	10	3,000	1.71	0.18	-0.27	0.00279	5.77	0.86	**0.39**	**0.58**	0.88
9	10	4,075	1.92	0.10	-0.23	0.00270	5.77	0.92	**0.39**	**0.58**	**0.88**
9	10	4,500	1.94	0.00	-0.16	0.00257	5.77	0.93	**0.39**	**0.58**	**0.88**
9	10	6,000	2.11	-0.19	0.00	0.00222	5.77	0.93	**0.39**	**0.58**	**0.88**
9	10	7,000	1.94	-0.55	0.30	0.00157	5.77	0.78	**0.39**	**0.58**	0.88

Note: Bold = boundary shear stress is greater than the critical shear stress
See equation 3 for computation of boundary shear stress.

Table 3.9. DR-137 boundary shear stress (*τ_0*) conditions at various locations and flow rates with the critical shear stresses required according to degree of transport and substrate D_{50}

Fig ID.	Fig ID.	Flow (cfs)	Mean Vel. (mps)	Change in Vel. (mps)	Change in Depth (m)	Friction Slope	Cobble D_{50} (cm)	τ_0 (lb/ft^2)	Critical Shear Stress (lb/ft^2): Cobble Incip. Motion τ^*_c=0.02	Cobble Avg. Motion τ^*_c=0.03	Cobble Full Motion τ^*_c=0.045
1	4	745	0.51	0.05	0.53	0.00107	5.57	0.34	0.38	0.56	0.85
1	4	1,017	0.66	0.07	0.52	0.00118	5.57	0.39	**0.38**	0.56	0.85
1	4	2,000	1.10	0.17	0.46	0.00150	5.57	0.55	**0.38**	0.56	0.85
1	4	3,000	1.47	0.32	0.42	0.00166	5.57	0.67	**0.38**	**0.56**	0.85
1	4	4,000	1.78	0.42	0.36	0.00189	5.57	0.81	**0.38**	**0.56**	0.85
1	4	4,900	2.00	0.44	0.33	0.00205	5.57	0.92	**0.38**	**0.56**	**0.85**
1	4	6,000	2.22	0.41	0.31	0.00217	5.57	1.03	**0.38**	**0.56**	**0.85**
1	4	7,000	2.37	0.31	0.32	0.00222	5.57	1.11	**0.38**	**0.56**	**0.85**
1	4	8,000	2.48	0.14	0.36	0.00225	5.57	1.17	**0.38**	**0.56**	**0.85**
2	3	745	0.50	-0.02	0.00	0.00027	5.63	0.06	0.38	0.57	0.86
2	3	1,017	0.68	-0.02	0.00	0.00056	5.63	0.13	0.38	0.57	0.86
2	3	2,000	1.16	-0.03	-0.01	0.00146	5.63	0.40	**0.38**	0.57	0.86
2	3	3,000	1.52	-0.03	-0.01	0.00157	5.63	0.47	**0.38**	0.57	0.86
2	3	4,000	1.83	-0.02	-0.01	0.00208	5.63	0.68	**0.38**	**0.57**	0.86
2	3	4,900	2.05	-0.01	-0.02	0.00254	5.63	0.89	**0.38**	**0.57**	**0.86**
2	3	6,000	2.22	0.00	-0.02	0.00241	5.63	0.91	**0.38**	**0.57**	**0.86**
2	3	7,000	2.33	-0.01	-0.02	0.00229	5.63	0.93	**0.38**	**0.57**	**0.86**
2	3	8,000	2.44	-0.02	-0.01	0.00223	5.63	0.95	**0.38**	**0.57**	**0.86**
5	6	745	0.50	-0.12	-0.31	0.00013	5.63	0.03	0.38	0.57	0.86
5	6	1,017	0.63	-0.15	-0.32	0.00098	5.63	0.28	0.38	0.57	0.86
5	6	2,000	1.06	-0.20	-0.31	0.00164	5.63	0.52	**0.38**	0.57	0.86
5	6	3,000	1.44	-0.18	-0.30	0.00110	5.63	0.38	**0.38**	0.57	0.86
5	6	4,000	1.76	-0.20	-0.30	0.00144	5.63	0.53	**0.38**	0.57	0.86
5	6	4,900	1.99	-0.24	-0.29	0.00178	5.63	0.68	**0.38**	**0.57**	0.86
5	6	6,000	2.25	-0.25	-0.28	0.00197	5.63	0.79	**0.38**	**0.57**	0.86
5	6	7,000	2.42	-0.24	-0.28	0.00196	5.63	0.83	**0.38**	**0.57**	0.86
5	6	8,000	2.49	-0.22	-0.28	0.00180	5.63	0.81	**0.38**	**0.57**	0.86
7	8	745	0.55	0.13	0.26	0.00158	7.42	0.31	0.50	0.75	1.13
7	8	1,017	0.70	0.09	0.27	0.00097	7.42	0.21	0.50	0.75	1.13
7	8	2,000	1.16	0.02	0.26	0.00212	7.42	0.58	**0.50**	0.75	1.13
7	8	3,000	1.47	0.17	0.26	0.00041	7.42	0.13	0.50	0.75	1.13
7	8	4,000	1.48	0.28	0.26	0.00082	7.42	0.30	0.50	0.75	1.13
7	8	4,900	1.47	0.32	0.26	0.00178	7.42	0.70	**0.50**	0.75	1.13
7	8	6,000	1.31	0.46	0.28	0.00384	7.42	1.61	**0.50**	**0.75**	**1.13**
7	8	7,000	1.17	0.57	0.30	0.00572	7.42	2.54	**0.50**	**0.75**	**1.13**
7	8	8,000	1.04	0.62	0.32	0.00707	7.42	3.30	**0.50**	**0.75**	**1.13**

Note: Bold = boundary shear stress is greater than the critical shear stress

Table 3.9. DR-137 boundary shear stress (τ_0) conditions at various locations and flow rates with the critical shear stresses required according to degree of transport and substrate D_{50} *(cont'd)*

									Critical Shear Stress (lb/ft^2)		
Fig ID.	Fig ID.	Flow (cfs)	Mean Vel. (mps)	Change in Vel. (mps)	Change in Depth (m)	Friction Slope	Cobble D_{50} (cm)	τ_0 (lb/ft^2)	Cobble Incip. Motion τ^*_c=0.02	Cobble Avg. Motion τ^*_c=0.03	Cobble Full Motion τ^*_c=0.045
21	22	2,000	0.14	-0.22	-0.07	0.00498	4.53	0.02	0.31	0.46	0.69
21	22	3,000	0.41	-0.30	-0.02	0.00441	4.53	0.15	0.31	0.46	0.69
21	22	4,000	0.82	-0.05	0.05	0.00340	4.53	0.21	0.31	0.46	0.69
21	22	4,900	1.18	0.09	0.10	0.00263	4.53	0.23	0.31	0.46	0.69
21	22	6,000	1.43	-0.11	0.16	0.00226	4.53	0.28	0.31	0.46	0.69
21	22	7,000	1.63	-0.26	0.19	0.00225	4.53	0.35	**0.31**	0.46	0.69
21	22	8,000	1.76	-0.33	0.22	0.00211	4.53	0.39	**0.31**	0.46	0.69
23	24	745	1.45	-0.18	-0.01	0.00632	5.57	0.46	**0.38**	0.56	0.85
23	24	1,017	1.59	-0.18	-0.01	0.00607	5.57	0.52	**0.38**	0.56	0.85
23	24	2,000	1.66	-0.23	0.07	0.00374	5.57	0.48	**0.38**	0.56	0.85
23	24	3,000	1.44	-0.30	0.12	0.00203	5.57	0.34	0.38	0.56	0.85
23	24	4,000	1.04	-0.31	0.13	0.00116	5.57	0.24	0.38	0.56	0.85
23	24	4,900	0.62	-0.27	0.14	0.00049	5.57	0.12	0.38	0.56	0.85
23	24	6,000	0.23	0.02	0.14	0.00014	5.57	0.04	0.38	0.56	0.85
23	24	7,000	0.20	0.34	0.13	0.00015	5.57	0.04	0.38	0.56	0.85
23	24	8,000	0.42	0.75	0.13	0.00100	5.57	0.33	0.38	0.56	0.85
25	26	745	1.57	-0.08	-0.03	0.00828	5.57	0.63	**0.38**	**0.56**	0.85
25	26	1,017	1.69	-0.09	-0.03	0.00767	5.57	0.70	**0.38**	**0.56**	0.85
25	26	2,000	1.82	-0.05	0.00	0.00336	5.57	0.48	**0.38**	0.56	0.85
25	26	3,000	1.82	0.00	-0.01	0.00321	5.57	0.62	**0.38**	**0.56**	0.85
25	26	4,000	1.82	-0.03	0.00	0.00235	5.57	0.54	**0.38**	0.56	0.85
25	26	4,900	1.78	-0.03	0.00	0.00196	5.57	0.52	**0.38**	0.56	0.85
25	26	6,000	1.80	-0.06	0.01	0.00150	5.57	0.46	**0.38**	0.56	0.85
25	26	7,000	1.91	-0.07	0.01	0.00145	5.57	0.49	**0.38**	0.56	0.85
25	26	8,000	1.99	-0.06	0.01	0.00129	5.57	0.47	**0.38**	0.56	0.85
27	28	745	1.36	0.03	-0.03	0.00367	5.57	0.39	**0.38**	0.56	0.85
27	28	1,017	1.50	-0.01	-0.02	0.00373	5.57	0.45	**0.38**	0.56	0.85
27	28	2,000	1.63	-0.01	-0.01	0.00240	5.57	0.43	**0.38**	0.56	0.85
27	28	3,000	1.93	-0.05	0.00	0.00248	5.57	0.52	**0.38**	0.56	0.85
27	28	4,000	1.93	0.03	-0.01	0.00170	5.57	0.44	**0.38**	0.56	0.85
27	28	4,900	1.91	0.03	0.00	0.00096	5.57	0.28	0.38	0.56	0.85
27	28	6,000	1.75	0.03	0.01	0.00019	5.57	0.07	0.38	0.56	0.85
27	28	7,000	1.72	0.03	0.01	0.00002	5.57	0.01	0.38	0.56	0.85
27	28	8,000	1.71	0.01	0.01	0.00001	5.57	0.01	0.38	0.56	0.85

Note: Bold = boundary shear stress is greater than the critical shear stress

The remaining analysis areas in DR 137 examine the theoretical localized transport capacity in areas of demonstrated cobble *movement*. The upper areas (2-3, 5-6, and 7-8) all demonstrate increasing potential for cobble transport with increased flows with average motion occurring in the 4,000 – 6,000 cfs range (Table 3.9). They are in areas of measured cobble scour between 2006 and 2007.

The lower areas (21-22, 23-24, 25-26 and 27-28) are in areas of cobble deposition or no change. The area around 21-22 exhibits very little potential for cobble movement at only the highest flows. It is in an area of bank instability with bank erosion, but local deposition away from the bank. The remaining sites show decreasing shear stress with increased flow. They have minor to modest potential for cobble transport at low flow, but none at high flow (Table 3.9). This pattern is consistent with the findings of the flow recommendations concerning low flows in some localized conditions that are adequate for cobble movement (Holden, 1999).

Habitat

For 2007, the detailed mapping provides finer resolution, with 1.4 (DR 137) to 2.1 (DR 82) times as many habitat polygons mapped compared to the standard mapping (Tables 3.10 and 3.11). This is particularly important in the smaller habitats that may be of importance to the endangered fishes (Table 3.12). For example, 2-3 times as many low velocity habitats were mapped during detailed mapping compared to standard mapping (Tables 3.10 and 3.11). Some individual habitats (e.g. eddies) are rarely mapped during standard mapping, yet are frequent in detailed mapping (Table 3.12). These features enhance habitat complexity and are often associated with endangered fish captures (see Chapter 4). Characterizing these features more accurately may improve the ability to assess habitat for endangered fish.

For DR 82, the increase in detail is similar to that seen in 2006. For DR 137 the increased detail over standard mapping is much less than in 2006. Most of the difference occurred in slackwater and vegetation habitat types (Table 3.11). The difference is at least partially explained by higher flow at mapping in 2006 which results in more slackwater and vegetation related habitats.

In the 2006 report we noted that there was a difference in some habitat categories that may be related to different interpretation of mappers (Bliesner and Lamarra, 2007). The difference was evidenced in transitional habitats (those that have some characteristics of two adjacent habitats) and was the greatest in the run/riffle habitat type. When summarized, run/riffles have been categorized with runs so a large change in run and riffle types were noted depending on the mapper. While evaluating this problem it was determined that run/riffles actually function more like riffles than runs. This change in characterization has been implemented in all data sets and less change is now noted in 2006 as a result (Tables 3.10 and 3.11). In 2007 the same person mapped at the detailed and standard level and there is less difference in these categories as a result. Habitat categories are being evaluated for simplification to improve repeatability of interpretation, particularly of these transitional habitats. Upon completion of the study, recommendations will be made concerning any changes in habitat categories or descriptions.

Of key importance is that the more detailed mapping identifies more locations and smaller habitat polygons of features that represent habitat complexity and low velocity habitat. This greater detail may be important to correlating habitat availability to habitat use.

Table 3.10. Comparison of detailed and standard habitat mapping for DR 82, 2006-2007

	2006 Count		Area – m^2		2007 Count		Area – m^2	
Habitat Category	**Detail**	**Standard**	**Detail**	**Standard**	**Detail**	**Standard**	**Detail**	**Standard**
Backwater	0	0	0	0	3	3	275	278
Other Low Velocity	4	2	728	751	13	4	661	261
Runs	13	13	56,946	66,273	22	17	54,043	58,536
Riffles	28	23	23,243	20,019	50	38	18,205	19,929
Shoals	31	20	4,453	5,113	59	20	6,955	5,770
Slackwater	33	5	3,924	1,732	39	11	5,008	1,708
Vegetation	45	10	773	212	9	0	432	0
Total wetted area	***154***	***73***	***90,066***	***94,100***	***195***	***93***	***85,580***	***86,482***
Islands	6	5	89,587	91,999	5	4	91,652	92,115
Sand Bar	35	24	12,404	10,095	20	12	8,848	5,445
Cobble Bar	19	15	4,442	6,107	21	19	13,416	15,436
Rootwad piles	40	10	770	505	24	6	579	275
Boulders	3	0	8	0	6	0	17	0
Total mapped area	***257***	***127***	***197,276***	***202,807***	***271***	***134***	***200,090***	***199,753***
Flow - cfs			1,190	1,190			931	931
Date			11/3/06	11/3/06			10/17/07	10/17/07
Map Scale ft/inch			75	150			75	150

Table 3.11. Comparison of detailed and standard habitat mapping for DR 137, 2006-2007

	Count 2006		Area 2006 – m^2		Count 2007		Area 2007 – m^2	
Habitat Category	**Detail**	**Standard**	**Detail**	**Standard**	**Detail**	**Standard**	**Detail**	**Standard**
Backwater	8	2	623	200	2	3	369	181
Other Low Velocity	3	0	64	0	4	2	81	68
Runs	10	9	35,605	35,232	15	13	43,621	45,248
Riffles	45	17	17,125	20,702	42	23	19,150	20,618
Shoals	29	14	2,389	6,410	33	27	4,068	3,021
Slackwater	62	20	5,110	4,551	30	18	3,321	627
Vegetation	68	19	1,286	1,602	13	13	1,733	2,574
Total wetted area	***225***	***81***	***62,203***	***68,697***	***139***	***99***	***72,343***	***72,338***
Islands	4	4	125,115	123,886	5	5	121,372	120,343
Sand Bar	7	6	643	2,967	14	9	6,698	823
Cobble Bar	12	6	5,592	4,292	13	11	7,242	6,479
Rootwad piles	22	7	170	310	16	12	225	141
Boulders	0	0	0	0	0	0	0	0
Total mapped area	***270***	***104***	***193,724***	***200,152***	***187***	***136***	***207,879***	***200,125***
Flow - cfs			1,084	1,084			871	871
Date			11/1/06	11/1/06			10/16/07	10/16/07
Map Scale ft/inch			75	150			75	75

Table 3.12. Habitat count for low velocity, slackwater and cobble shoal habitats, DR 82 and DR 137, 2005-2007

Survey	Low Velocity Types						Slack water	Cobble Shoals	Flow
	1	3	4	5	6	22	20	8B	cfs
DR 82									
Nov 05 Standard	0	1	0	0	0	0	2	13	891
Nov 05 Detailed	3	2	0	2	14	2	47	25	951
Nov 06 Standard	0	2	0	0	0	0	4	7	1,190
Nov 06 Detailed	0	3	0	0	1	0	30	10	1,190
Oct 07 Standard	2	4	0	0	0	1	9	14	931
Oct 07 Detailed	2	10	0	0	3	1	37	25	931
Standard average	0.7	2.3	0.0	0.0	0.0	0.3	5.0	11.3	1,004
Detailed average	1.7	5.0	0.0	0.7	6.0	1.0	38.0	20.0	1,024
Detailed/standard	2.5	2.1	n/a	n/a	n/a	3.0	7.6	1.8	
DR 137									
Nov 06 Standard	0	0	0	0	0	2	20	10	1,084
Nov 06 Detailed	2	0	0	0	3	6	62	15	1,084
Oct 07 Standard	1	0	1	0	1	2	18	20	871
Oct 07 Detailed	0	0	1	0	3	2	30	23	871
Standard average	0.5	0.0	0.5	0.0	0.5	2.0	19.0	15.0	977
Detailed average	1.0	0.0	0.5	0.0	3.0	4.0	46.0	19.0	977
Detailed/standard	2.0	n/a	1.0	n/a	6.0	2.0	2.4	1.3	

Note: See Table 4.1 for description of habitat code

Extrapolation of this higher resolution mapping to the full standard data set would be possible if a relationship could be established between the high resolution mapping and the standard mapping. With only three years of data (two years for DR 137) there are insufficient data points to develop habitat specific relationships. Grouping habitats in any regression analysis creates an accuracy bias towards the more abundant habitats and diminishes the predictive accuracy for categories with low abundance. Habitat specific relationships will be required and the analysis will be attempted with the 2008 data. The results of that analysis will provide insight into the viability of the process and the need and advisability of completing the full five years of analysis as originally proposed. The end result of the analysis is to be able to better interpret historical low level mapping and to develop a future habitat monitoring program at the appropriate temporal and spatial scale to allow evaluation of the efficacy of the flow recommendations in habitat maintenance, keyed to those habitats most important to the endangered fish.

Model and Habitat Data Integration

Depth and velocity within 4 selected run habitats with shoreline connection are plotted with distance from the shore in Figure 3.13. Using a threshold velocity of around 0.6 m/sec (See Chapter 4), the most logical break between shore-run and mid-channel run is in the range of 1.5 to 3.0 m. Velocity begins to increase at about 1.5 m, but average depth is still less than 0.5 m. At 3.0 m the trend in depth increase is flattening, the average velocity is about 0.5 m/sec and the maximum velocity readings are approaching 1 m/sec. At 2.5 m, the high velocities are mostly below 0.5 m/sec with only 1 or 2 values above the 0.6 m threshold. For determination of habitat availability within these detailed reaches, 2.5 m was selected as a reasonable limit. With this offset applied to runs that contact the bank, 10.7% of the run habitat in both reaches would be classified as shore-run. For determination of habitat availability, a value of 10% was used.

This approach needs some refinement as all shorelines are not equal. For example, runs next to a cut bank will typically be deep and swift, not meeting the desired velocity and depth conditions. Screening of bank conditions could improve the availability estimate. Further refinement in consultation with the Biology Committee is recommended.

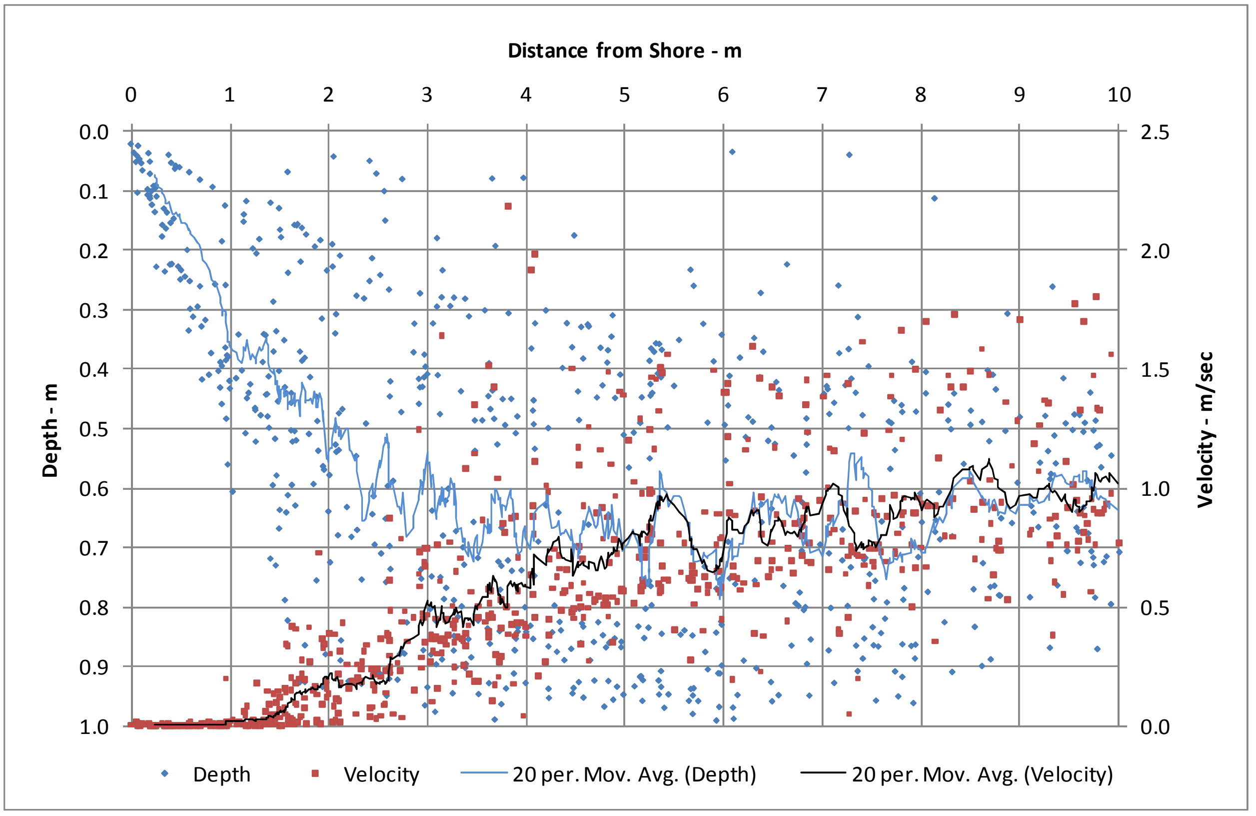

Figure 3.13. Depth and velocity in selected runs with distance from shore –DR 82 and DR 137

CONCLUSIONS AND RECOMMENDATIONS

Analysis of the first three years of data from the detailed reaches has led to some important findings, substantially enhanced by the addition of the fish survey in 2007. The objectives of the study are being met, although some of the original methods have been changed. Following are the detailed findings and recommendations:

Channel Change

- DR 82 demonstrated about 8 cm of net deposition between August 2006 and August 2007, with both scour and deposition within the reach. Both cobble/gravel and sand increased in the reach in 2007, compared to a net decrease for both in 2006. 86% of the net increase was sand, likely as a result of a large storm event a few days before the survey.
- DR 137 demonstrated nearly 5 cm of net deposition during the same time period with both scour and deposition within the reach. There was a net loss of cobble/gravel and a net import of sand. Two thirds of the total deposition was sand, much of it likely as a result of the storm event discussed above.
- The change in bed elevation is statistically significant for both cobble and sand.

River2D Model

- River2D models have been developed and operated for DR 82 and 137 that cover ranges in flow from about 700 cfs to around 8,000 cfs.
- The models provide sufficiently reliable results to forecast depth, velocity and wetted area over a range of flows.
- At high flows, continuity of wetted area remains a problem. Additional survey break lines will be needed to improve the visual representation of wetted area at high flow.
- Model results indicate that DR 82 reaches maximum average flow velocity at about 6,000 cfs and bank-full conditions at 7,000 – 8,000 cfs.
- For DR 137, maximum average flow velocity is reached at about 5,000 cfs and bank-full conditions occur at between 6,000 and 7,000 cfs.

Coarse Sediment Transport

- Boundary shear stress is adequate in both reaches to mobilize cobble into the reaches at flows near bank-full (6,000 – 8,000 cfs).
- Localized shear stress analysis indicates conditions within the detailed reaches that scour at low flow and deposit at high flow and vice versa.
- The analysis within the detailed reaches confirms conclusions in the flow recommendation report for cobble transport.
- Providing survey data upstream and downstream of the detailed reaches is recommended to allow computation of boundary shear stress in the inlet and outlet areas of the detailed reach

Detailed Reach Habitat

- Detailed mapping identifies from 2 to 3 times as many habitat polygons as standard mapping overall. For important low velocity habitats, the increase in resolution is much higher.

- Habitat grouping was changed as a result of habitat classification review to include run-riffles in the riffle rather than run category.
- Extrapolation of detailed mapping results to the river-wide data set will require at least one more year of data before regressions can be attempted and the originally planned 5-year data set will be required for reliable relationships.

Model and Habitat Data Integration

- Availability of shore-run habitat was determined by applying depth/velocity criteria to establish a typical distance from shore as the break between shore-run and mid-channel run habitat types. 2.5 m was found to best represent the transition between the two habitats based on data from the detailed reaches.
- Application of the 2.5 m offset for the detailed reaches resulted in about 10% of the run habitat being classified as shore-run.
- Shoreline discrimination for selection of appropriate edge conditions should be included in future definitions.
- Shore-run habitat definition should be refined after receiving input from the Biology Committee.

CHAPTER 4: DETAILED REACH FISH SURVEY

INTRODUCTION

During the integration of San Juan River Basin Recovery Implementation Program (SJRIP) monitoring data from 1999-2003, it became obvious that combining habitat data and fish data was extremely difficult (Miller 2005) since these two data sets were taken at different levels of detail. Adult fish monitoring data were too coarse to allow correlation with habitat data while habitat mapping units were too large to see details that were often the focus of sampling by larval and juvenile fish sampling programs. While larval and small-bodied fish sampling collect habitat data, the habitat categories do not match those in the habitat mapping program. Finally, although GPS locations are provided for recently collected larval and small-bodied fish sampling programs, the accuracy is not adequate to place them on the habitat maps with sufficient precision to correlate the two data sets.

Backwater and other low velocity habitat have been hypothesized to be important to larval and young juvenile endangered fishes (Bestgen et al. 2006, Modde et al. 1996, Modde et al. 2001). Backwater habitat is low in abundance in the San Juan River and has declined substantially since 1995 (Bliesner and Lamarra, 2006). However, sampling for age-0 and age-1 Colorado pikeminnow in the last several years has indicated that they use other low velocity habitat that is not necessarily mapped by the standard mapping program (Golden, et al. 2006).

To identify the habitat utilized by young endangered fishes and to provide information to allow this habitat to be mapped more broadly in the river, the following objectives were addressed.

1. Sample for young-of-year Colorado pikeminnow and razorback sucker within the two complex reaches to determine habitat use of endangered fish.

2. Map habitat in each complex reach each time fish sampling occurs.

3. Use supplemental data on young Colorado pikeminnow and razorback sucker captures of any size class throughout the San Juan River from other SJRIP sampling efforts and use these data to add to the habitat use information in the complex reaches.

The mapping, combined with detailed channel topology measurements and hydraulic modeling, would also provide insight into the mechanism or process for creation and maintenance of these complex reaches and provide a better understanding of the loss or creation of backwater habitats or other low velocity habitats used by the endangered fishes.

METHODS

Fish sampling of two complex reaches located at river mile 82 (DR 82) and 137 (DR 137), occurred in August 2007. Each reach was sampled twice within a six day period. The first sampling event occurred over two days and the second followed after a short “rest” of one or two days. This “rest” period was intended to allow displaced fish to redistribute among available habitats. “Block” seining was the primary method used to capture fish. This method involved using two 2m x 9m double weighted seines with a 6mm mesh. To sample a particular location, one seine was dragged downstream through the sample area while the other was held in place at the downstream end and pivoted towards the shore behind the first seine. In addition, when conditions favored using a smaller seine, a few samples were also collected using a single 2m x 3m seine with a 3mm mesh size.

All Colorado pikeminnow and razorback sucker captured in each of the complex reaches were measured. For other species captured, measurements of up to 50 randomly selected individuals of each species were recorded. A PIT tag reader was used to scan all Colorado pikeminnow and razorback sucker over 150 mm TL for PIT tags. Numbers of PIT tags detected were recorded and a new tag was inserted when detection did not occur. All Colorado pikeminnow that were less than 150 mm TL were marked with a VIE tag (marking color and location: pink right dorsal) during the first pass.

The selection of sampling habitats was intended to be proportional to the occurrence of habitats within the two complex reaches. However, previous sampling has shown that age-1 pikeminnow (total length >100mm) tend to use fairly complex portions of the river with some current, while young-of-the-year Colorado pikeminnow (total length < 100 mm) occur more commonly in backwaters and shoals (Golden et al. 2006, Robertson and Holden 2007). Based on this evidence, some habitats were sampled in a relative lower or higher proportion than they occurred in each reach. Backwaters, embayments, and eddies are relatively uncommon and all or the majority of these low-velocity habitat types were sampled. Conversely, runs are among the most common habitat types, but only a small area of this habitat type was sampled.

Prior to the field data collection, a plan for selecting sample sites was developed based on previous mapping efforts and anticipated number of samples that could be collected in the allocated sample period. We anticipated that approximately 40 samples would be taken during each pass in each reach (pass 1 on each site was spread across 2 days). Based on this number of samples approximately 10 were expected to be allocated to backwaters and other low-velocity habitats and 30 would be randomly selected based on previous mapping estimates of relative abundance of various habitat types. However, it quickly became apparent while in the field that we would be able to effectively seine all samplable habitats during the timeframe of a single day. Thus, after the initial sampling pass, the habitats sampled were reviewed, and the second sampling event was utilized to sample habitats that were missing, and/or that were not sampled in approximate relative proportion during the initial sampling event. The second pass also served to increase the number of seine hauls pulled and to boost pikeminnow captures.

In DR 82, shoals and slackwater habitats were common and each was allocated approximately 10 samples. Riffles and runs were allocated 5 samples. As noted above, although runs were abundant, this habitat was sampled in lower frequency to ensure that habitats with a greater likelihood of having Colorado pikeminnow or razorback sucker present were sampled more frequently. In the *DR 137* site, slackwaters were most common and allocated 14 of 40 samples. Shoals, riffles, and runs were anticipated to include 8, 4, and 4 samples, respectively. Sand shoals were more common than cobble shoals in DR 82 by a 2:1 ratio, which was expected to be reflected in the habitat sampling distribution. In DR 137, sand and cobble shoals were similar in abundance. Approximate site locations were chosen in advance (except for backwaters and other low-velocity habitats) using maps from the previous year as well as a grid and random number generator. In the field, many of these sites were no longer in the same habitat category or were not suitable to sampling with seines. Thus, sample sites were adjusted as needed. It should also be noted that despite detailed planning, the final allocation of sampled habitat types were more closely associated with habitat conditions observed in the field than the anticipated sample locations determined from previous mapping efforts.

In all sample efforts, a single habitat type was targeted for sampling. However, effective sampling of small habitat features often required beginning a seine haul in one habitat feature, passing through the targeted habitat, and completing the sample in the second or even possibly a third habitat feature. In such cases, effort was focused on minimizing the area sampled in adjacent habitats. All captured organisms were presumed to have been captured in the target habitat for data analysis.

Physical characteristics recorded at each habitat sampled included multiple depth and velocity measurements, primary and secondary substrate types, and primary and secondary cover features (if present). The habitat type, area sampled (width and length of seine haul) and water temperature were also recorded. Depth and velocity measurements were collected in 3 to 5 locations per site and chosen to be representative of the range of conditions within the site. Velocity measurements were collected at 60 percent below the water surface in all locations with depth less than 2.5 feet and at 20, 60, and 80 percent below the surface with depth greater than 2.5 feet. In these locations, velocity was averaged for the three values to generate a mean velocity value for that location. Depth and mean velocity for each of the 3-5 locations were then averaged to find a mean depth and velocity for the sample site. Substrate was classified as silt, sand, fine gravel (<1 in.), coarse gravel (1-3 in.), small cobble (3-6 in.), large cobble (6-10 in.), or boulder (>10 in.). Categories for cover included inundated vegetation, roots, small woody debris, large woody debris, overhanging vegetation/roots, boulders, and bedrock shelves.

Sample locations were identified on an ortho-rectified digital photograph base map on which were drawn habitat features collected at the same time as fish sampling, and GPS coordinates were recorded at each sampling site. Habitat types follow Bliesner et al. (1999; Table 4.1). During data collection, a new habitat category was identified, the riffle plunge. This new category is considered an important habitat feature that provides low velocity microhabitat at the base of a riffle (a food source). This habitat feature was sampled for fish and will be mapped at the complex reach level in future efforts.

Other San Juan River fishery studies were also reviewed for the potential to use them in the habitat selection analysis. Data from the larval fish, non-native fish removal, adult monitoring, and small-bodied monitoring studies were evaluated.

Data Analysis

All available habitats were mapped in the complex study reaches (DR 82 and DR 137) and categorized by habitat unit type. For each habitat type, the frequency of sampling, total area sampled, and proportion available were calculated.

Habitat selection of fishes in the complex study reaches (DR 137 and DR 82) was analyzed by examining the proportional use of individual habitat types (number of fish collected divided by total number of fish caught) in relation to their proportional availability (amount of that habitat sampled divided by the total amount of habitat sampled). Habitat selection was analyzed for Colorado pikeminnow, as well as for the entire fish assemblage, the native fish assemblage, the non-native fish assemblage, and other individual fish species of interest (i.e., bluehead sucker, flannelmouth sucker, speckled dace, channel catfish, fathead minnow, and red shiner). Habitat selection of Colorado pikeminnow was analyzed by combining the use and available habitat of both complex study reaches, as well as DR 137 individually. Analyses of habitat selection for DR 82 were not conducted separately because of the small number of Colorado pikeminnow captured in this reach.

Table 4.1. Habitat classification types used in mapping detailed reaches (DR 137 and DR 82) and for classification of samples collected during the detailed reach fish survey of summer 2007

Habitat Classifications	
Backwater	Slackwater
Backwater Pool	Isolated Pool
Pool	Embayment
Debris Pool	Overhang Vegetation
Rootwad Pool	Cobble Bar
Eddy	Rootwad Pile
Edge Pool	Abandoned Channel (dry)
Sand Shoal	Sand Bar
Cobble Shoal	Tributary
Sand Shoal/Run	Shoal/Riffle
Cobble Shoal Run	Island
Run	Rapids
Scour Run	Irrigation Return
Shore Run	Flooded Vegetation
Undercut Run	Pocket Water
Run/Riffle	Boulder
Riffle	Waterfall
Riffle Eddy	Pier (bridges)
Shore Riffle	Diverted Water
Riffle/Chute	Diversion Structure
Chute	Island between or within Secondary and Main Channel

Two types of chi-square analysis were used to test the null hypothesis that fish are randomly selecting habitats in proportion to their availability. These tests of “no selection” included the Pearson chi-square statistic (χ^2_p), which is driven by differences between the observed and expected number of used resource units of each type and the Log-likelihood statistic (χ^2_l), which is based on the ratio of the observed and expected resource units used. Significant chi-square values ($p<0.05$) indicate that selection occurs (Manly et al. 1993).

Selection of particular habitat unit types was determined by the proportional use and availability (given by the area of habitat sampled) of each habitat type. Resource selection ratios (w) were calculated for each habitat type by dividing the proportion of fish using the habitat type by the proportion of habitat sampled (Manly et al. 2002). The selection ratio statistic allowed for the determination of habitat selection. Selection ratios equal or close to one ($w=1$ of $w\approx1$) indicate no selection. Values much smaller than one ($w<1$) suggest selection against a particular habitat type and ratios greater than one ($w>1$) indicate selection. Selection becomes increasingly stronger as the statistic increases further from one. The Z-squared statistic was used to test the hypothesis that a particular selection ratio equals one. Statistical significance ($p<0.05$) of this test is based on p-values calculated using the chi-squared distribution minus one degree of freedom. All habitat selection analyses were conducted using the Stats-Alive RSTool program developed by Ken Gerow (2007) of the University of Wyoming.

In addition to analyses of habitat availability and use, basic fishery information for the complex reaches sampled including effort, fish captured, CPUE, and endangered fish size information were also summarized.

The potential relationship between Colorado pikeminnow fish capture and habitat associations was also explored. Using digitized habitat and fish sample location datasets, buffer distances of from 5 to 30 m around each sample site were set and habitat types within that buffer identified. Combinations of habitats (habitat associations) within each buffer zone were then examined in relation to the capture of Colorado pikeminnow. The average availability of each combination for sites with and without Colorado pikeminnow capture was determined and the ratios of availability for each category (with and without pikeminnow) computed. When ratios are greater than 1.0, preference is indicated. Significant differences between samples with and without Colorado Pikeminnow were determined using a two-tailed t-test for non-equal variance.

The GPS location data for Colorado pikeminnow first collected in 2007 in the non-native removal program provided the first opportunity to examine capture location on a resolution less than 1 mile for any electrofishing data. While the accuracy of the GPS data and the nature of electrofishing do not allow specific habitat use data, it is possible to refine the analysis to 0.1 mile segments. An analysis similar to that described above for the detailed reach fish sampling locations was performed to examine the potential relationship between habitat richness (number of habitats per tenth of river mile) and capture of Colorado pikeminnow by electrofishing during the non-native removal program. GPS locations and dates of pikeminnow captures were obtained from the non-native removal program (Davis, Pers. Com. 2008). The locations were tabulated to the nearest 1/10 mile. Habitat richness for each 1/10 mile from the 2006 river-wide habitat survey (latest survey for which data were available) was computed by using a 220 m buffer around each 1/10 river mile mark in the SJRIP GIS. This buffer allows for possible GPS location error and fish movement that might be outside the 1/10 mile range. The habitat richness of the 1/10 river mile segments for which Colorado pikeminnow were captured was compared to those for which there were no captures using a two-tailed student t-test for non-equal variance to test the hypothesis that the mean habitat richness for the two cases are different. The presence/absence of individual habitats in each 0.1 mile reach for the two cases was also compared by the same method. The analysis range was limited to RM 94.8 to RM 138 as this range had the same sampling dates and frequency.

RESULTS

Habitat Availability

A total of 180,420 m^2 of habitat were mapped within the complex study reaches (DR 82 and DR 137). While mid-channel runs accounted for 59 percent of the total area mapped, riffles, run/riffles, slackwaters, and shore runs accounted for 8.7, 7.5, 6.7, and 6.5 percent of the total mapped area, respectively. Sixteen other habitat types accounted for the remaining 11.6 percent of the mapped area (Table 4.2).

Table 4.2. Summary of habitats mapped and sampled in the San Juan River during August of 2007: DR 82 and DR 137 (combined)

Habitat description	Mapped		Sampled			Pikeminnow
	Area (m2)	%	Frequency	Area* (m2)	% of area mapped	n
Mid-channel Run	106,238	59	1	140	0.1	0
Riffle	15,698	8.7	12	1,690	11	0
Run/riffle	13,456	7.5	0	ns		ns
Slackwater	12,006	6.7	93	11,350	95	8
Shore Run	1,1804	6.5	27	3,696	31	2
Cobble shoal	8,917	4.9	21	3,275	37	8
Sand shoal	5,304	2.9	17	1,936	36	3
Sand shoal/run	1,870	1.04	0	ns		ns
Overhanging vegetation	1,504	0.83	0	ns		ns
Pool	729	0.40	9	441	60	0
Shoal/riffle	652	0.36	0	ns		ns
Backwater	476	0.26	3	118	25	0
Eddy	370	0.20	7	681	184	3
Cobble shoal/run	229	0.13	0	ns		ns
Shore riffle	227	0.13	0	ns		ns
Pocket water	227	0.13	0	ns		ns
Embayment	219	0.12	0	ns		ns
Chute	208	0.12	0	ns		ns
Isolated pool	158	0.09	1	6	4	0
Riffle/chute	92	0.05	0	ns		ns
Riffle/plunge	36	0.02	3	139	383	0
Total	**180,420**	**100**	**194**	**23,471**	**13**	**24**

* Includes the entire area sampled (not corrected for actual habitat size)

The total number of habitat types identified through mapping was 21. Eleven of these habitats were sampled[5]. Habitats not sampled were typically too swift, too deep, or presented debris that precluded effective seining. The total number of habitat units sampled in both complex reaches was 194. These habitat units represented approximately 23,471 m^2 or 13 percent of the total area mapped. The habitat type sampled most frequently was slackwater with 93 seine hauls, followed by shore runs, cobble shoals, sand shoals, and riffles with 27, 21, 17, and 12 seine hauls, respectively (Table 4.2). However, in terms of sampled proportion of the mapped area, the area sampled in riffle/plunge represented 383 percent and eddies represented 184 percent of these mapped habitat types. Percentages greater than 100 are the result of replicate sampling within these rare habitats types and/or due to the total actual area sampled (i.e., seine haul area) being larger than the mapped area. A substantial area of mapped slackwaters (95 percent) and pools (60 percent) were also sampled. Lower proportions of mapped areas were

[5] Since mid-channel runs were grossly under-represented relative to their abundance (1 sample) this category is not used in the analysis, reducing the total to 10 (Table 4.5).

sampled in cobble shoals (37 percent), sand shoals (36 percent), shore runs (31 percent), riffles (11 percent), isolated pools (4 percent), and mid-channel runs (0.1 percent; Table 4.2).

Looking at the two complex study reaches independently, the total area of habitat mapped was 77,705 m^2 at DR 137 and 102,715 m^2 at DR 82. Along both complex study reaches, the dominant habitat type was mid-channel run. Of the total mapped area along DR 137 and DR 82, mid-channel runs represented 63 percent and 56 percent, respectively (Table 4.3 and Table 4.4). In DR 137, riffles (9.1 percent), shore runs (7 percent), run/riffles (6.5 percent), slackwaters (5.2 percent), cobble shoals (2.9 percent), sand shoals (2.6 percent), and overhanging vegetation (1.5 percent) accounted for approximately 35 percent of the total area mapped. Each of the remaining 11 habitat types in DR 137 represented less than one percent of the area mapped (Table 4.3).

The total area sampled in DR 137 was 11,808 m^2 (or 15.2 percent of the mapped area). A total of 88 seine hauls were pulled along habitats in this reach. Habitats sampled along DR 137 included slackwaters (44 seine hauls), shore runs (12 seine hauls), cobble shoals (9 seine hauls), sand shoals (7 seine hauls), riffles (7 seine hauls), eddies (6 seine hauls), riffle/plunge (2 seine hauls), and mid-channel runs (1 seine haul; Table 4.3). In relation to the total area mapped by habitat type, the habitat types sampled more extensively were riffle/plunge (347 percent), eddies (229 percent), and slackwaters (143 percent). The area sampled on cobble shoals, sand shoals, shore runs, riffles, and mid-channel runs represented 65, 48, 28, 16, and 0.3 percent of their corresponding mapped areas (Table 4.3).

In DR 82, a total of 102,715 m^2 of habitat were mapped. As noted above, mid-channel run was also the dominant habitat type along this reach (Table 4.4). Approximately 42 percent of the total habitat mapped was comprised by riffles (8.4 percent), run/riffles (8.2 percent), slackwaters (7.8 percent), cobble/shoal (6.5 percent), shore runs (6.2 percent), sand shoals (3.2 percent), and sand shoal/runs (1.3 percent). The remaining 2.4 percent of the total area mapped comprised 11 other habitat types.

Approximately 11 percent (11,663 m^2) of the total area mapped in DR 82 was sampled. A total of 106 seine hauls were pulled along habitats in this reach. The habitats sampled more frequently were slackwaters (49 seine hauls), shore runs (15 seine hauls), cobble shoals (12 seine hauls), and pools (9 seine hauls). Other habitat types sampled included riffle (5 seine hauls), backwater (3 seine hauls), eddy (1 seine haul), isolated pool (1 seine haul), and riffle/plunge (1 seine haul; Table 4.4). In relation to mapped areas by habitat type, the habitats sampled more extensively in DR 82 were slackwaters (70 percent), eddies (66 percent), and pools (60 percent). Backwaters (39 percent), shore runs (34 percent), sand shoals (30 percent), cobble shoals (27 percent), riffles and isolated pools (6 percent each) were sampled in relatively smaller proportions of their respective mapped area (Table 4.4).

Habitat Utilization

Sampling in DR 137 produced 19 age-1 Colorado pikeminnow, 11 in the first pass and 8 in the second pass. Sampling at DR 82 produced only 5 total pikeminnow, 2 in the first pass and 3 in the second pass. Fish ranged in size from 110 to 269 mm total length. Given that only three of the fish captured had total lengths greater than 180 mm (Figure 4.1) and are likely age-2 or older, these were considered age-1 pikeminnow for the purpose of habitat selection analyses. As noted above, age-1 pikeminnow (fish that had been stocked in the river the previous autumn) were the primary focus of the detailed reach fish survey of 2007.

Table 4.3. Summary of habitats mapped and sampled in the San Juan River during August of 2007: DR 137

Habitat description	Mapped		Sampled			Pikeminnow
	Area (m2)	%	Frequency	Area (m2)	%	n
Mid-channel Run	48,762	63	1	140	0.3	0
Riffle	7,110	9.1	7	1,171	16	0
Shore Run	5,418	7.0	12	1,534	28	1
Run/riffle	5,071	6.5	0	ns		ns
Slackwater	4,039	5.2	44	5,762	143	6
Cobble shoal	2,279	2.9	9	1,491	65	6
Sand shoal	2,035	2.6	7	971	48	3
Overhanging vegetation	1,175	1.5	0	ns		ns
Sand shoal/run	535	0.69	0	ns		ns
Eddy	267	0.34	6	613	229	3
Chute	208	0.27	0	ns		ns
Backwater	174	0.22	0	ns		ns
Embayment	159	0.20	0	ns		ns
Shore riffle	155	0.20	0	ns		ns
Shoal/riffle	97	0.12	0	ns		ns
Cobble shoal/run	78	0.10	0	ns		ns
Isolated pool	63	0.08	0	ns		ns
Riffle/chute	42	0.05	0	ns		ns
Riffle/plunge	36	0.05	2	126	347	0
Pool	0	0.00	0	ns		ns
Pocket water	0	0.00	0	ns		ns
Total	**77,705**	**100**	**88**	**11,808**	**15.2**	**19**

* Includes the entire area sampled (not corrected for actual habitat size)

Table 4.4. Summary of habitats mapped and sampled in the San Juan River during August of 2007: DR 82

Habitat description	Mapped		Sampled			Pikeminnow
	Area (m2)	%	Frequency	Area* (m2)	%	n
Mid-channel Run	57,476	56	0	ns		ns
Riffle	8,588	8.4	5	519	6	0
Run/riffle	8,385	8.2	0	ns		ns
Slackwater	7,967	7.8	49	5,588	70	2
Cobble shoal	6,638	6.5	12	1,784	27	2
Shore Run	6,386	6.2	15	2,162	34	1
Sand shoal	3,269	3.2	10	965	30	0
Sand shoal/run	1,334	1.3	0	ns		ns
Pool	729	0.71	9	441	60	0
Shoal/riffle	555	0.54	0	ns		ns
Overhanging vegetation	329	0.32	0	ns		ns
Backwater	302	0.29	3	118	39	0
Pocket water	227	0.22	0	ns		ns
Cobble shoal/run	150	0.15	0	ns		ns
Eddy	103	0.10	1	68	66	0
Isolated pool	95	0.09	1	6	6	0
Shore riffle	73	0.07	0	ns		ns
Embayment	60	0.06	0	ns		ns
Riffle/chute	50	0.05	0	ns		ns
Riffle/plunge		0.00	1	13		0
Chute		0.00	0	ns		ns
Total	**102,715**	**100**	**106**	**11,663**	**11.35**	**5**

* Includes the entire area sampled (not corrected for actual habitat size)

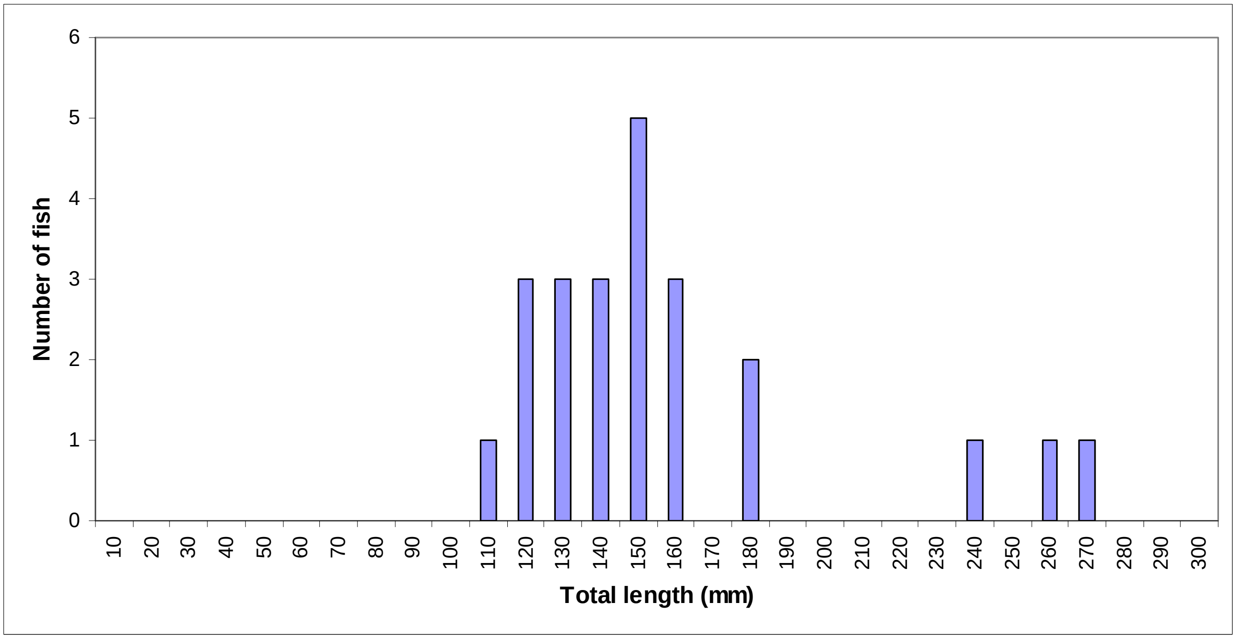

Figure 4.1. Length-frequency distribution of age-1 Colorado pikeminnow captured within DR 137 and DR 82 during detailed fish surveys conducted in the summer of 2007

In addition, the three common native species (bluehead sucker, flannelmouth sucker, and speckled dace) were also caught in both reaches. A total of 202 fish were captured in DR 137, of which 129 were native species. Total fish captured in DR 82 was 900, with 185 being native species. No razorback suckers were captured.

As noted above, analyses of habitat selection for DR 82 were not conducted because of the small number of Colorado pikeminnow captured in this reach (5 pikeminnow). While there are adequate numbers of captures in DR 137 and DR 137 and 82 combined to complete the analysis, the numbers are lower (about ½) than typically recommended for full confidence in the test results. Until additional fish are captured or multiple samplings confirm the results, the findings are statistically weak and should be considered preliminary for Colorado pikeminnow.

Habitat Selection Analysis

DR 137 and DR 82 (combined)

Overall, when combining habitat availability and use for DR 137 and DR 82, tests of "no selection" for age-1 Colorado pikeminnow indicated that habitat selection does occur in these reaches (Table 4.5). For Colorado pikeminnow, significant (χ^2_p= 19.1; *p*=0.02) to marginally significant (χ^2_l= 16.5; *p*=0.056) chi-square tests suggested that this species selects particular habitat types. Significant habitat selection ratios for pikeminnow were limited to two habitat types, cobble shoal (w= 2.39; *p*=0.006) and eddy (w=4.31; *p*=0.005; Table 4.5). There was no significant selection against any habitats.

Table 4.5. Summary of habitat selection ratios and test of no selection for Colorado pikeminnow, all fish assemblage, all native and all non-native fish in DR 82 and DR 137 (combined)

Habitat	Available*	Age-1 Pikeminnow			All fish assemblage			All Native fish			All Non-Natives		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Backwater	0.0050	0	0.00	0.728	83	14.99[a]	0.000	0	0.00	0.208	83	20.96[a]	0.000
Cobble shoal	0.1397	8	2.39[a]	0.006	60	0.39[b]	0.000	31	0.71[b]	0.036	29	0.26[b]	0.000
Eddy	0.0290	3	4.31[a]	0.005	26	0.81	0.283	13	1.43	0.192	13	0.57[b]	0.036
Isolated pool	0.0003	0	0.00	0.938	26	94.28[a]	0.000	3	38.18[a]	0.000	23	116.64[a]	0.000
Run	0.1636	2	0.51	0.288	72	0.40[b]	0.000	22	0.43[b]	0.000	50	0.39[b]	0.000
Pool	0.0178	0	0.00	0.509	151	7.69[a]	0.000	32	5.72[a]	0.000	119	8.48[a]	0.000
Riffle	0.0721	0	0.00	0.172	23	0.29[b]	0.000	20	0.88[b]	0.566	3	0.05[b]	0.000
Riffle plunge	0.0059	0	0.00	0.706	11	1.69	0.077	5	2.70[a]	0.021	6	1.29	0.531
Sand shoal	0.0826	3	1.51	0.450	141	1.55[c]	0.000	28	1.08	0.670	113	1.74[a]	0.000
Slackwater	0.4840	8	0.69	0.140	509	0.95	0.141	160	1.05	0.366	349	0.91[c]	0.021
Total	**1.0000**	**24**			**1102**			**314**			**788**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	19.10	16.555	4,557.40	1,076.297	263.27	109.605	5,201.00	1,094.095
p-value	0.02	0.056	0.000	0.000	0.000	0.000	0.000	0.000

***** Significant chi-square values indicate selection; non-significant values indicate no selection

Based on the combined reach data, a strong habitat selection was evident for the entire fish assemblage (χ^2_p= 4557.4, *p*=0.000; χ^2_l= 1076.3; *p*=0.000), the native fish assemblage (χ^2_p= 263.3, *p*=0.000; χ^2_l= 109.6; *p*=0.000), and the non-native fish assemblage (χ^2_p= 5201, *p*=0.000; χ^2_l= 1094.1; *p*=0.000; Table 4.5). For the entire fish assemblage, significant (*p*<0.05) habitat selection occurred for backwaters (w= 14.9), isolated pools (w= 94.3), pools (w= 7.69), and sand shoals (w= 1.55). Significant selection against cobble shoals (w= 0.39), runs (w= 0.4), and riffles (w= 0.29) was evident.

For the native fish assemblage, habitat selection was significant (*p*<0.05) for isolated pool (w=38.18), pool (w=5.72), and riffle plunge habitats (w=2.70; Table 4.5). Selection against cobble shoal (w= 0.71) and run habitats (w=0.43) was significant. On the other hand, all but two of the estimated selection ratios for non-native fish were significant (*p*<0.05). Significant ratios for selection by the non-native fish assemblage included backwaters (w=21), isolated pool (w=116.6), pool (w=8.48), and sand shoal (w=1.74). The nonnative fish assemblage selected against cobble shoal (w=0.26), eddy (w=0.57), run (w=0.39), riffle (w=0.05), and slackwater (w=0.91) habitats.

While significant selection for particular habitats was shown for speckled dace (χ^2_p= 159.1, *p*=0.00; χ^2_l= 102.9; *p*=0.000) and flannelmouth sucker (χ^2_p= 367.8, *p*=0.00; χ^2_l= 68.8; *p*=0.000) indicated that these native species select particular habitats, no selection was evident for bluehead sucker (χ^2_p= 4.29, *p*=0.89; χ^2_l= 3.86; *p*=0.92; Table 4.6). Significant habitat selection (*p*<0.05) occurred for speckled dace in eddy (w=1.95), pool (w=7.06), and riffle plunge (w=5.32) habitats. No selection by speckled dace occurred for or against slackwater (w=1.17). Significant selection against cobble shoal (w=0.14), run (w=0.46), and sand shoal (w=0.38) habitats was evident for speckled dace. For flannelmouth sucker, significant selection (*p*<0.001) was evident for isolated pool (w=104), pool (w=5.37), and sand shoal (w=1.9; Table 4.6). Run (w=0.37) habitat had significant selection against.

Significant selection for particular habitats was evident for fathead minnow (χ^2_p= 16,070, *p*=0.00; χ^2_l= 996.1; *p*=0.000), red shiner (χ^2_p= 1358.7, *p*=0.00; χ^2_l= 323.6; *p*=0.000), and channel catfish (χ^2_p= 259, *p*=0.00; χ^2_l= 238; *p*=0.000). For fathead minnows, ratios calculated for all habitat types were significant (*p*<0.05) with the exception of riffle-plunge (w= 0; *p*=0.38; Table 4.7). Significant ratios indicating selection for backwater (w=117), isolated pool (w=465), and pool (w=11.8) habitats. Fathead minnows selected against cobble shoal (w=0.06), eddy (w=0), run (w=0), riffle (w=0), sand shoal (w=0.09), and slackwater (w=0.14) habitats (Table 4.7).

For red shiner, significant ratios (*p*<0.001) indicated selection for backwater (w=6.32), isolated pool (w= 95), and pool (w=22.3) habitats. Ratios estimated for this species indicated selection against riffle (w=0.0), cobble shoal (w=0.11), and run (w=0.05) habitats.

Lastly, habitat selection ratios for channel catfish were significant (*p*<0.05) for isolated pool (w=7.58), pool (w=4.47), and sand shoal (w= 2.3) habitats. While cobble shoal (w=0.35), run (w=0.57), and riffle (w=0.08) habitats were selected against by this species, no selection was evident for slackwater habitat (w=1.12; Table 4.7).

Table 4.6. Summary of habitat selection ratios and test of no selection for age-1 Colorado pikeminnow compared to other native fish in DR 82 and DR 137 (combined)

Habitat	Available*	Age-1 Pikeminnow			Speckled dace			Bluehead sucker			Flannelmouth		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Backwater	0.0050	0	0.00	0.728	0	0.00	0.370	0	0.00	0.776	0	0.00	0.446
Cobble shoal	0.1397	8	2.39[a]	0.006	3	0.14[b]	0.000	3	1.34	0.581	17	1.06	0.801
Eddy	0.0290	3	4.31[a]	0.005	9	1.95[a]	0.038	1	2.15	0.425	0	0.00	0.064
Isolated pool	0.0003	0	0.00	0.938	0	0.00	0.842	0	0.00	0.950	3	104.25[a]	0.000
Run	0.1636	2	0.51	0.288	12	0.46[b]	0.003	1	0.38	0.274	7	0.37[b]	0.003
Pool	0.0178	0	0.00	0.509	20	7.06[a]	0.000	1	3.51	0.177	11	5.37[a]	0.000
Riffle	0.0721	0	0.00	0.172	15	1.31	0.278	1	0.87	0.882	4	0.48	0.122
Riffle plunge	0.0059	0	0.00	0.706	5	5.32[a]	0.000	0	0.00	0.758	0	0.00	0.408
Sand shoal	0.0826	3	1.51	0.450	5	0.38[b]	0.019	2	1.51	0.537	18	1.90[c]	0.004
Slackwater	0.4840	8	0.69	0.140	90	1.17[c]	0.039	7	0.90	0.709	55	0.99	0.901
Totals:	**1.0000**	**24**			**159**			**16**			**115**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	19.10	16.555	159.09	102.94	4.29	3.858	367.79	68.828
p-value	0.02	0.056	0.00	0.000	0.89	0.921	0.00	0.000

***** Significant chi-square values indicate selection; non-significant values indicate no selection

Table 4.7. Summary of habitat selection ratios and test of no selection for Colorado pikeminnow compared to non-native fish in DR 82 and DR 137 (combined)

Habitat	Available*	Age-1 Pikeminnow			Fathead minnow			Red shiner			Channel catfish		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Backwater	0.0050	0	0.00	0.728	76	117.24 [a]	0.000	4	6.32 [a]	0.000	3	1.13	0.828
Cobble shoal	0.1397	8	2.39[a]	0.006	1	0.06 [b]	0.000	2	0.11 [b]	0.000	26	0.35 [b]	0.000
Eddy	0.0290	3	4.31[a]	0.005	0	0.00 [b]	0.050	1	0.27	0.158	11	0.72	0.265
Isolated pool	0.0003	0	0.00	0.938	15	464.66 [a]	0.000	3	95.14 [a]	0.000	1	7.58 [a]	0.017
Run	0.1636	2	0.51	0.288	0	0.00 [b]	0.000	1	0.05 [b]	0.000	49	0.57 [b]	0.000
Pool	0.0178	0	0.00	0.509	27	11.75 [a]	0.000	50	22.27 [a]	0.000	42	4.47 [a]	0.000
Riffle	0.0721	0	0.00	0.172	0	0.00 [b]	0.002	0	0.00 [b]	0.002	3	0.08 [b]	0.000
Riffle plunge	0.0059	0	0.00	0.706	0	0.00	0.381	0	0.00	0.387	6	1.93	0.101
Sand shoal	0.0826	3	1.51	0.450	1	0.09 [b]	0.002	12	1.15	0.605	100	2.30 [a]	0.000
Slackwater	0.4840	8	0.69	0.140	9	0.14 [b]	0.000	53	0.87	0.154	286	1.12[c]	0.007
Totals:	**1.0000**	**24**			**129**			**126**			**527**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	19.10	16.555	16,070.14	996.074	1,358.74	323.630	279.10	238.428
p-value	0.02	0.056	0.00	0.000	0.00	0.000	0.00	0.000

***** Significant chi-square values indicate selection; non-significant values indicate no selection

DR 137

Tests of "no selection" based on habitat use and availability data from DR 137, indicated that habitat selection by age-1 Colorado pikeminnow occurred in this reach. Both Pearson and Log-likelihood Chi-square tests were significant for age-1 pikeminnow (χ^2_p= 14.77, *p*=0.02; χ^2_l= 14.1, *p*=0.028; Table 4.8). For age-1 Colorado pikeminnow in DR 137, significant ratios (*p*<0.05) indicated selection for eddy (w=3.01) and cobble shoal habitat (w=2.47). There is no evidence of selection for, against, or no-selection for any of the other habitat types sampled (Table 4.8).

Consistent with results based on combined data from DR 137 and DR 82, "no selection" tests for the entire fish assemblage (χ^2_p= 51.5, *p*=0.00; χ^2_l= 54, *p*=0.000), the native fish assemblage (χ^2_p= 21.34, *p*=0.00; χ^2_l= 22.46, *p*=0.001), and the non-native fish assemblage (χ^2_p= 35.75, *p*=0.00; χ^2_l= 41, *p*=0.000), provided evidence of habitat selection. For the entire fish assemblage, only eddy habitat (w=2.26) was selected for. Cobble shoal (w=0.46), run (w=0.56), and riffle (w=0.25) habitats were selected against and no selection was evident for slackwater (w=1.31).

Based on all native fish captured in DR 137, the only ratio showing selection for a particular habitat type was the estimated for eddy (w=1.92). For the native fish assemblage, significant ratios indicated selection against cobble shoal (w=0.55) and riffle (w=0.39), and no-selection for slackwater habitat (w=1.26; Table 4.8). A similar selection pattern was noted for the non-native fish assemblage; while significant selection ratios for this assemblage indicated selection for eddy (w=2.87), ratios showed selection against cobble shoal (w=0.32) and riffle (w=0.0) habitats, and no-selection was for slackwater (w=1.41).

Of the tests of "no selection" run for other native species, only that for speckled dace provided evidence of habitat selection (χ^2_p= 26.3, *p*=0.00; χ^2_l= 28.3, *p*=0.000; Table 4.9). Significant selection ratios (*p*<0.05) for this species indicated selection for eddy (w=2.14), selection against cobble shoal (w=0.269), and no-selection for slackwater (w=1.39) habitats. Tests of "no selection" for bluehead sucker and flannelmouth sucker were not significant (Table 4.9).

No evidence of selection, based on DR 137 data, were found for fathead minnow (χ^2_p= 3.08, *p*=0.80; χ^2_l= 4.2, *p*=0.6) and red shiner (χ^2_p= 3, *p*=0.81; χ^2_l= 4.7, *p*=0.58; Table 4.10). Tests of "no selection" for channel catfish indicated that this species does select particular habitat types (χ^2_p= 33.9, *p*=0.00; χ^2_l= 38.2, *p*=0.000). Significant habitat selection ratios (*p*<0.05) were calculated for 4 of the 7 habitat types sampled in this reach. Selection for eddy (w=3.23) habitat, and selection against cobble shoal (w=0.15) and riffle (w=0.0) were evident. The ratio estimated for slackwater (w=1.45) indicated no-selection by channel catfish (Table 4.10).

Other SJRIP Studies

Other SJRIP studies were reviewed for use in determining habitat selection. The general criteria were that fish sampling locations and habitats needed to be known and most or all habitats were represented in the sampling. The larval fish studies collected 54 age-1 pikeminnow primarily in April, May, and June and primarily from backwaters and other low velocity habitats. Three pikeminnow over 100 mm were collected, one each in a backwater, embayment, and pool habitat. This study primarily samples only low velocity habitats looking for larval fish so not all habitats were sampled. Therefore, these data could not be used for habitat selection but will be discussed later. Similarly, given that electrofishing techniques are used for

Table 4.8. Summary of habitat selection ratios and test of no selection for Colorado pikeminnow, all fish assemblage, all native and all non-native fish in Detailed Reach 137 (DR 137)

Habitat	Available*	Age-1 Pikeminnow			All fish assemblage			All Native fish			All Non-Natives		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Eddy	0.0525	3	3.01[a]	0.040	24	2.26[a]	0.000	13	1.92[a]	0.014	11	2.87[a]	0.000
Sand shoal	0.0832	3	1.90	0.239	13	0.77	0.332	10	0.93	0.815	3	0.49	0.193
Cobble shoal	0.1278	6	2.47[a]	0.014	12	0.46[b]	0.004	9	0.55[b]	0.048	3	0.32[b]	0.026
Run	0.1315	1	0.40	0.309	15	0.56[b]	0.016	10	0.59	0.070	5	0.52	0.111
Riffle/plunge	0.0108	0	0.00	0.649	2	0.92	0.906	2	1.44	0.602	0	0.00	0.373
Riffle	0.1004	0	0.00	0.145	5	0.25[b]	0.000	5	0.39[b]	0.020	0	0.00[b]	0.004
Slackwater	0.4938	6	0.64	0.121	131	1.31[c]	0.000	80	1.26[c]	0.004	51	1.41[c]	0.000
Totals:	**1.0000**	**19**			**202**			**129**			**73**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	14.77	14.113	51.48	54.035	21.34	22.459	35.75	41.015
p-value	0.02	0.028	0.00	0.000	0.00	0.001	0.00	0.000

***** Significant chi-square values indicate selection; non-significant values indicate no selection

Table 4.9. Summary of habitat selection ratios and test of no selection for age-1 Colorado pikeminnow and other native fish in Detailed Reach 137 (DR 137)

Habitat	Available*	Age-1 Pikeminnow			Speckled dace			Bluehead sucker			Flannelmouth		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Eddy	0.0525	3	3.01[a]	0.040	9	2.14[a]	0.016	1	2.38	0.358	0	0.00[b]	0.269
Sand shoal	0.0832	3	1.90	0.239	2	0.30	0.059	1	1.50	0.669	4	2.18	0.094
Cobble shoal	0.1278	6	2.47[a]	0.014	3	0.29[b]	0.016	0	0.00	0.279	0	0.00	0.073
Run	0.1315	1	0.40	0.309	5	0.48	0.068	1	0.95	0.957	3	1.04	0.946
Riffle/plunge	0.0108	0	0.00	0.649	2	2.32	0.217	0	0.00	0.768	0	0.00	0.625
Riffle	0.1004	0	0.00	0.145	4	0.50	0.134	0	0.00	0.345	1	0.45	0.391
Slackwater	0.4938	6	0.64	0.121	55	1.39[c]	0.001	5	1.27	0.458	14	1.29	0.181
Totals:	**1.0000**	**19**			**80**			**8**			**22**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	14.77	14.113	26.34	28.309	3.16	4.810	8.34	11.995
p-value	0.02	0.028	0.00	0.000	0.79	0.568	0.21	0.062

***** Significant chi-square values indicate selection; non-significant values indicate no selection

Table 4.10. Summary of habitat selection ratios and test of no selection for age-1 Colorado pikeminnow and non-native fish in Detailed Reach 137 (DR 137)

Habitat	Available*	Age-1 Pikeminnow			Fathead minnow			Red shiner			Channel catfish		
		Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value	Use	Ratio (w)	p-value
Eddy	0.0525	3	3.01 [a]	0.040	0	0.00	0.683	1	1.27	0.806	9	3.23[a]	0.000
Sand shoal	0.0832	3	1.90	0.239	0	0.00	0.602	2	1.60	0.482	1	0.23	0.090
Cobble shoal	0.1278	6	2.47 [a]	0.014	0	0.00	0.507	2	1.04	0.949	1	0.15[b]	0.018
Run	0.1315	1	0.40	0.309	0	0.00	0.500	1	0.51	0.458	4	0.57	0.228
Riffle/plunge	0.0108	0	0.00	0.649	0	0.00	0.857	0	0.00	0.686	0	0.00	0.448
Riffle	0.1004	0	0.00	0.145	0	0.00	0.563	0	0.00	0.196	0	0.00[b]	0.015
Slackwater	0.4938	6	0.64	0.121	3	2.03	0.080	9	1.22	0.411	38	1.45[c]	0.001
Totals:	**1.0000**	**19**			**3**			**15**			**53**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection*	Age-1 Pikeminnow		All fish assemblage		All Native Fish		All Non-Natives	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	14.77	14.113	3.08	4.235	3.00	4.688	33.93	38.229
p-value	0.02	0.028	0.80	0.645	0.81	0.584	0.00	0.000

***** Significant chi-square values indicate selection; non-significant values indicate no selection

the capture of the rare fish during non-native removal and adult monitoring studies, the exact location and specific type of habitat are not known. Data from these studies did not meet the general criteria and could not be used for habitat selection analyses. However, since the non-native removal study collected GPS locations when Colorado pikeminnow were netted, habitat association in the localized area of capture was analyzed and will be discussed in a later section.

On the other hand, the small-bodied monitoring program conducted by New Mexico Game and Fish Department met the general criteria for habitat selection analysis. Overall, 12,126 m^2 encompassing 14 habitat types were sampled during the 2007 small-bodied monitoring program. Runs and shoals were the habitat types sampled more frequently during these efforts, accounting for 204 and 94 of the total 545 habitat units sampled, respectively. Runs represented 42 percent of the total area sampled. Shoals represented 22 percent of the area (Table 4.11). Riffles (8.4 percent), backwaters (7 percent), eddies (6 percent), riffle-run (5.3 percent), riffle-eddy (4.3 percent), and pool-run (2 percent) represented approximately 33 percent of the total area sampled. The remaining proportion of area sampled (approximately 3 percent) encompassed 6 other habitat types (Table 4.11).

A total of 31 age-1 pikeminnow with total length greater than 100 mm (TL>100mm) were captured during the small bodied sampling efforts in 2007. Tests of “no selection” based on small-bodied monitoring data (habitat availability and use data shown in Table 4.11) indicated that habitat selection by pikeminnow is likely. The Pearson Chi-squared test was significant (χ^2_p= 37, p=0.00) and the Log-likelihood Chi-squared test was marginally significant (χ^2_p= 22.1, p=0.057; Table 4.12). Colorado pikeminnow showed selection for riffle-eddy (w=3), pool (w=6.7), and debris pile (w=17.4).

Table 4.11. Summary of habitats sampled during the 2007 small-bodied monitoring program (Data supplied by New Mexico Game and Fish)

Habitat	Area	Frequency	%	Age-1 Pikeminnow >100mm	Age-0 Pikeminnow <100mm
Run	5,128	204	42	15	1
Shoal	2,670	94	22	3	1
Riffle	1,013	74	8.4	0	1
Back water	847	43	7.0	3	23
Eddy	727	38	6.0	1	0
Riffle-run	638	24	5.3	1	0
Riffle-eddy	521	24	4.3	4	0
Pool-run	241	15	2.0	1	0
Pool	117	14	0.96	2	0
Eddy-pool	82	5	0.68	0	0
Slackwater	61	3	0.50	0	1
Isolated pool	38	3	0.31	0	0
Debris pile	23	3	0.19	1	0
Overhang vegetation	22	1	0.18	0	1
Total	**12,126**	**545**	**100**	**31**	**28**

Table 4.12. Summary of habitat selection ratios and test of no selection for age-1 Colorado pikeminnow captured during small-bodied and detailed reach fish sampling

Habitat	Small bodied monitoring				Detailed reach fish survey**			
	Available*	Use	Ratio (w)	p-value	Available*	Use	Ratio (w)	p-value
Run	0.4228	15	1.14	0.492	0.1636	2	0.51	0.288
shoal	0.2202	3	0.44	0.097	ns	ns	ns	ns
riffle	0.0835	0	0.00	0.093	0.0721	0	0.00	0.172
back water	0.0698	3	1.39	0.556	0.0050	0	0.00	0.728
eddy	0.0599	1	0.54	0.516	0.0290	3	4.31[a]	0.005
riffle-run	0.0526	1	0.61	0.612	ns	ns	ns	ns
Riffle-eddy	0.0430	4	3.00[a]	0.018	ns	ns	ns	ns
pool-run	0.0198	1	1.63	0.620	ns	ns	ns	ns
pool	0.0096	2	6.70[a]	0.002	0.0178	0	0.00	0.509
eddy-pool	0.0068	0	0.00	0.645	ns	ns	ns	ns
slackwater	0.0050	0	0.00	0.692	0.4840	8	0.69	0.140
Isolated pool	0.0031	0	0.00	0.755	0.0003	0	0.00	0.938
debris pile	0.0019	1	17.04[a]	0.000	ns	ns	ns	ns
overhang vegetation	0.0018	0	0.00	0.812	ns	ns	ns	ns
Cobble shoal	ns	ns	ns	ns	0.1397	8	2.39[a]	0.006
Sand shoal	ns	ns	ns	ns	0.0826	3	1.51	0.450
Riffle plunge	ns	ns	ns	ns	0.0059	0	0.00	0.706
Total	**1**	**31**			**1**	**24**		

* Proportional availability of habitat based on actual area sampled
** Ratios based on combined data from DR 137 and DR 82
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one
[c] No selection: significant selection ratio value close to one

Test of No Selection*	Small bodied monitoring		Detailed reach fish survey	
Test	Pearson	Log-likelihood	Pearson	Log-likelihood
X^2	36.87	21.921	19.097	16.555
p-value	0.00	0.057	0.024	0.056

***** Significant chi-square values indicate selection; non-significant values indicate no selection

Habitat selection was also evident for the 28 age-0 pikeminnow (TL<100mm) captured during small-bodied monitoring efforts (χ^2_p= 270, *p*=0.00; χ^2_l= 113, *p*=0.00; Table 4.13). Significant ratios for age-0 pikeminnow indicated selection for backwater (w=11.7), slackwater (w=7.1) and overhanging vegetation (W=19.7) habitats and selection against run (w=0.084) and shoal (w=0.018) habitat.

Table 4.13. Summary of habitat selection ratios and test of no selection for age-0 Colorado pikeminnow captured during small-bodied monitoring sampling

Habitat	Available	Use	Ratio (w)	p-value
run	0.4228	1	0.084[b]	0.000
shoal	0.2202	1	0.162[b]	0.018
riffle	0.0835	1	0.428	0.361
back water	0.0698	23	11.767[a]	0.000
eddy	0.0599	0	0.000	0.182
riffle-run	0.0526	0	0.000	0.213
Riffle-eddy	0.0430	0	0.000	0.262
pool-run	0.0198	0	0.000	0.451
pool	0.0096	0	0.000	0.602
eddy-pool	0.0068	0	0.000	0.661
slackwater	0.0050	1	7.095[a]	0.022
isolated pool	0.0031	0	0.000	0.767
debris pile	0.0019	0	0.000	0.818
overhang veg	0.0018	1	19.686[a]	0.000
Cobble shoal	ns			
Sand shoal	ns			
Riffle plunge	ns			
Total	**1**	**28**		

* Proportional availability of habitat based on actual area sampled
[a] Selection for: significant selection ratio value greater than one
[b] Selection against: significant selection ratio value lower than one.
[c] No selection: significant selection ratio value close to one.

Test of No Selection* Test	Pearson	Log-likelihood
X^2	270.10	113.015
p-value	0.00	0.000

***Significant chi-square values indicate selection; non-significant values indicate no selection

Capture per Unit of Effort (CPUE)

Overall, a total of 1,102 fish were captured in DR 137 and DR 82. Of this total, 314 were native fish and 788 were non-native (Table 4.14). The overall CPUE for the entire fish assemblage was 0.047 fish/ m^2. For native and non-native fish assemblages, CPUE was 0.0134 fish/ m^2 and 0.0336 fish/ m^2, respectively.

Table 4.14. Summary of captures per unit of effort (CPUE) for the detailed reach fish survey conducted in summer of 2007

Detailed Reach	Area Sampled (m2)	Number of seine hauls	Species	Number of fish captured	CPUE (fish/m2)	CPUE (fish/seine)
137 & 82 combined	23,471	194	Channel catfish	527	0.0225	2.7165
			Speckled dace	159	0.0068	0.8196
			Fathead minnow	129	0.0055	0.6649
			Red shiner	126	0.0054	0.6495
			Flannelmouth sucker	115	0.0049	0.5928
			Age-1 Pikeminnow	**24**	**0.0010**	**0.1237**
			Bluehead sucker	16	0.0007	0.0825
			All native fish	314	0.0134	1.6186
			All non-native fish	788	0.0336	4.0619
			All fish assemblage	1102	0.0470	5.6804
137	11,808	88	Speckled dace	80	0.0068	0.9091
			Channel catfish	53	0.0045	0.6023
			Flannelmouth sucker	22	0.0019	0.2500
			Age-1 Pikeminnow	**19**	**0.0016**	**0.2159**
			Red shiner	15	0.0013	0.1705
			Bluehead sucker	8	0.0007	0.0909
			Fathead minnow	3	0.0003	0.0341
			All native fish	129	0.0109	1.4659
			All non-native fish	73	0.0062	0.8295
			All fish assemblage	202	0.0171	2.2955
82	11,663	106	Channel catfish	474	0.0406	4.4717
			Fathead minnow	126	0.0108	1.1887
			Red shiner	111	0.0095	1.0472
			Flannelmouth sucker	93	0.0080	0.8774
			Speckled dace	79	0.0068	0.7453
			Bluehead sucker	8	0.0007	0.0755
			Age-1 Pikeminnow	**5**	**0.0004**	**0.0472**
			All native fish	185	0.0159	1.7453
			All non-native fish	715	0.0613	6.7453
			All fish assemblage	900	0.0772	8.4906

By and large, of all the fish captured along DR 137 and DR 82, Colorado pikeminnow had the lowest CPUE after bluehead sucker (0.001 fish/ m^2 and 0.0007 fish/ m^2, respectively). However, CPUE for pikeminnow was higher in DR 137 (0.0016 fish/m2) than in DR 82 (0.0004 fish/m^2). CPUE for the native fish assemblage was relatively similar in DR 137 (0.0109) and DR 82 (0.0159). Conversely, CPUE for the non-native fish assemblage was substantially lower in DR 137 (0.00620) than in DR 82 (0.0313; Table 4.14).

Physical Characteristics

Analyses of physical characteristics indicated that mean depth and velocity for samples with and without Colorado pikeminnow were not significantly different (p = 0.93, 0.90, respectively; Table 4.15). However, the maximum velocity for samples containing pikeminnow was 0.6 m/sec, while 11% of all the samples exceeded this value (Figure 4.2). Verification of an upper velocity limit and establishment of depth/velocity preference may be possible as more fish are collected in 2008. Comparisons between small age-0 fish (< 100 mm) and larger age-1 fish will be possible with the inclusion of 2008 data.

Table 4.15. Depth, velocity, and primary substrate at sites where pikeminnow were captured during detailed reach fish surveys

Habitat	Mean depth (M)	Mean velocity (m/s)	Primary substrate	Number of pikeminnow captured
SLACKWATER	0.39	0.46	Coarse gravel	1
SLACKWATER	0.41	0.55	Coarse gravel	2
SLACKWATER	0.22	0.20	Large cobble	1
SHORE RUN	0.29	0.37	Large cobble	1
SHORE RUN	0.39	0.57	Large cobble	2
SAND SHOAL	0.21	0.26	Sand	1
SLACKWATER	0.35	0.11	Sand	1
SAND SHOAL	0.37	0.29	Sand	1
SLACKWATER	0.38	0.10	Sand	1
SLACKWATER	0.48	0.41	Sand	2
EDDY	0.75	0.05	Sand	2
EDDY	0.73	0.50	Silt	1
COBBLE SHOAL	0.23	0.31	Small cobble	1
COBBLE SHOAL	0.28	0.46	Small cobble	1
COBBLE SHOAL	0.30	0.34	Small cobble	1
COBBLE SHOAL	0.34	0.17	Small cobble	3
SLACKWATER	0.46	0.21	Small cobble	2

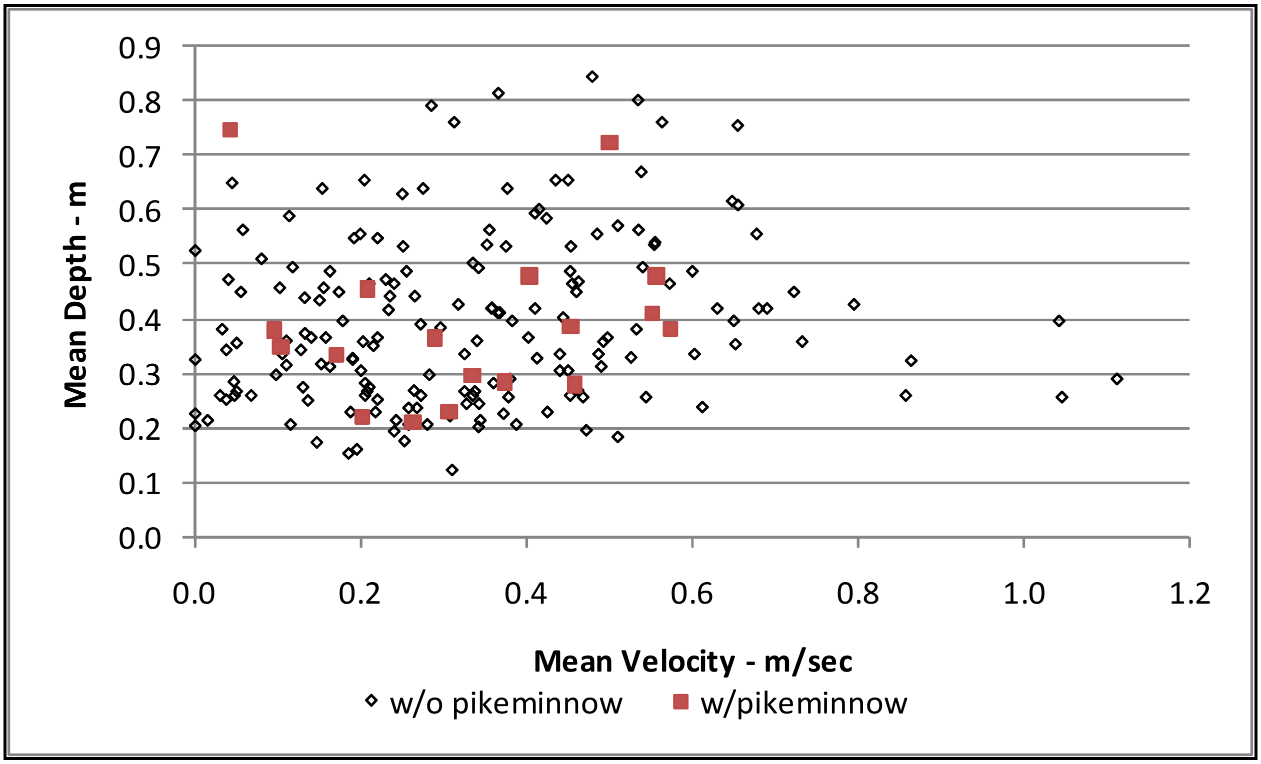

Figure 4.2. Scatter plot of mean velocity and depth for all samples and for those at which pikeminnow were captured

Substrate selection by age-1 Colorado pikeminnow was apparent, with selection for cobble/gravel and against sand/silt (Table 4.16). Fine textured substrate (sand/silt) dominated the sample sites (64%) with cobble/gravel accounting for just 36% of the area sampled. Conversely, 63% of the Colorado pikeminnow captures occurred over cobble/gravel substrates and only 37% over sand/silt.

Habitat Association

Detailed Reach Analysis

Two of the habitats, runs and cobble shoals, appear significant to pikeminnow capture as well as the following three habitat associations: cobble shoal plus slackwater, run plus cobble shoal, and run plus cobble shoal plus slackwater (Table 4.17) Generally, significance decreases with distance from the sample site, but not always. For example, runs are not significant at 5 m, but are at 10 m.

The interpretation of this association analysis is somewhat different than the habitat preference analysis, which showed significant selection for eddies and cobble shoals. Here, the habitats are required only to be in proximity by the distance shown to be included rather than be the habitat sampled. This changes the relationship to Colorado pikeminnow captures and thus the significance. This analysis was directed at finding associations of habitats that may be important in addition to the individual habitats that are indicated as preferential.

Table 4.16. Summary of substrate selection ratios and test of no selection for age-1 Colorado pikeminnow captured during detailed reach sampling

Substrate	Available	Use	Ratio (w)	p-value
Sand/silt	0.64	9	0.586	0.0068
Cobble/gravel	0.36	15	1.736	0.0068
Total	**1.00**	**24**		

Test of No Selection		
Test	**Pearson**	**log-likelihood**
X^2	7.32	6.93
p-value	0.0068	0.0085

Table 4.17. Summary of habitat association analysis for DR 82 and DR 137 (combined)

Radius-m	PTYLUC	Eddy	Run	Slack water	Cobble Shoal	SW+CS	Run +CS	Run+ SW+CS
5	no	6%	65%	58%	**21%**	**9%**	**12%**	*6%*
	yes	17%	72%	61%	**50%**	**33%**	**39%**	*28%*
	ratio yes/no	2.92	1.12	1.05	**2.43**	**3.89**	**3.24**	*4.42*
	p-value	0.25	0.51	0.86	**0.03**	**0.05**	**0.04**	*0.07*
10	no	9%	**74%**	67%	**29%**	*17%*	**18%**	**11%**
	yes	17%	**94%**	78%	**56%**	*39%*	**56%**	**39%**
	ratio yes/no	1.94	**1.27**	1.15	**1.94**	*2.27*	**3.14**	**3.58**
	p-value	0.43	**0.01**	0.55	**0.05**	*0.09*	**0.01**	**0.03**
15	no	11%	87%	74%	39%	41%	*32%*	26%
	yes	22%	94%	83%	61%	56%	*56%*	44%
	ratio yes/no	2.05	1.09	1.12	1.55	1.37	*1.74*	1.73
	p-value	0.27	0.44	0.56	0.11	0.25	*0.08*	0.15
20	no	14%	90%	79%	48%	56%	**41%**	**34%**
	yes	22%	94%	89%	67%	72%	**67%**	**61%**
	ratio yes/no	1.56	1.11	1.12	1.39	1.29	**1.64**	**1.81**
	p-value	0.53	0.20	0.47	0.23	0.17	**0.04**	**0.04**
30	no	25%	94%	86%	10%	83%	60%	53%
	yes	28%	100%	89%	11%	83%	72%	67%
	ratio	1.13	1.06	1.03	1.08	1.00	1.20	1.25
	p-value	0.72	0.38	0.51	0.78	0.99	0.30	0.27

Note: Bolded values indicate significance (p≤0.05) and italics indicates marginal significance (p>0.05 and ≤0.10).

Non-Native Removal Colorado Pikeminnow Habitat Association

Habitat richness is marginally greater (p=0.087) for 0.1 mile reaches with Colorado pikeminnow captures (6.55 habitats per reach) than for reaches with no captures (5.83 habitats per reach). Colorado pikeminnow are more likely to be captured in reaches with low velocity habitats (p=.002), rootwad piles (p=0.003) and sandbars (p=0.01; Table 4.18). Significance is also shown for sand shoal/runs (p=0.04), although the occurrence is so low it is uncertain if this relationship is meaningful. The presence of islands, cobble bars and irrigation returns show marginal significance (p=0.08, 0.10 and 0.08, respectively). The significance of sand and cobble bar presence is likely an indicator of increased channel complexity as they are most often mapped in areas of islands and multiple channels. Irrigation return channel abundance is very low and the absence of this feature is indicated as marginally important (ratio of 0.0, p = 0.08). Given the very low occurrence (three within the study reach) the result may not be meaningful.

DISCUSSION

Overall, despite efforts to sample representative areas of the habitats mapped, the selection of sampling habitats during the detailed reach fish survey was typically not proportional to their occurrence for various reasons. For example, sampling mid-channel run and riffle was very limited due to waters that were too swift or too deep. Samples from some areas were not collected because we were unable to find an effective place to finish the seine haul (i.e., no place to pull up the seine effectively). However, given that the majority of habitats mapped were sampled, it is unlikely that limited sampling in the dominant habitat types (particularly along mid-channel run), biased the results of our habitat selection analyses.

In terms of the proportion of area mapped that was sampled, riffle/plunge and eddy habitats were sampled more extensively along both complex reaches (Table 4.2). The proportion of the area mapped that was sampled in these habitat types, which exceeded 100 percent in both cases, indicates that habitat units of these types were sampled multiple times and/or that the seine hauls encompassed more area than the target habitat.

On the other hand, regardless of covering a relatively larger area, more than 100 percent of the mapped slackwater type was sampled in DR 137 (143 percent; Table 4.3). This contrasts with sampling efforts in DR 82, where, while a substantial area of mapped slackwater (70 percent; Table 4.3) was also sampled, this proportion was considerably lower than that of DR 137. This again points out that not all habitats can be effectively seined. By and large the effort expended in the two detailed reaches sampled all habitats that could be efficiently sampled so differences between the two detailed reaches reflect portions of habitats that could, or could not, be efficiently seined.

Habitat selection ratios calculated with detailed reach fish survey data indicated that age-1 pikeminnow selected two habitat types, eddy and cobble shoal. In contrast, selection against cobble shoal by the entire fish community, both natives and non-natives, was evident (Table 4.5 and 4.8). Among native species, speckled dace was the only species that showed a definite selection against shoals (Table 4.6 and 4.9). Selection ratios for other native species were not significant. Further, among non-native species, selection against shoals was evident when we looked at the combined data for fathead minnow, red shiner, and channel catfish. These results were not entirely consistent with findings from DR 137 which indicated that only channel catfish selected against shoal habitat (Table 4.6 and 4.10). This might be more a result of relatively

Table 4.18. Summary of habitat association analysis for Colorado pikeminnow captures by the non-native removal program, RM 94.8 – RM 138

		Percent Occurrence in 0.1 Mile Sample Reaches		Ratio	
		With	W/O		
Code	Habitat	PTYLUC	PTYLUC	with/without	p-value
1	Backwater	11%	6.8%	1.68	0.08
3	Pool	8.2%	4.0%	2.05	0.06
6	Eddy	2.7%	3.8%	0.72	0.47
10	Run	99%	100%	0.99	0.38
14	Run/riffle	34%	39%	0.87	0.22
15	Riffle	61%	57%	1.06	0.39
17	Shore riffle	0.5%	0.9%	0.58	0.56
18	Riffle/chute	1.1%	0.8%	1.44	0.70
19	Chute	1.6%	1.1%	1.44	0.63
20	Slackwater	54%	50.3%	1.08	0.34
21	Isolated Pool	6.5%	3.0%	2.16	0.08
22	Embayment	5.4%	1.9%	2.88	0.05
24	Overhanging Vegetation	19%	20.2%	0.94	0.72
25	Cobble bar	53%	45.6%	1.16	0.10
26	Rootwad pile	33%	21.0%	1.55	0.003
28	Sand bar	77%	67.9%	1.14	0.01
29	Tributary	0.5%	0.2%	2.88	0.54
30	Shoal/riffle	24%	22.5%	1.09	0.59
31	Island	47%	39.5%	1.18	0.09
32	Rapid	0.0%	0.2%	-	0.32
33	Irrigation return	0.0%	0.6%	-	0.08
34	Inundated vegetation	0.0%	0.2%	-	0.32
35	Pocket water	2.7%	1.3%	2.05	0.28
36	Boulders	4.9%	4.2%	1.18	0.69
38	Irrigation diversion	0.0%	0.2%	-	0.32
40	Diversion structure	0.5%	0.2%	2.88	0.54
8A	Sand shoal	49%	44.4%	1.10	0.30
8B	Cobble shoal	30%	28.4%	1.07	0.60
9A	Sand shoal/run	13%	7.4%	1.77	0.04
9B	Cobble shoal/run	0.5%	0.0%	n/a	0.32
	All shoal types	65%	62%	1.04	0.55
	All riffle types	68%	65.6%	1.04	0.47
	All low velocity types	30%	18.3%	1.63	0.002

few non-native fish being collected at DR 137 rather than actual habitat preferences. Overall, these findings highlight the importance of cobble shoals for age-1 Colorado pikeminnow and that relatively few other fish species prefer that habitat type.

As noted above, analyses with combined data (DR 137 and DR 82) suggest that eddy habitat is selected by age-1 pikeminnow. Ratios estimated with this data for all of the fish assemblages (i.e., all fish, natives, and non-natives) were not significant with the exception of all non-natives, which appeared to select against this habitat type. These results are not consistent with those based on DR 137 data, as selection for eddies were significant for all three assemblages in this reach (Table 4.5 and 4.8). Analyses of the combined data and DR 137 only, indicated that speckled dace was the only species that also appeared to select eddy habitat (Table 4.6 and 4.9). The selection of this slow water habitat type by both age-1 pikeminnow and speckled dace is consistent with results from predator-prey experiments that have indicated a strong preference of Ag-0 pikeminnow for small native prey (Franssen et al. 2007). Selection for or against this habitat was not evident for the other two native species analyzed (i.e., bluehead sucker and flannelmouth sucker). Flannelmouth sucker appeared to select for pools and against runs. Lack of selection by bluehead sucker is likely due to the small sample size (Table 4.6).

The observed pattern of selection for and against particular habitat types by native and non-native fish provided evidence of the high overlap in resource use (Table 4.5). Both groups (native and non-native fishes) appeared to select isolated pool and pool habitat, while selecting against cobble shoal, run, and riffle habitats. Our results support findings from previous studies that have documented overlaps in resources used by native and non-native fishes in the San Juan River. For example, the food web dynamics study of Gido et al. (2006) in the San Juan River confirmed a high degree of overlap in diet composition and suggested that most native and non-native species fed on macro-invertebrates (particularly chironomids) in low-velocity habitats. Gido and Propst (1999) also documented high levels of habitat overlap between native and non-native fishes in secondary channels of the San Juan River, particularly among juvenile and larval fish. These noted patters of habitat selection and overlap highlight the potential for negative interspecies interactions (e.g., competition) between native and non-native fishes.

For non-native species, while fathead minnow also appeared to select against eddy habitat, analyses of DR 137 data suggested that channel catfish selects this habitat type (Table 4.7 and 4.10). Eddy habitat in the complex reaches accounts for only a small fraction of the total habitat available in both complex reaches (i.e., 0.2 percent of the mapped area; Table 4.2). Thus, it is possible that competition for this limited resource may occur between age-1 pikeminnow and small channel catfish. The 2008 detailed reach study will provide additional information on habitat selection overlap.

In addition, our analyses also provided evidence of the overall tendency of all fish assemblages (i.e., all fish, natives, and non natives) to select isolated pool and pool habitats and to select against run and riffle habitat types along complex reaches. Although no age-1 pikeminnow were captured in backwaters, selection for this habitat type was evident for the entire fish assemblage and for non-native fishes. The non-native fish assemblage also selected sand shoal along both complex reaches and showed evidence of no-selection for slackwaters (Table 4.5). These results are likely due to the large number of young channel catfish, fathead minnow and red shiner collected overall, tending to swamp out the pikeminnow preferences due to larger numbers of fish captured.

Both eddies and cobble shoal habitats are types of “edge” habitats, usually with riffles or runs being an adjacent habitat. The edge between these habitats was often the targeted habitat. We are investigating ways to enumerate this feature of complexity but do not have anything definitive at this time.

Habitat selection analyses based on small-bodied monitoring data suggested that age-1 pikeminnow selected riffle-eddy, pool, and debris pile habitats (Table 4.12). The riffle-eddy habitat selection is similar to the eddy selection shown in the detailed reach study. We also collected age-1 pikeminnow in pools but selection was not significant. On the other hand, habitats selected by age-0 pikeminnow included backwater, slackwater, and overhanging vegetation. Selection against runs and shoals by age-0 pikeminnow was also evident (Table 4.13). The larval study captured a number of smaller age-1 pikeminnow in backwaters and other low velocity habitats, typical habitats for these sizes of pikeminnow (Golden et al. 2006), but since not all habitat types were sampled it is difficult to determine if that data support the habitat selection from other studies.

The habitat nomenclature of the small bodied study differs somewhat from the detailed reach study. For example shoals are not broken into sand or cobble, and eddy pool is not in the detailed reach nomenclature. One goal of the detailed reach study is to make all SJRIP habitat studies more consistent so results can be combined. During 2008 we anticipate working to achieve this goal by looking at all the habitat classifications being used and suggesting changes where appropriate.

Overall, results from detailed reach and small-bodied fish studies support findings from previous research that indicate age-1 Colorado pikeminnow typically use habitats with some current, while age-0 fish tend to use slow-water habitat types such as backwaters and slackwaters (Golden et al. 2006, Robertson and Holden 2007). Shifts in habitat use of this nature have also been documented for other species (Gido and Propst, 1999; Mullen and Burton, 1995). For Colorado pikeminnow, differences in habitat use across age classes can be associated to shifts in diet composition. Further, Franssen et al (2007), point out that age-0 Colorado pikeminnow feed mainly on insects and may require shifting to piscivory by age one for optimal growth and survival.

Further, it should be noted that while previous research has identified low water velocity habitat as important for small Colorado pikeminnow, the detailed reach fish survey has allowed the identification of specific habitat types with some current, namely cobble shoals and eddies, that are important for age-1 Colorado pikeminnow. Further sampling in 2008 will likely allow us to assess differences in habitat use by age-0 and age-1 pikeminnow.

Analyses of physical characteristics show that while no preference in combinations of depth and velocity were evident below 0.6 m/sec velocity, samples with mean velocities above 0.6 m/sec did not contain Colorado pikeminnow. As noted above, verification of an upper velocity limit and establishment of depth/velocity preference may be possible as more fish are collected in 2008. Comparisons between small age-0 fish (< 100 mm) and larger age-1 fish will be possible with the inclusion of 2008 data.

Combinations of certain habitats within the proximity of Colorado pikeminnow captures also appear to be important. Occurrences of a combination of cobble shoals with slackwater, runs with cobble shoals, and runs plus cobble shoals plus slackwaters within 5 m of the sampling location were significantly higher for sites where Colorado pikeminnow were captured. These preferences also appear to be consistent with evidence of substrate selection that indicate age-

1 Colorado pikeminnow select coarse (i.e., cobble/gravel) and against fine (i.e., sand/silt) substrates.

GPS data for Colorado pikeminnow capture locations by the non-native removal program allowed examination of habitat association from electrofishing for the first time in this program. The results indicate greater habitat diversity or richness in locations of Colorado pikeminnow capture. Low velocity habitats, bars and to a lesser extent islands, occurred more frequently in these locations. Greater habitat richness and the presence of bars and low velocity habitat are higher in complex channel areas, underscoring the importance of complex channel areas to age 1+ Colorado pikeminnow. The use of areas that encompass very diverse habitats with numerous habitat types present has also been documented for adult Colorado pikeminnow during the suspected spawning period. Miller and Ptacek (2000) noted that areas with high habitat diversity are typically associated with complex bar and island systems that have various habitat types in a relatively small area. These authors also indicated that habitat types present in suspected spawning areas included eddies or pools (used as resting habitat) located in close proximity to fast water velocity habitats (chutes or steep riffles) with loose cobble substrate.

Detailed reach fish survey efforts undertaken in 2008 that include both spring and summer sampling, coupled with results of other sampling programs, will allow us to contrast habitat use between times of the year and between years, and to strengthen our assertions regarding habitat availability and use by young Colorado pikeminnow. As suggested by Gido et al (2006), understanding which habitats are needed by each life stage in this highly modified system has important implications for the management and conservation of this species.

CHAPTER 5: RIVER-WIDE HABITAT MAPPING

BACKGROUND

River-wide habitat mapping began in 1991 as part of the seven-year research study. Results of the habitat mapping and response of habitat to flow became a key part of the flow recommendations formulated in 1999 (Holden 1999). Annual mapping of habitat in reaches 1 through 6 became a part of the standardized monitoring plan in 1999.

OBJECTIVES

The objectives of river-wide habitat mapping are:

1. Annually monitor habitat abundance (count and total area) in the lower six reaches of the San Juan River.
2. Determine the relationship between habitat abundance and flow.

METHODS

Habitat quantity was determined using airborne videography as previously described by Bliesner and Lamarra (2000) and as established as part of the Long Range Monitoring Program. In 2005 the registration process was changed to digitally register and rectify the mapping images to 1997 digital orthophoto quads. Habitat types mapped can be seen in Table 5.1, summarized into seven general categories. After a detailed review of these groupings during the detailed reach mapping, it was determined that run/riffles function more like riffles than runs and should be summarized in that manner. This is a change in reporting for the 2006 habitat data reported here and the change has been made in all previous summaries for comparison.

Trend analysis was completed for the period of record by regressing the backwater habitat area with flow at mapping and then plotting the residuals of this relationship with time after shifting the values to preserve the mean habitat area.

Reported here are the results from 2006 mapping. Mapping is completed in late autumn. After mapping, the photos must be rectified and digitized. Processing time is such that this cannot be completed by the report date deadline so there is a one-year lag in reporting results.

Table 5.1. Seven General Categories of Habitat Types on the San Juan River

Low Velocity Types	Run Types	Riffle Types	Back-Water Types	Shoal Types	Slack-Water Types	Vegetation Associated Habitat Types
				sand		overhanging
pool	shoal/run	riffle	backwater	shoal	slackwater	vegetation
debris pool	run	shore riffle	backwater	cobble	pocket	Inundated
rootwad	scour run	riffle chute	pool	shoal	water	vegetation
pool	shore run	shoal riffle	embayment			
eddy	undercut	rapid				
edge pool	run	chute				

RESULTS

2006 Mapping Summary

In 2006 mapping was completed in November at a higher mean flow than in the previous four years (Table 5.2 for 2002-2006). In 2006, the sequence of dominant to subdominant habitat types based upon the amount of surface area between RM 2 to RM 180 had the same distribution as the four previous years (Figure 5.1). These distributions can be seen in Figure 5.2 and the results in terms of the percent of total wetted area are summarized in Table 5.2. Run habitats continue to dominate with 70.3% of the total wetted area (TWA), a slight increase from 2005. Riffles had the second largest surface area with 19.6% of the total wetted area. The third most plentiful habitat was shoal types with 5.5% of TWA. This is a decrease from 2005, but about the same as earlier years. Slackwaters are the fourth dominant habitat at 3.5%, increasing from 2005, but similar to 2003-2004. Backwaters made up only 0.27% of the surface area of habitats in 2006, showing a small decrease from 2005, which was a high flow year.

The spatial distribution of these same general categories can be seen in Figures 5.2 and 5.3 for 2006. Figure 5.3 truncates the vertical scale to allow better viewing of the subdominant habitat distribution. Backwater habitats were distributed throughout the river but are in moderate amounts in Reaches 1, 2 and 5 (4,100 m^2, 3,900 m^2 and 5,000 m^2, respectively), highest in Reaches 3 and 4 (17,900 m^2 and 13,300 m^2), and lowest in Reach 6 (1,540 m2). Low velocity habitat types had a patchy distribution (Figure 5.3) and were found to be most plentiful in Reach 6 (20,000 m^2), followed by Reaches 5 and 3 (16,900 and 15,700 m^2). Other low velocity habitat generally decreases with distance up-river and is in greatest abundance in reaches of the highest complexity (Reaches 3, 5 and 6). Shoals which are the third most dense habitat type are found throughout the river system but are a major habitat feature in the lower 19 miles of the San Juan River where it is influenced by the backwater effects of Lake Powell. Slackwater habitats are most abundant between RM 15 and RM 83, but are also plentiful between RM 115 and 160, and are associated with riffle complexes.

Table 5.2. Summary of mapping dates, flows and habitat distribution for 2002-2006

Year	Dates	Flow – cfs Range	Flow – cfs Average	Runs	Riffles	Shoals	Slack-water	Back-water	Low Velocity	Veg.
2002	7/23-8/04	329-704	431	77.1%	13.8%	6.4%	1.6%	0.17%	0.62%	0.09%
2003	10/20-24	337-511	448	75.1%	16.3%	4.7%	3.2%	0.13%	0.21%	0.11%
2004	11/03-08	758-891	811	71.3%	18.4%	5.7%	3.8%	0.21%	0.23%	0.25%
2005	11/12-18	830-1,020	928	68.8%	19.1%	9.1%	2.0%	0.29%	0.56%	0.04%
2006	9/18-10/19	865-1,187	1,068	70.3%	19.6%	5.5%	3.5%	0.27%	0.41%	0.20%

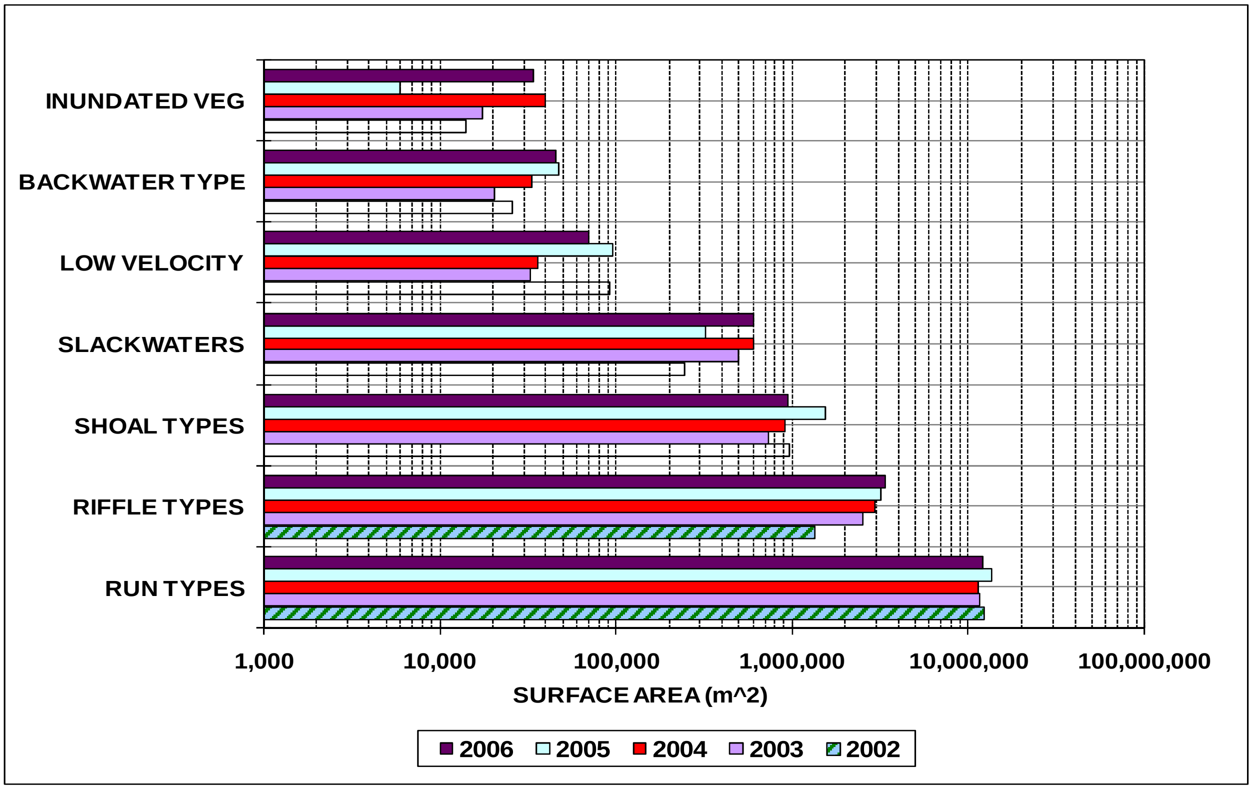

Figure 5.1. **A comparison of the amount of surface area by general habitat type in the San Juan River (RM2 to RM180) for 2002 – 2006**

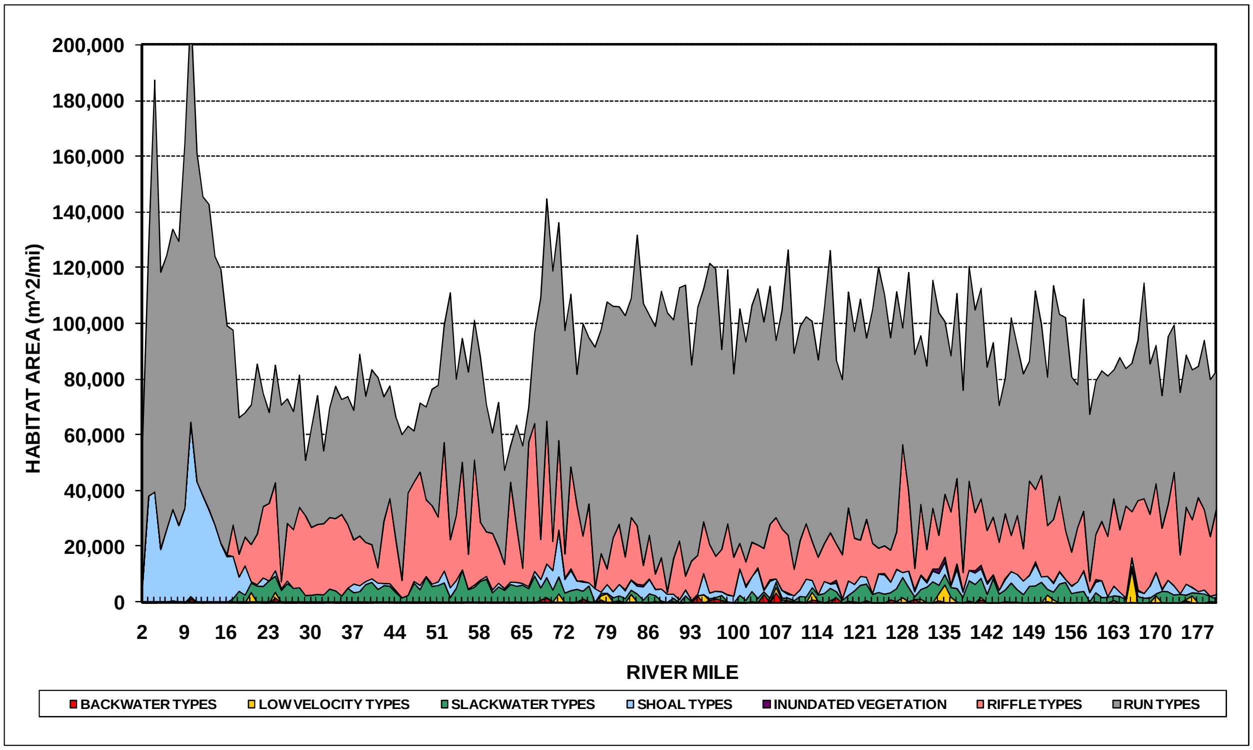

Figure 5.2. **The spatial distribution of major habitat types in the San Juan River for 2006**

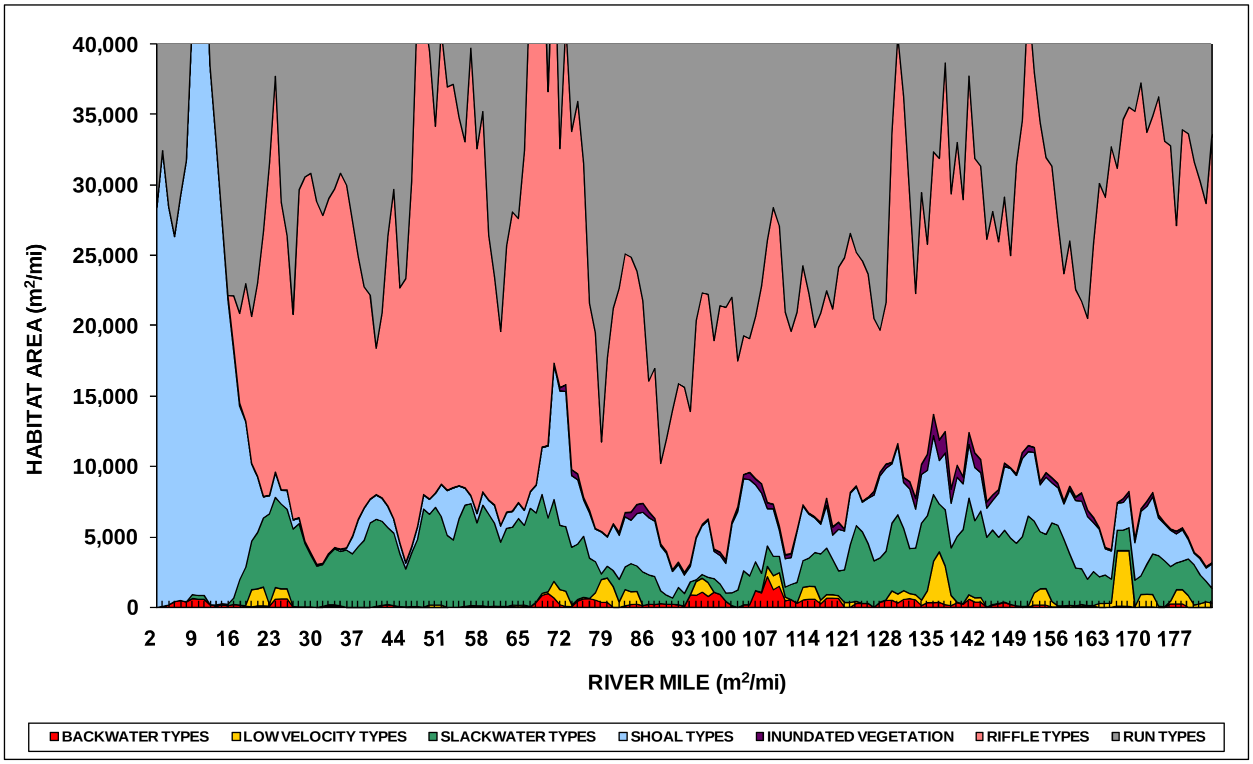

Figure 5.3. The spatial distribution of major habitat types in the San Juan River in 2006, scaled to better show subdominant habitat distribution

Backwater Trend Analysis

Backwater habitats represent an important component of the life cycle of many of the native species found in the San Juan River. Because of this fact, the temporal trend in the magnitude of surface area of this habitat type is used as a monitoring indicator to assess influences of flows on habitat quantity. As noted in previous investigations (Bliesner and Lamarra 2000), the magnitude of backwater habitats are influenced by their location in the river, flow magnitude, and summer storm events. A summary of the total surface areas for 2006 (45,817 m^2) compared to previous years is shown in Figure 5.4 for surface area and in Figure 5.5 for the count (numbers) of backwaters. The data indicate that after reaching a maximum surface area of 143,000 m^2 (373 backwaters) between RM 2 and RM 180 in 1995, there was a decrease to 26,000 m^2 (53 backwaters) in the summer of 2003. Since that time, backwaters have shown an upward trend which continued through 2005, flattening off in 2006. Backwater habitat area was essentially the same in 2006 as 2005 at slightly higher flow. However, individual reaches exhibited more change. Reach 6 had the greatest decline from 2005 (-76%), followed by Reach 5 (-54%), after increases in both reaches in 2005. Reaches 3 and 4 had the greatest increase in backwater habitat area from 2005 (64% and 36%, respectively), following a similar response in 2005. Other low velocity area decreased overall, with the bulk of the decrease in Reaches 4 and 5 (-70% and -46%) following large increases in these reaches in 2005. Reach 3 low velocity habitat increased three-fold from 2005. Reach 2 also increased with no change in Reaches 1 and 6. The backwater count in 2006 was 144, an increase of 22 from 2006 and is the highest since 1999 (Figure 5.5).

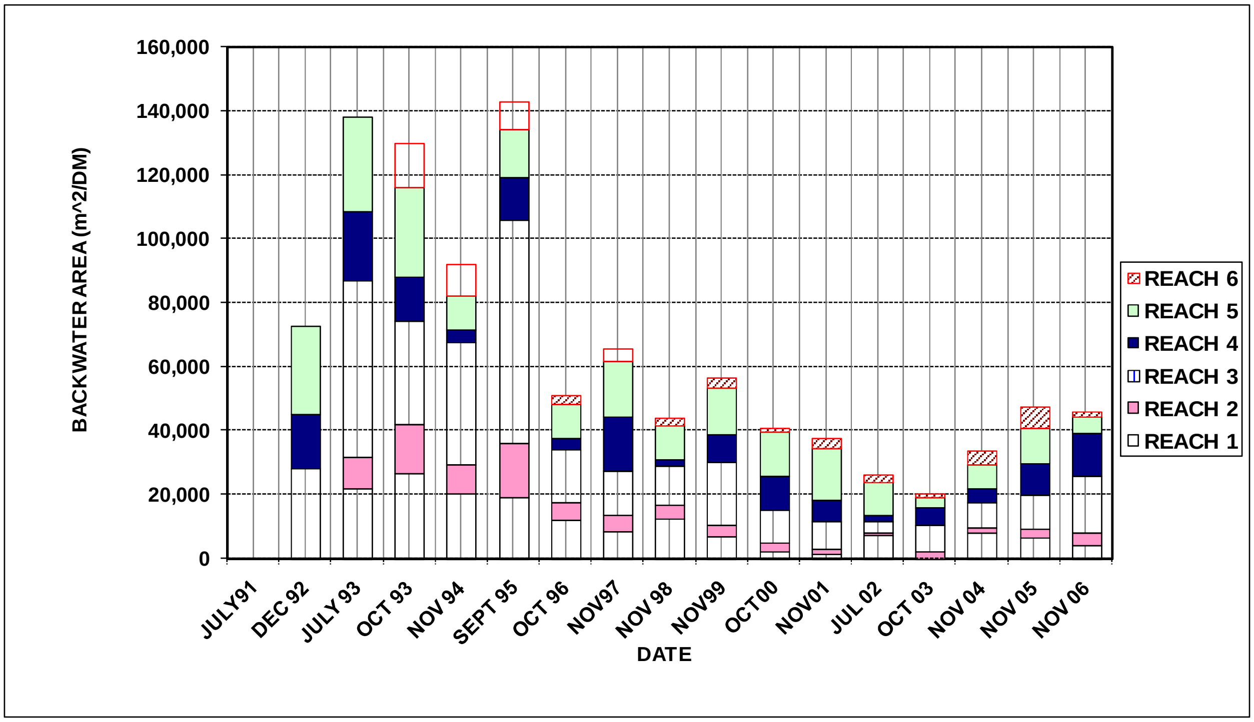

Figure 5.4. **A comparison of the backwater surface areas mapped at low flow in the San Juan River since 1991 (450-1200 cfs)**[6]

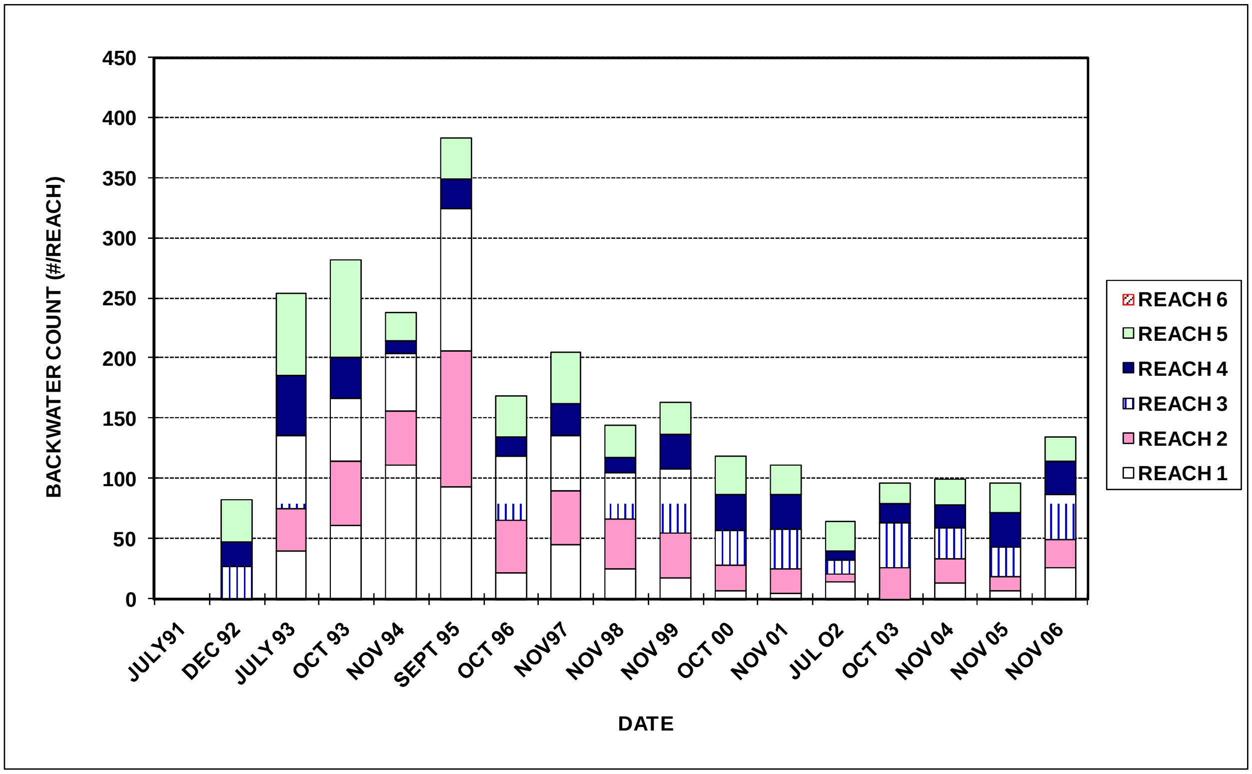

Figure 5.5. **A comparison of the number of backwaters in the San Juan River mapped at low flow since 1991 (450-1200 cfs)** [5]

[6] Reach 1 not surveyed in December 92. Reach 6 not surveyed in December 92 or July 93.

Even though all these mappings occurred at low flow, there was still a relatively large range in flow at mapping (450 to 1,200 cfs). To better determine the change with time, the backwater areas were normalized by regressing habitat area against flow at mapping and then plotting the residuals of this relationship (adjusted to preserve the mean habitat area) with time (Figure 5.6). Only habitat data sets with flows under 1,200 cfs and for which reaches 1-6 were sampled are included. The relationship is significant with a downward trend through 2003, showing loss of habitat with time and then an increase to 2005 showing a reversal in the trend. When corrected for flow, the trend from October 1996 through November 2004 is nearly flat with an increase in 2005 to levels seen in 1998-1999. There is a slight decrease in 2006 in the data that is not reflected in the trend.

The increase in backwater and low velocity habitat in 2005 is in response to the high flows during 2005 spring runoff when all of the desired flow statistics were met. 2006 was a dry year, with a minimum reservoir release. Only the 2,500 cfs flow statistic was met, so no increase in backwater habitat was expected. With these conditions only a minor decrease in total backwater habitat was noted, although the decrease in other low velocity habitat was more substantive.

Channel Complexity

Island count is used as an indicator of channel complexity as it represents the number of multiple channels in a given reach. The island count, normalized for flow at mapping shows a significant (p=<0.01) downward trend with time, indicating channel simplification (Figure 5.7). A second and related relationship of total wetted area with time, normalized for flow at mapping, shows the same trend (Figure 5.8). In the 15 years since mapping began there has been a cumulative reduction in island count at low flow of about 25%. During the same time the total wetted area has decreased by about 10%.

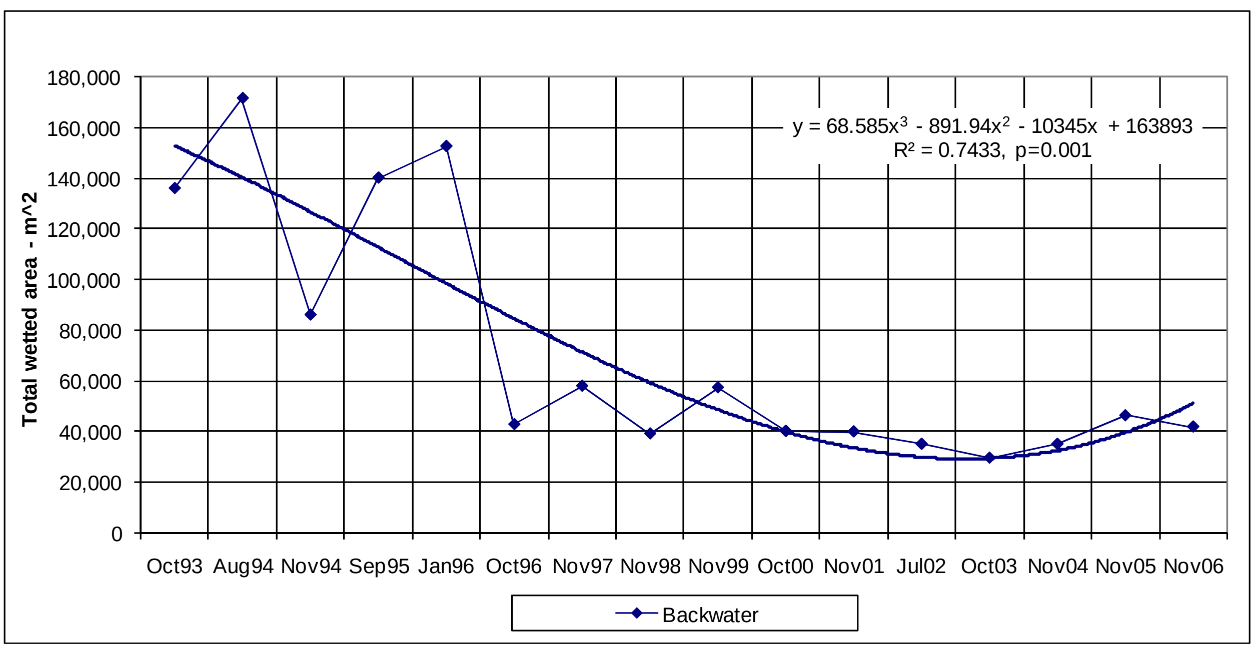

Figure 5.6. Backwater area residual (adjusted to yield mean habitat area) from habitat-flow regression with time

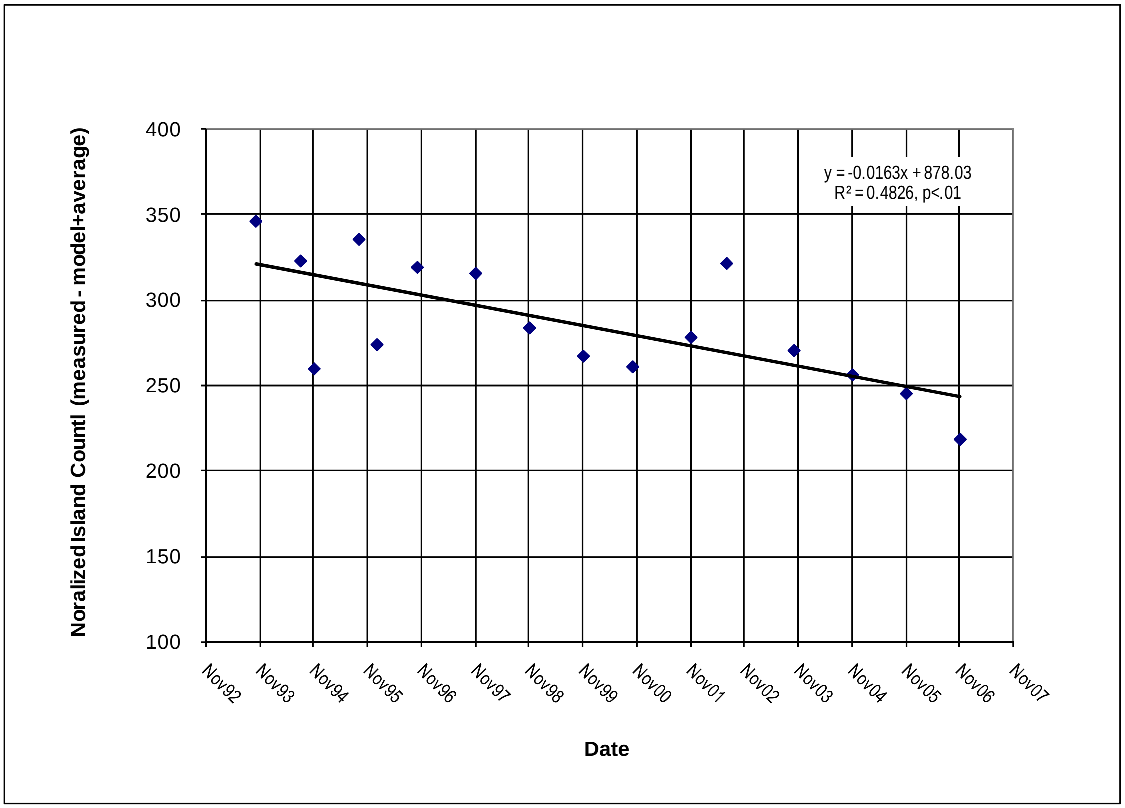

Figure 5.7. Change in normalized island count (residual from flow-island count relationship plus the average island count) with time

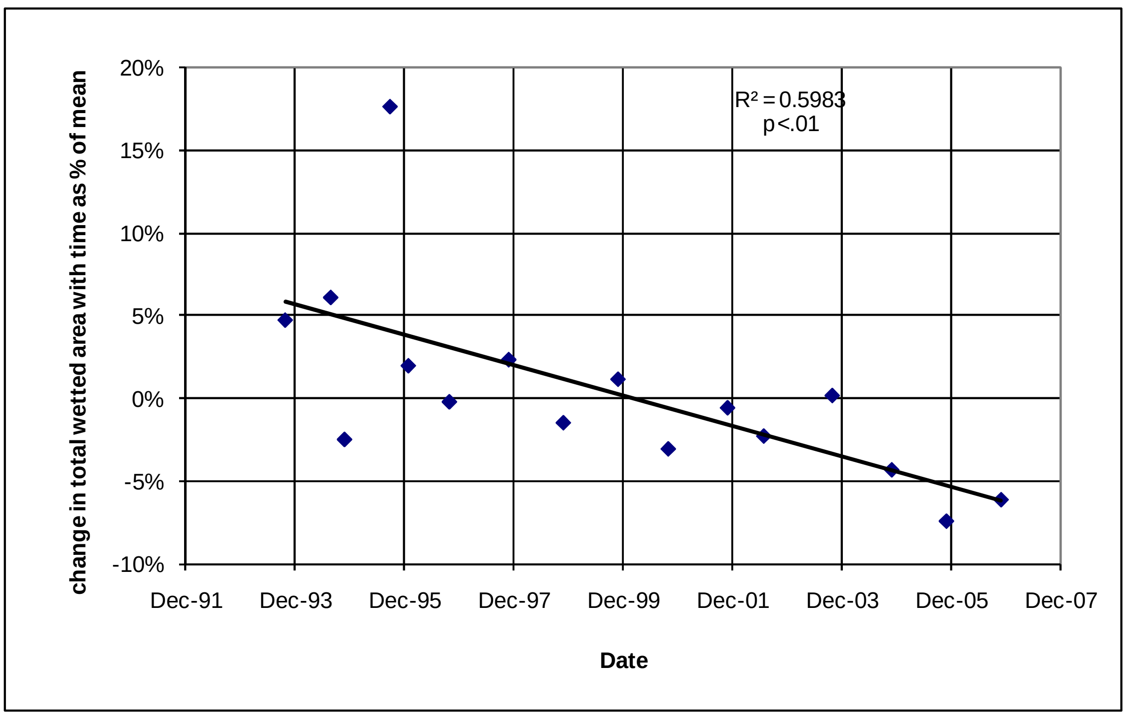

Figure 5.8. Change in normalized total wetted area (residual from flow-island count relationship plus the average island count) for reaches 3-6 with time

The loss of islands has not been uniform among reaches. A comparison of island count by reach with time during years when flows at mapping were similar shows that a number of the reaches have stabilized, but Reach 5 continues to decline (Table 5.3). This is an indication of channel simplification which appears to be continuing in Reach 5.

This channel simplification may be attributed to two possible causes: extended drought and encroachment of non-native vegetation, primarily Russian olive and salt cedar. The 10-year antecedent average runoff has been decreasing since the beginning of this study (Figure 2.3). Examination of Island count normalized for flow at mapping with 10-year antecedent flow a significant relationship (Figure 5.9). However, the 2006 data point falls considerably below the trend line and is the lowest on record, indicating that the extended drought is not the only cause of channel simplification. Further, the single large runoff year in 2005 was not adequate to reverse the trend.

Encroachment of salt cedar and Russian olive has been observed during mapping over the past 15 years. This is exacerbated during dry periods when flow in secondary channels is inadequate to remove young vegetation. Once the vegetation is established it becomes an effective trap for fine sediments by creating increased channel roughness and low boundary velocities. With this established vegetation on main channel margins and within secondary channels it is more difficult for those channels to be flushed and for new ones to be created during high flow years. Stamp, et al (2006) observed these conditions in Reach 6 and recommended testing removal of non-native vegetation in the mouths of secondary channels as a mechanism for increasing low velocity habitat. The same conditions occur in Reach 5, where the greatest loss of islands has occurred and is still occurring (Table 5.3). In 2006, Reach 3 had an increase in island count and an increase in backwater and other low velocity habitat while Reach 5 experienced a loss in both.

Bliesner, et al. (2007) recommended studying the feasibility of non-native vegetation removal in channel mouths in Reach 5, if increased low velocity habitat was deemed important to the recovery of the endangered fish. The trends in channel simplification and loss of low velocity habitat in Reach 5 support that recommendation.

Table 5.3. Island count by reach for select years with similar flows, 1993-2006

Reach	1993	1999	2004	2005	2006
3	98	60	58	63	66
4	83	58	48	48	49
5	105	88	77	78	72
6	77	54	60	64	63
Total	**363**	**260**	**243**	**253**	**250**
Flow - cfs	944	828	798	905	1,017

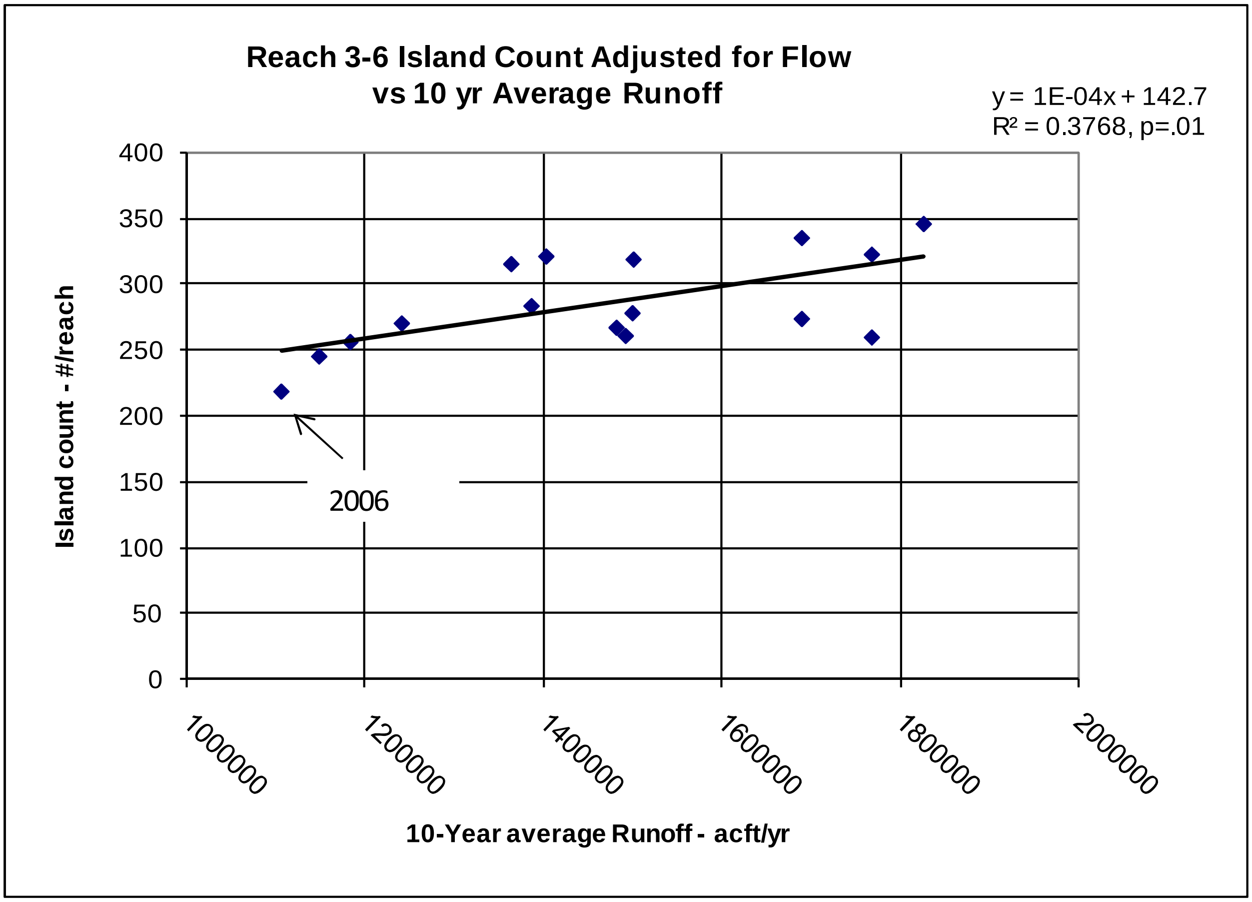

Figure 5.9. Island count adjusted for flow as influenced by the 10-year average antecedent flow in the San Juan River near Bluff, Utah

CONCLUSIONS

The following conclusions can be drawn from river-wide habitat mapping:

- Relative abundance among habitat categories has not changed during the 15 years of data collection. Runs, riffles and slackwater still dominate.
- Backwater habitat reached a low in 2003 at about 20% of the peak value. The trend started to reverse in 2004 and increased even more in 2005. There was a small decease in 2006, possibly as a result of the dry year and small reservoir release.
- The channel is simplifying with time as evidenced by a loss of islands and reduction in total wetted area with time.
- The channel simplification is related to both the extended dry period and encroachment of non-native vegetation along main channel margins and within secondary channels.
- Reach 5 has experienced the greatest loss of islands over time and is continuing to lose island while other reaches seem to have stabilized.
- While Reach 3 lost the greatest amount of backwater habitat over time, it actually gained backwaters, other low velocity habitat and islands in 2006, while Reach 5 lost in all three categories.
- Flow manipulation alone may be inadequate to restore channel complexity and increase backwater and other low velocity area in the river.

CHAPTER 6: 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 6.1. 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. 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. They record water temperature every 15-minutes.   Table 6.1 also shows the periods of record at each site. 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.

The records are maintained in a Microsoft Access Database. Also included in the database are temperature data from other sites that have been measured in the past or from USGS records. These sites are also shown in Table 6.1 with their period of record. All sites except Four Corners are missing data between September 16 and October 11-12, 2006. The storage space was exceeded on these recorders prior to servicing. The Animas at Farmington recorder malfunctioned and is missing data from September 16, 2006 to April 25, 2007.

RESULTS

The temperature profiles plotted with the hydrograph at the Four Corners gage illustrate the negative correlation between flow and water temperature (Figure 6.1). The Navajo Dam release made April 30, 2007 to May 23, 2007 caused an average drop of approximately 2 - 4° C over a two week period throughout most of the river system. At high flow, the temperature at Archuleta was suppressed by about 2 degrees, but remained warmer than the release temperature.   The temperature of the San Juan at Farmington ranged 1 - 6° C cooler than the Animas at Farmington, depending on the flow in the Animas. By the end of the fish release (May 23), the San Juan and Animas Rivers at Farmington were approximately the same water temperature (12° C). The water temperatures on the San Juan and Animas Rivers at Farmington remained nearly the same until mid-June. After which, the water temperatures on the Animas River was 1 - 4° C warmer than the San Juan throughout the rest of the 2007water year, coinciding with the period after spring runoff on the Animas River.

This temperature suppression in 2007 occurred earlier than in other years as a result of an early reservoir release, but was of similar magnitude for years with similar flows. The temperature suppression was less in 2007 than in 2006, which was a dry year.

Table 6.1. Water Temperature Monitoring Locations and Period of Record

Location	RM	Period of Record
Active Temperature Recording Sites		
Near Navajo Dam	225.0	7/9/1999 to 9/15/06, 10/12/06 to 9/30/07
Archuleta - San Juan at USGS Gage Location	218.6	7/23/92 to 9/15/06, 10/12/06 to 9/30/07
Farmington - San Juan at USGS Gage Location	180.1	8/5/92 to 1/16/96, 7/8/99 to 11/4/01, 10/3/02 to 9/15/06, 10/11/06 to 9/30/07
Shiprock - San Juan at USGS Gage Location	148.0	7/8/99 to 9/16/06, 10/11/06 to 9/30/07
Four Corners - San Juan at USGS Gage Location	119.4	10/7/94 to 3/11/96*, 7/9/99 to 9/30/07
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 3/11/05, (sensor stolen. Replaced 10/31/05) 10/31/05 to 9/16/06, 10/12/06 to 9/30/07
Mexican Hat - San Juan near Bluff Gage Location	52.1	7/9/99 to 3/27/02 , 9/18/02 to 8/1/06, 10/12/06 to 9/30/07
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, 7/8/99 to 9/15/06, 4/25/07 to 9/30/07
Other Temperature Records in Database		
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
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 at Farmington	n/a	10/1/52 - 9/30/90 with some missing data
Cedar Hill - Animas at USGS Gage nr Cedar Hill, NM	n/a	8/7/92 to 9/22/98

Note: All locations missing October 1992 data.
*Installed 8/10/92 but bad data were logged until thermistor was changed in October 1994. Prior to this time it was thought sediment accumulation was causing the warmer readings instead of a bad thermistor.

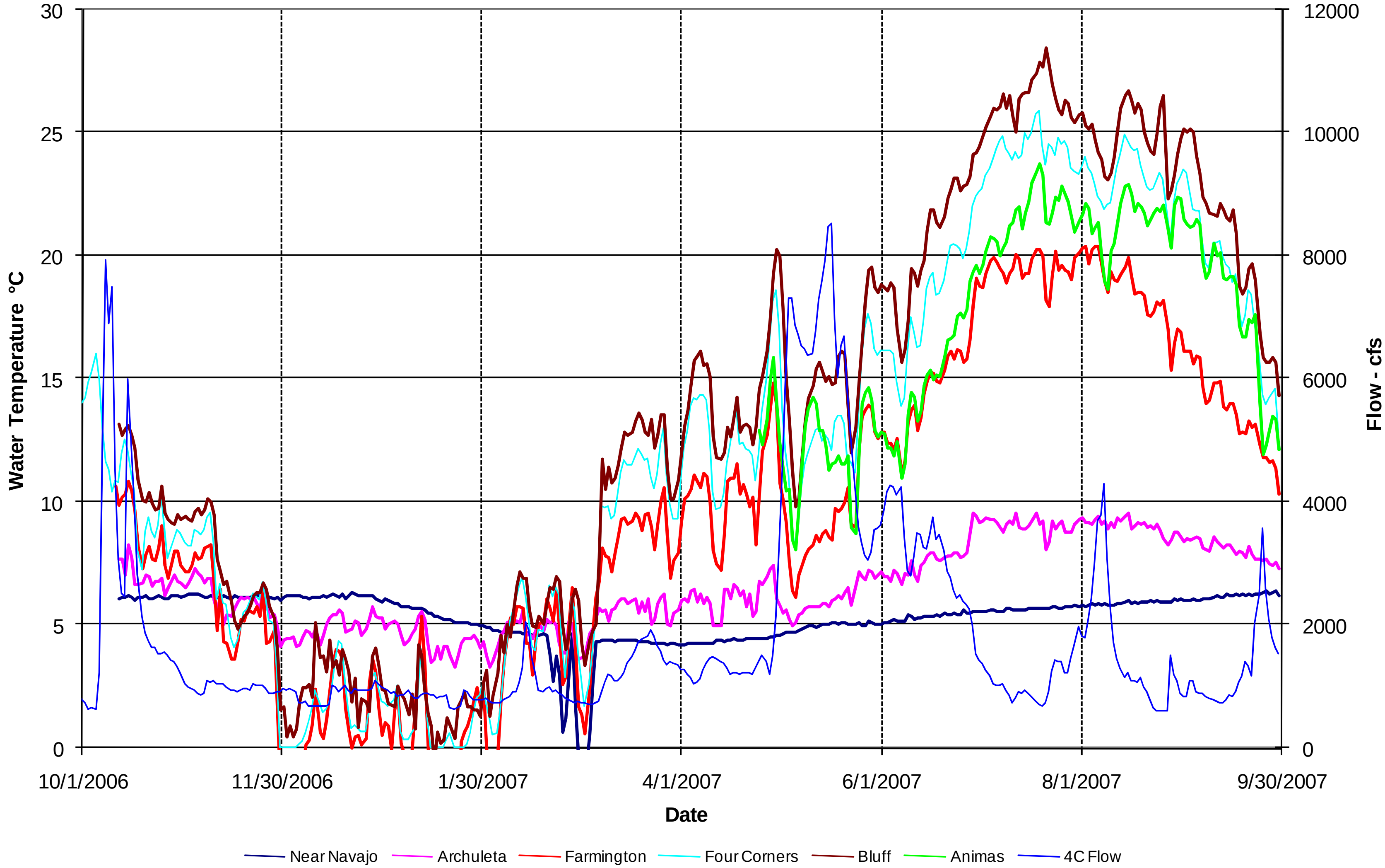

Figure 6.1. San Juan Basin Average Water Temperature Data, 2007

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