SAN JUAN RIVER BASIN
RECOVERY IMPLEMENTATION PROGRAM

HYDROLOGY, GEOMOPHOLOGY, HABITAT LONG-TERM MONITORING 1999 PLAN

prepared by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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. The work reported here summarizes data collected in 1999 as a part of the long-term monitoring program and compares these data to that collected since 1992.

Data collected in the following areas are summarized here:

- Hydrology
- River Cross-Section Measurement
- Cobble Bar Characterization
- Suspended sediment and turbidity
- Water Temperature
- Water Quality
- Aquatic Habitat Mapping from the confluence of the San Juan and Animas Rivers (RM180) to the confluence with Lake Powell (RM 0)
- Backwater Characterization (total depth, sediment depth, water depth)

All data sets are from the 1999 field season except 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 are covered in the Long-Term Monitoring Plan and are not described in detail in this annual progress report. The 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, 1999). Figure 1 shows these reach locations. 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 effect the critical habitat. The study area for each data set is described with the summary of that data set.

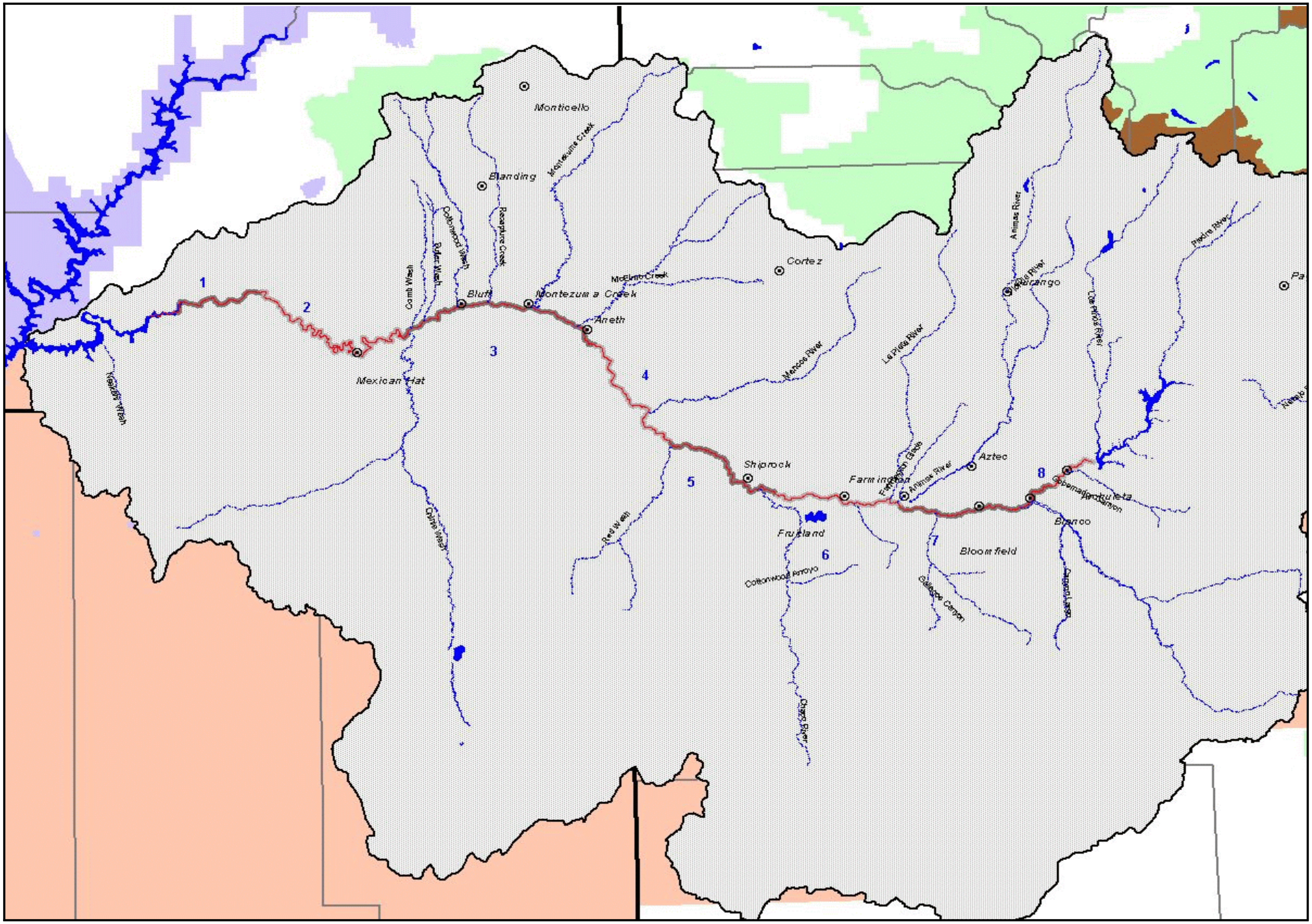


Figure 1.1. San Juan Basin Location Map Showing Geomorphic Reaches

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. Since the depletion prior to Navajo Dam was relatively small and the flow was not regulated by major storage reservoirs, the conditions during the pre-dam period (1929-1961) are used to judge effects of later development and the value of future modification of the hydrology for the benefit of the endangered fishes.

Daily flow data recorded by the USGS (Hydrosphere 1999) from 1929 through the present are available for the key points on the San Juan River. These data have been used to analyze the 1999 hydrology and compare the statistics to other years. The foundation of comparison are the flow statistics in the SJRIP Flow Recommendation Report (Holden, 1999).

METHODS

Beginning in 1999, the operating rules recommended in the Flow Recommendation Report have been employed by Reclamation as far as restrictions would allow. Presently, the only restriction is to the minimum release from Navajo Dam, which cannot fall below 500 cfs until an Environmental Impact Statement (EIS) is completed. 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 indicated.

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. The fall of 1998 was identified as a perturbation year, calling for a minimum release of 114,000 af with a 1 week ramp up, one-week peak and one-week ramp down. Table 2.1 describes the nature of the release each year since 1991. The volume of water released in excess of an assumed base release of 600 cfs normally required to meet downstream demands is also shown. The volume released exceeded the minimum required by about 52,000 af.

Table 2.1. Summary of Navajo Dam release hydrograph characteristics since the beginning of the research period, 1992 to 1999.

YEAR	ASCENDING LIMB	PEAK	DESCENDING LIMB	MATCHED ANIMAS RIVER PEAK	VOLUME ABOVE 600 CFS BASE - AF
1992	6 weeks starting April 13	2 weeks at 4,500 cfs	4 weeks ending July 15	Yes	409,740
1993	Starting March 1, rapid increase to 4,500 (compare with 1987)	split peak, 45 days at 4,500 cfs, 7 days at 4,500 cfs	4 weeks ending July 13	No	773,820
1994	4 weeks starting April 23	3 weeks at 4,500 cfs	6 weeks ending July 28	Yes	486,620
1995	3 weeks at 2,000 cfs in March, ramp to 4,500 over 6 weeks starting April 1	3 weeks at 5,000 cfs	4 weeks ending July 14 (summer flow 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

To fit operational requirements at the dam, the ramp up, peak and ramp down were all slightly longer than required, resulting in a larger release, placing the actual release closer to the intermediate release shown in the operation rule tree of the Flow Recommendation Report.

Table 2.2 compares the flow statistics from 1999 to those of the 1992-1998 period for each category identified in the Flow Recommendation Report. Also indicated are the desired conditions that were met. With the exception of average base flow, all flow conditions were met.

The 1999 hydrographs for the San Juan River at Archuleta (release hydrograph) and at Four Corners are presented in Figure 2.1. Inflows into Navajo Dam were much greater than normal during the summer of 1999, resulting in a large release from Navajo Dam to prevent spill and provide space to prevent a further spill later in the year. This summer release was the decision of Reclamation and was not the recommendation of the Biology Committee, although the Biology Committee was informed that the release would take place.

The hydrographs at Four Corners for these years appear in Figures 2.2 and 2.3. The flow statistics that apply to these hydrographs appear in Table 2.3. The Four Corners gage is considered the most representative gage for the habitat range and is used in all correlations reported here.

Table 2.2. Flow Statistics met in each year

Flow Condition	Std	1992	1993	1994	1995	1996	1997	1998	1999
Days at10,000 cfs or more	5	0	1	0	**11**	0	**10**	0	0
Days at 8,000 cfs or more	10	3	**16**	**13**	**27**	0	**33**	2	0
Days at 5,000 cfs or more	21	**54**	**109**	**49**	**72**	0	**50**	**34**	**29**
Days at 2,500 cfs or more	10	**81**	**128**	**67**	**135**	**36**	**100**	**65**	**70**
Yrs w/o meeting 10,000cfs	10	**6**	**7**	**8**	**0**	**1**	**0**	**1**	**2**
Yrs w/o meeting 8,000 cfs	6	**4**	**0**	**0**	**0**	**1**	**0**	**1**	**2**
Yrs w/o meeting 5,000 cfs	4	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**
Yrs w/o meeting 2,500 cfs	2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

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

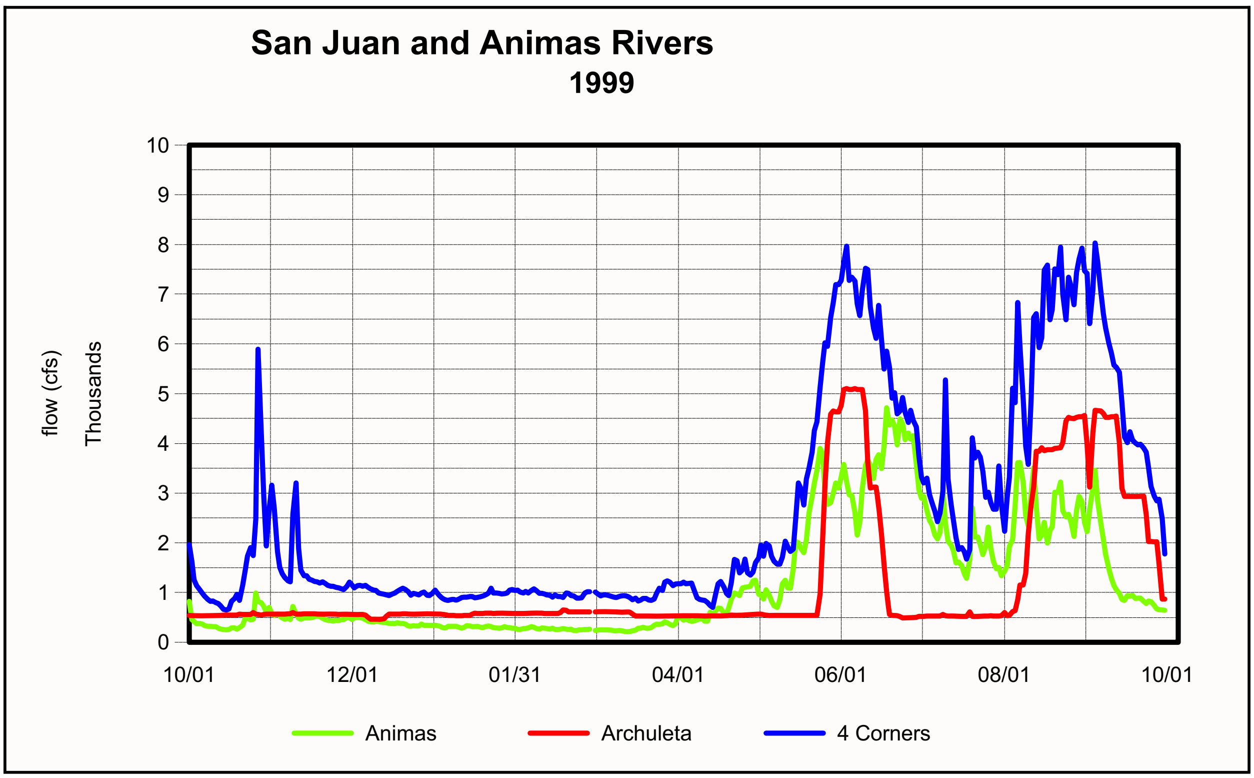


Figure 2.1. 1999 hydrographs for Anims River at Farmington, San Juan River at Archuleta and Four Corners.

Table 2.3. Summary of flows for the research (1991-1998) and monitoring (1999)periods, San Juan River at Four Corners, New Mexico.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
	San Juan River at Four Corners, New Mexico								
Peak Runoff-cfs	5,160	8,900	10,300	10,000	12,100	3,540	11,900	8,580	8,030
Runoff(Mar-Jul)-af	599,459	1,074,795	1,714,328	1,039,601	1,624,927	431,913	1,338,539	931,106	876,846
Runoff(total annual)-af	1,086,676	1,512,795	2,216,819	1,448,893	2,102,228	815,795	1,844,019	1,401,536	1,901,803
Peak Date	16-May	29-May	03-Jun	05-Jun	19-Jun	18-May	04-Jun	04-Jun	03-Jun
Days>10,000	0	0	1	0	11	0	10	0	0
Days>8,000	0	3	16	13	27	0	33	2	0
Days>5,000	2	54	109	49	72	0	50	34	29
Days>2,500	46	81	128	67	135	36	100	65	70
Ave. Daily Flow for month									
October	1,449	769	827	941	1,109	1,091	1,276	1,404	1,533
November	1,127	1,356	911	1,210	1,077	1,139	883	1,175	1,494
December	1,080	1,088	957	1,105	960	1,088	702	1,154	1,031
January	1,173	859	1,358	1,050	918	785	789	1,208	947
February	1,289	1,298	1,511	781	1,076	899	690	1,239	976
March	995	1,173	5,463	967	2,782	766	2,255	1,267	969
April	1,810	3,723	6,188	1,028	3,478	607	2,529	1,910	1,174
May	3,739	6,634	7,298	5,251	6,119	2,150	6,000	5,831	3,439
June	2,580	4,844	7,701	7,836	9,367	2,925	8,514	4,542	5,986
July	801	1,444	1,776	2,170	5,187	715	2,904	1,802	2,925
August	556	927	1,348	552	1,564	492	2,310	1,073	6,135
September	1,441	997		1,142	1,193	891	2,365	574	4,852
Uniqueness		Control	early ave.	early ascent	late ave.	late peak	dry	narrow runoff	early ave.
			storm @ spawn					storm @ spawn	storm @ spawn

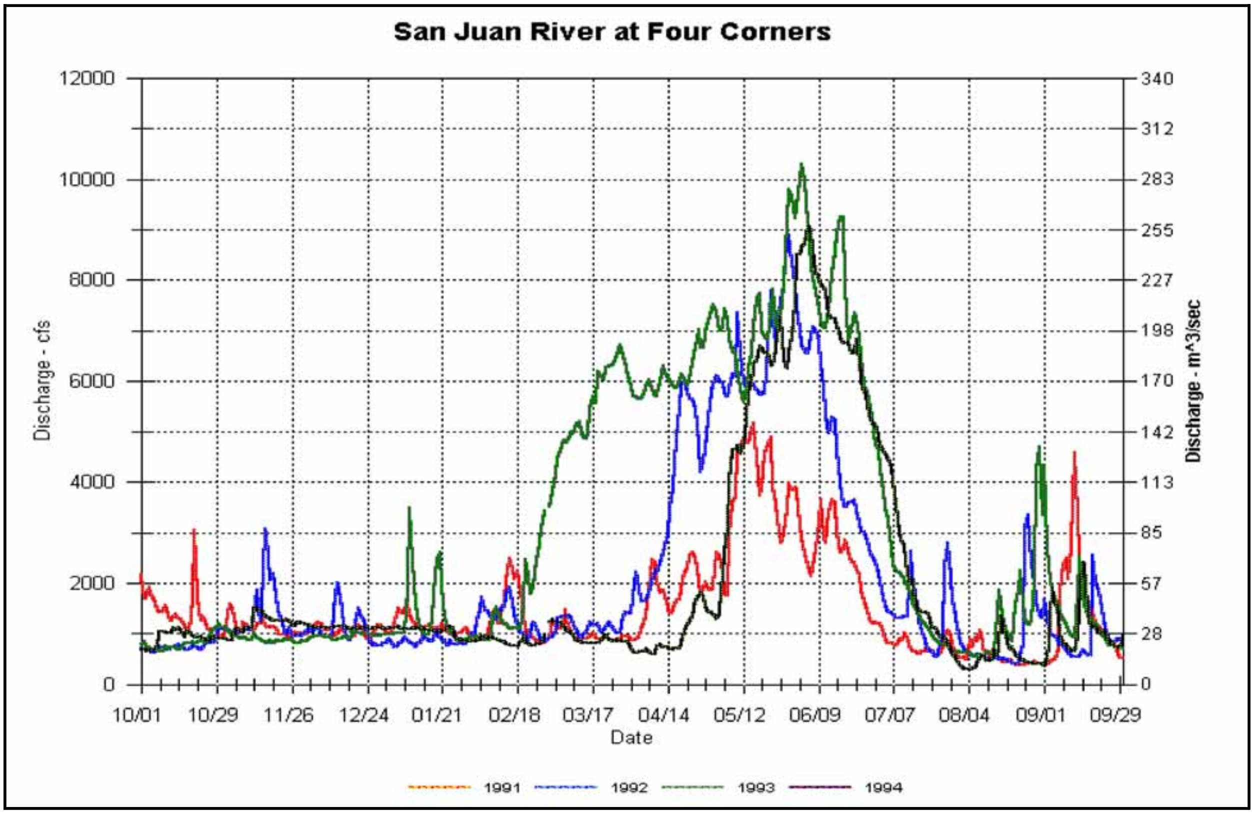


Figure 2.2. Hydrographs for the San Juan River at Four Corners for 1991 - 1994.

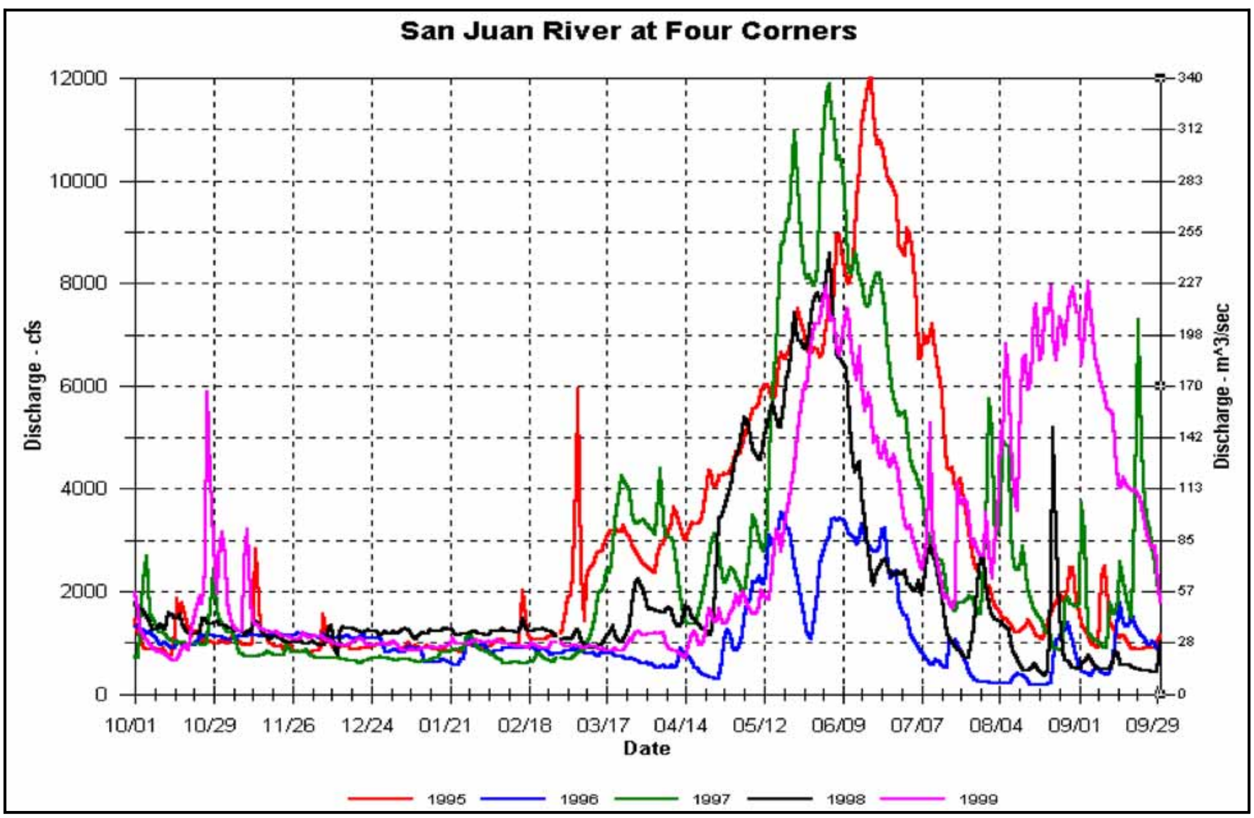


Figure 2.3. Hydrographs for the San Juan River at Four Corners for 1995 - 1999.

Storm Influence

The San Juan River is heavily influenced by high intensity summer and fall advective storms. These storms produce short duration flow increases that are heavily sediment laden and have been associated with deterioration of habitat quality in the San Juan River. The post-runoff season of 1999 was unusually wet. For most of August and half of September the flows at Four Corners were in excess or 5,000 cfs and peaked over 8,000 cfs.

In the Flow Recommendation Report (Holden, 1999), the conditions that impacted habitat quality were described, based on calibration to observed impacts from storm events. A storm-event day is defined as a day in which the daily gain in flow between Farmington, New Mexico and Bluff, Utah, and the daily flow at Bluff, Utah, were each more than 150 cfs greater than the 5-day average. A storm-event day was given a weight of 2 if the gain in flow was 3,000 cfs or more. A year in which there were more than 12 storm-event days between August 25 and the end of February was determined to be a year in which the backwater habitats were filled with sediment (perturbated) to the point that flushing was required to restore them. 1999 was considered a perturbated year using this standard. However, the flows were so high that some backwater flushing occurred, partially flushing the sediment that would normally accumulate. While substantial sediment filling occurred, it is less than would have been anticipated for the number of sediment flow days.

CHAPTER 3. GEOMORPHOLOGY

METHODS

Channel Morphology - River Transects

Cross sections have been identified in five of the six geomorphic reaches for monitoring of bed elevation change with time. Reach 2 (RM 67 to RM 17) is canyon-bound and is not subject to channel change so it is not monitored. Two to three cross-sections in each geomorphic reach were identified for monitoring. Each cross-section is surveyed across the active river channel pre- and post-runoff each year. At lease one cross-section in the reach will span the floodplain and the full width will be surveyed every fifth year to monitor the effect of high flows on the floodplain. These were surveyed in 1999.

Table 3.1 lists the cross-sections in each geomorphic reach as identified in the Long-Term Monitoring Plan. The cross sections were selected from those established in 1962 (lettered cross-sections), those established in 1992, and new cross-sections (where existing cross-sections were not representative of a geomorphic reach). Monitoring program cross-sections are coded by geomorphic reach (e.g., CS6-02 = second cross-section in geomorphic reach 6).

Table 3.1. San Juan River channel morphology monitoring cross-section locations by geomorphic reach.

Geomorphic Reach	X-Section No.	Former Identification	River mile
6	CS6-01	NEW	175.0
	CS6-02	RT-01	168.3
	CS6-03	RT-02	154.4
5	CS5-01	RT-03	142.7
	CS5-02	RT-04	136.6
	CS5-03*	RT-05	132.7
4	CS4-01	RT-06	124.0
	CS4-02	RT-07	122.1
	CS4-03*	Section E	118.2
3	CS3-01	RT-09	90.8
	CS3-02*	RT-10	82.3**
	CS3-03	RT-11	70.0
1	CS1-01	C-01	12.7
	CS1-02	C-02	4.1

*Valley-wide cross-sections surveyed every fifth year to monitor floodplain changes
**Valley-wide cross-section located at RM 82.2

Water depth and channel depth is obtained by stretching a marked cable across river between anchor points for each transect and measuring the channel depth relative to a local bench mark. River depths are measured with a survey level and rod at 5 ft increments unless cross-section length exceeds approximately 300 ft. In such situations, areas of the cross-section that have a change in depth of less than 0.5 ft in 10 ft may be surveyed in 10 ft increments. Substrate type at each survey point is characterized as sand or gravel/cobble and recorded. The full-width floodplain surveys were completed with a total station outside the active channel. The points surveyed correspond to grade breaks such as a change in slope, top of a hill or edge of a channel or bank.

Cobble Bar Characterization

Four cobble bars on the San Juan River (RM 173.7, RM 168.4, RM 132.0, and RM 131.0) that were identified as having attributes suitable for spawning by the Colorado pikeminnow were selected for monitoring. Topographic surveys were completed for each of these cobble bars, utilizing total station survey equipment. Control was provided by established bench marks at each location. Surveys are typically completed as soon as practical (flow at 1,000 cfs or less) after spring runoff, usually during late July or early August. However, in 1999, unusual summer storms prevented starting the surveys until the end of October.
In addition to the standard required survey data, at each cobble bar the following data were recorded.

- Point descriptions for each point. Edge-of-water points noted and recorded.

- At each non-benchmark point the depth to embeddedness and corresponding surveyed point number is recorded.

- The physical structure of each cobble bar is assessed by measurement of randomly selected particles of surface bed material. Particles are selected by the Wolman pebble count method (Wolman, 1954) over the full extent of the bar within the survey boundary. A minimum of 200 samples is typically collected in a linear pattern over the bar with a spacing of about 8-10 ft (3 steps) within the line and between lines. Particle size is determined by sieving particles through a square hole in a steel plate, cut to represent an equivalent screen size from 1 through 10 cm at 1-cm increments, then 2-cm increments through 20 cm. Particles larger than 20 cm are recorded as greater than 20 cm. Interstitial material smaller than 1 cm is recorded as < 1 cm but is not included in analysis of size distribution.

- Depth of open interstitial space (depth to embeddedness) is measured at the same time and location as the survey points to characterize topography of the bar over the extent of the spawning bar. Measurement is made by a field technician working his/her hand among rocks until the fingers just touch embedded sand. Depth of penetration, measured from adjacent average cobble top-surface, will be recorded as depth of open interstitial space (Osmundson and Scheer, 1998).

Turbidity Monitoring

The continuous turbidity monitoring equipment installed at Shiprock and Montezuma Creek is used monitor sediment producing events. The turbidity monitoring equipment at Shiprock consists of a D&A OBS-3 turbidity probe connected to a Campbell Scientific CR-510 data logger. The probe is calibrated to read between 0 and 4000 NTU's. Turbidity is measured every hour. The equipment installed at Montezuma Creek is an OmniData data logger with an OBS-3 probe that is calibrate to measure between 0 and 3000 NTU's. Turbidity is measured every two hours. The Shiprock installations has performed flawlessly while the Montezuma Creek installations has been plagued with problems. The Montezuma Creek installation will probably be replaced in late 2000 or early 2001 depending on its performance during the Summer of 2000.

RESULTS

Channel Morphology - River Transects

Cross-section plots referenced in Table 3.1 are contained in Appendix A for 1999. The long-term valley wide cross-sections are also shown in Appendix A. The figures show the pre- and post-runoff cross-section of each transect. The bars with the various hatch patterns show the substrate conditions at the time of survey.

The relative bed elevation for each of the Reach 3-6 transects since the initial survey in 1992 is shown in Figure 3.1. In this plot, the average bed elevation of the first survey in 1992 was normalized to one meter. The change with subsequent surveys is then reported as a relative difference. A bed elevation greater than one shows net deposition since the first survey. Conversely, a bed elevation less than one shows scour. Figure 3.2 shows the minimum relative bed elevation. It shows how the minimum elevation in each of the transects has changed since the first survey in 1992. The transects that were first surveyed in 1999 are not shown.

The variability makes Figures 3.1 and 3.2 difficult to interpret. Figures 3.3 and 3.4 are the average relative and minimum relative bed elevation, respectively. The values represented in figures 3.3 and 3.4 are calculated by averaging the individual bed elevations as shown in Figures 3.1 and 3.2 for each survey date. Figure 3.5 shows the cumulative deposition and scour for the Reach 3-6 transects for 1992 to 1999. The net change line shows that on average the channel has aggraded back near 1992 levels following a period of scour. However, the deepest part of the cross-sections remain 0.1 meter lower than in 1992. Figure 3.5 shows that most of the change during the period has been scour and deposition of sand, with relatively little net change in cobble, although there has been a slight net loss of cobble over the 7-year period. The figures also show the post-runoff filling of the cross-sections with sediment and the subsequent flushing between years. Table 3.2 shows the volume and peak discharge in each year. Typically, the largest scour occurs during the highest flow years although heavy sediment inflow can refill a previous year's scour, even in the relatively wet years.

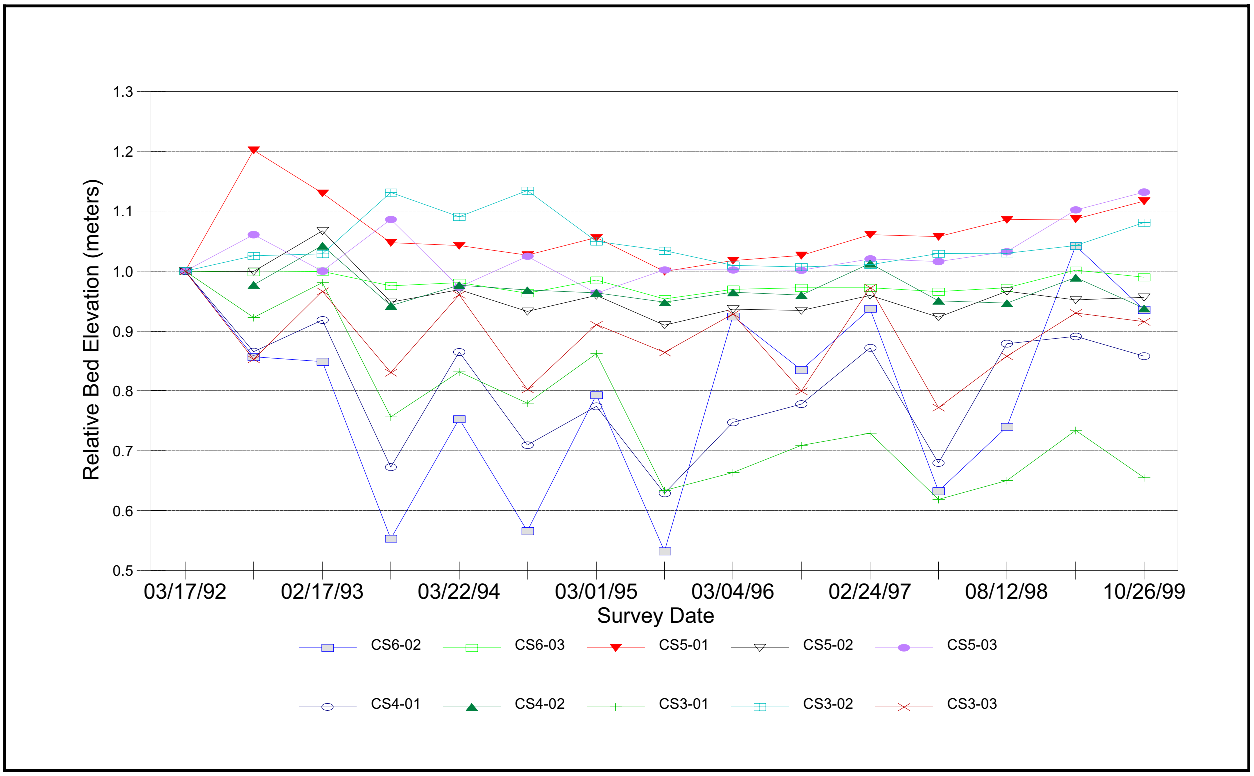


Figure 3.1. Average relative bed elevation for Reach 3-6 transects, 1992-1999.

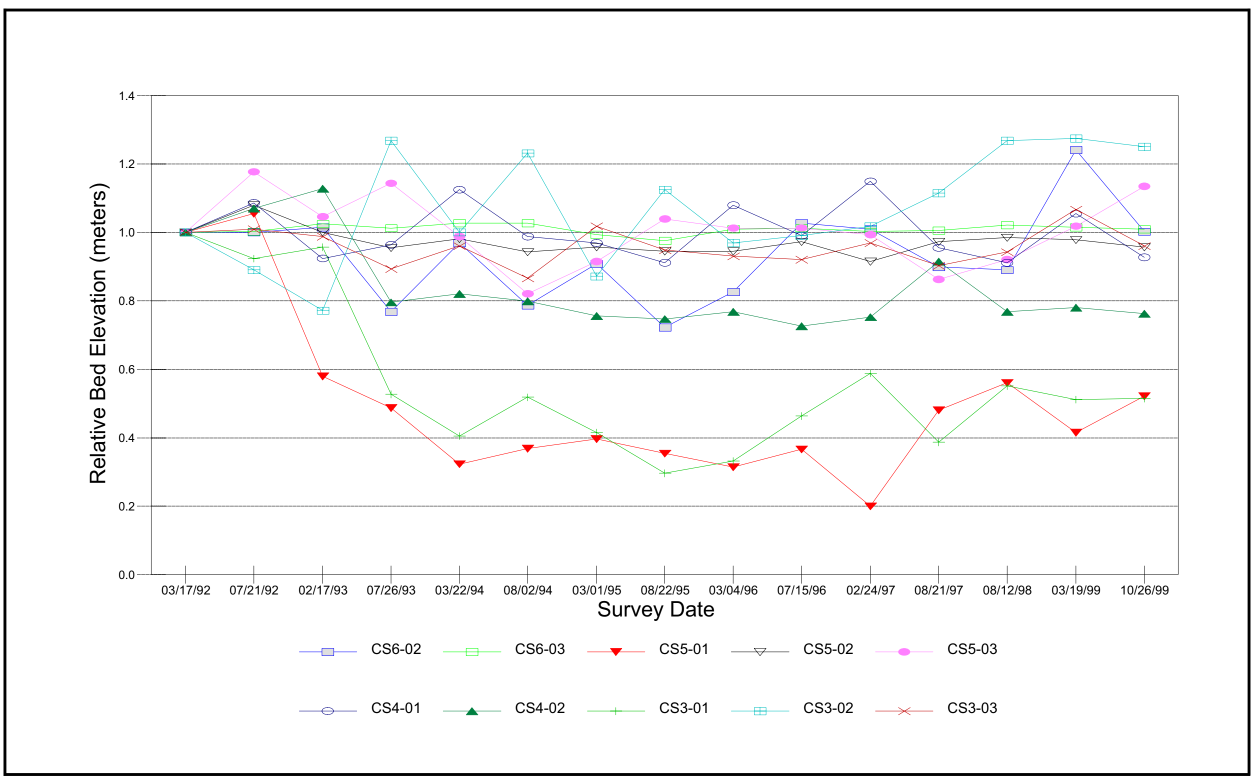


Figure 3.2. Minimum relative bed elevation for Reach 3-6 transects, 1992-1999

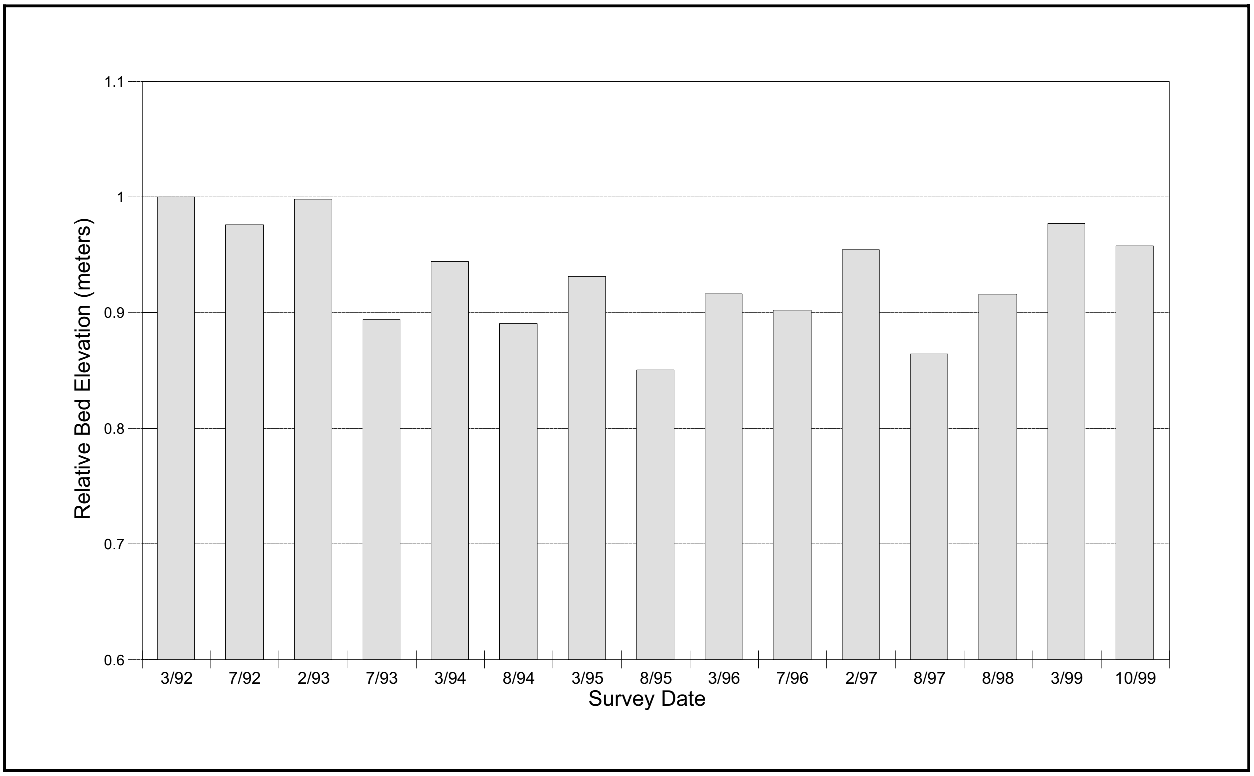


Figure 3.3. Mean relative bed elevation for Reach 3-6 Transects, 1992-1999

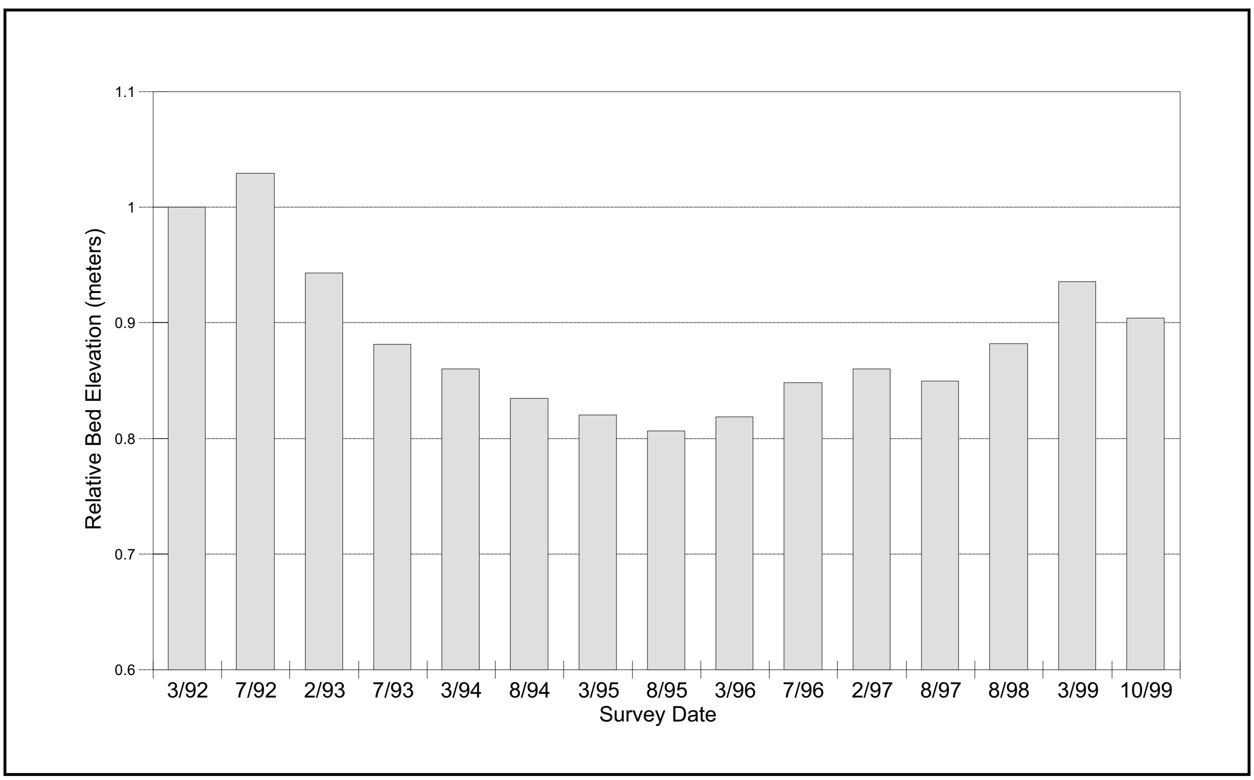


Figure 3.4. Minimum bed elevation averaged for Reach 3-6 Transects, 1992-1999

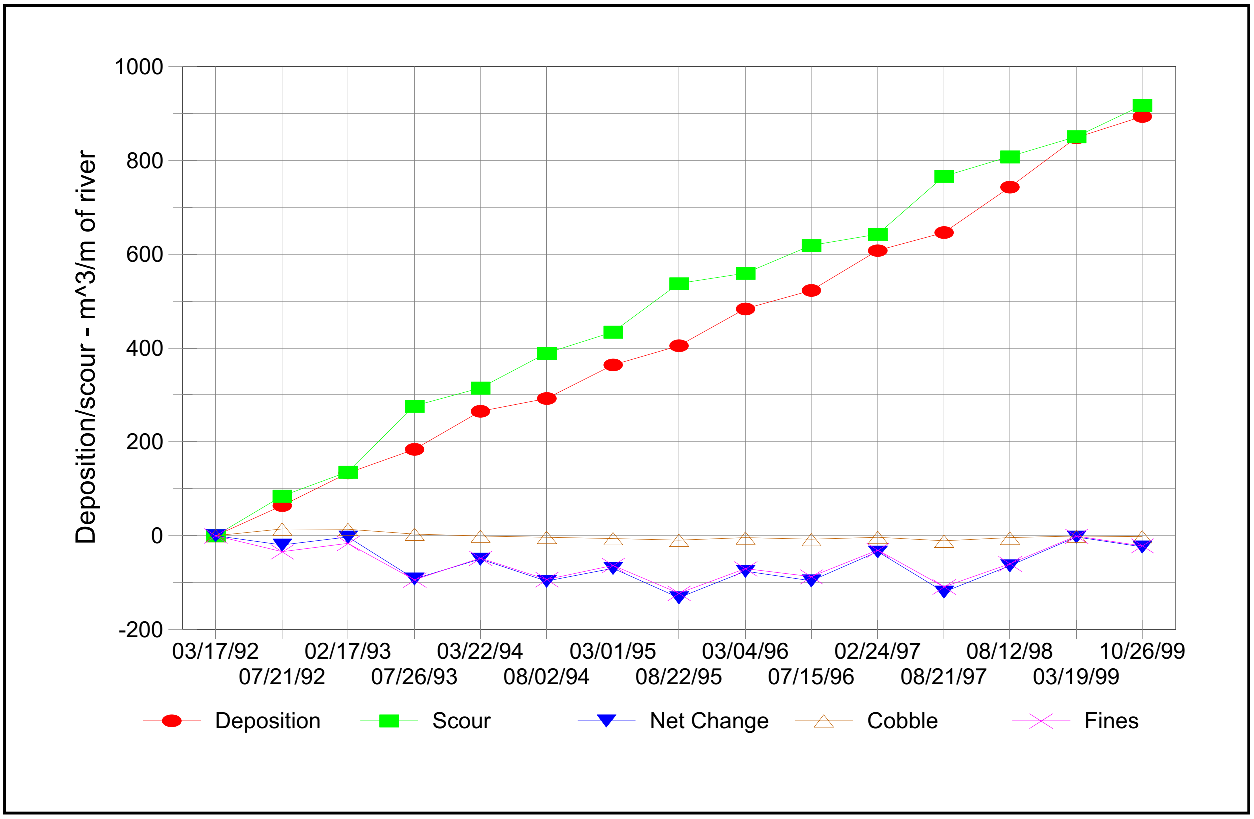


Figure 3.5. Net change in Reach 3-6 Transects, 1992-1999

Table 3.2. Peak discharge and Volume at Bluff (1991 - 1999)

Year	March to July Runoff Volume (ac-ft)	Peak Flow (cfs)
1991	574,000	4,530
1992	1,026,000	8,510
1993	1,681,000	9,650
1994	887,000	8,290
1995	1,504,000	11,600
1996	421,000	3,280
1997	1,279,000	11,300
1998	871,000	8,070
1999	812,000	7,420

The 1999 cross-section surveys and other field data collection were completed after an unusually high flow period in August and the first half of September. The average flow at Bluff between August 1 and September 15, 1999 was nearly 5,900 cfs, with peaks exceeding 8,000 cfs. For this same period in 1992 to 1998, the average flow at Bluff was approximately 1,200 cfs. Since the 1999 runoff season peak was only 7,400 cfs, some of the system cleaning or decrease in average relative bed elevation may be due to the late high flow conditions.

Measurement of Change in Reach 1 Cross-Sections

The mean bed elevation for each Reach 1 transect is shown in Figure 3.6. The average bed elevation for both transects is shown in Figure 3.7. All data were normalized to use the October 1993 survey as the baseline and the relative elevation of each transect was set to 1.0 meter for that survey. These transects are located in a canyon reach that is influenced by Lake Powell. There is approximately 40-ft of sediment, primarily sand, deposited in the bottom of the canyon in this location. This makes the river bottom very mobile. The thalweg is constantly shifting by eroding and depositing sand shoals. Most of the change in the two cross-sections through July 1996 is a result of this erosion and deposition within the cross-sections.

Beginning in 1996, the elevation of the downstream cross-section (CS1-02) began increasing. CS1-01 began increasing in 1997. Both are at maximum in the fall of 1999. Prior to 1995, Lake Powell levels were sufficiently low to not influence this reach. Even though the lake levels were low, rerouting of the channel at RM 0 placed the channel on a sandstone ledge, preventing erosion upstream. In 1995 lake levels reached a level sufficient to submerge the waterfall that had developed at the ledge, but did not markedly impact channel elevations upstream until 1996. Between 1996 and the 1999, the bed elevation gradually increased in response to this backwater effect. A plot of Lake Powell water surface elevation is shown in Figure 3.8. Also shown is the approximate elevation of the waterfall.

Substrate is 100% sand for both of these transects and will remain so regardless of the elevation of the bed. The changes in bed elevation in this reach (below RM 18) are more influenced by Lake Powell than San Juan River discharge.

Cobble Substrate Characterization

Topographic Changes in Cobble Bars

Topographic surveys were completed for the cobble bars at RM 173.7, 168.4, 132 (M-6) and 131 (M-4). The rendered images for the latest survey as well as images for the previous surveys are shown in Figures 3.9, 3.10, 3.11, and 3.12. Each color band represents 15-cm (6-inches) of elevation change. Table 3.3 summarizes the elevation changes of three of the four bars. The cobble bar at RM 131 (M-4) is not included because the survey boundaries have been inconsistent. This will rectified on future surveys.

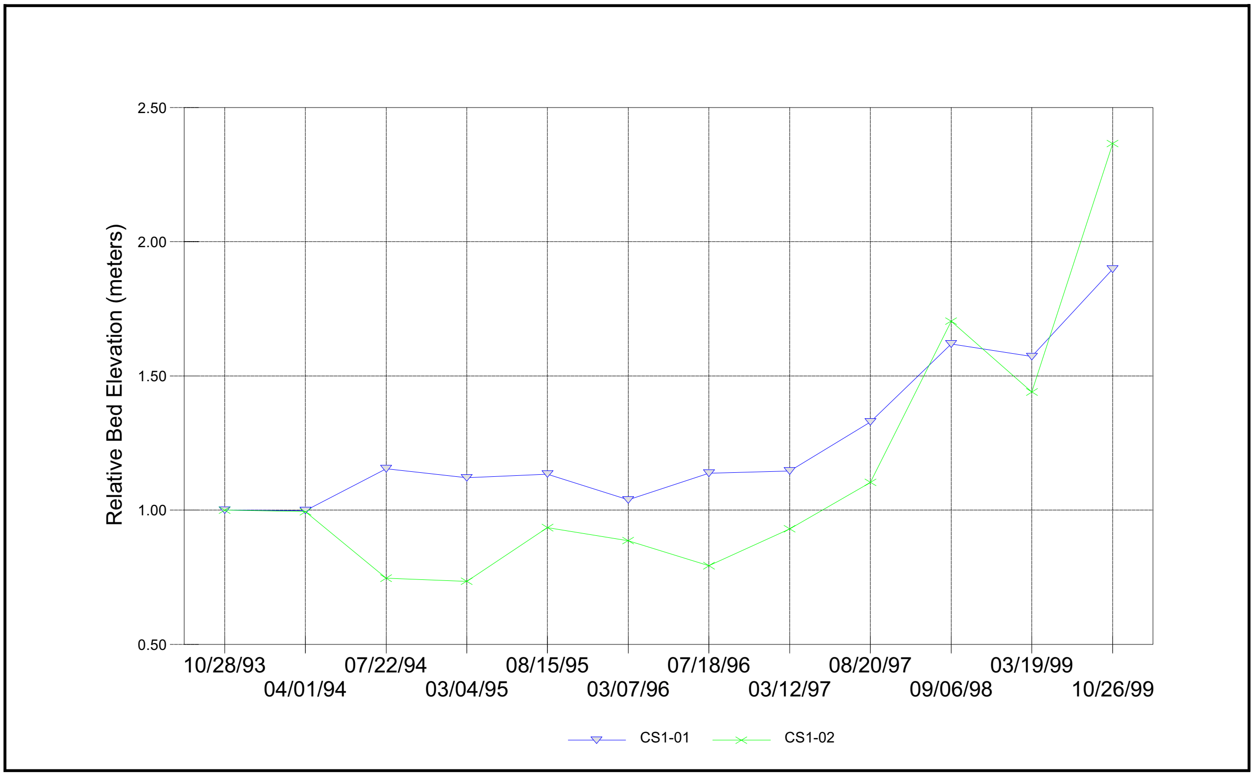


Figure 3.6 Average relative bed elevation for Reach 1 transects, 1993-1999.

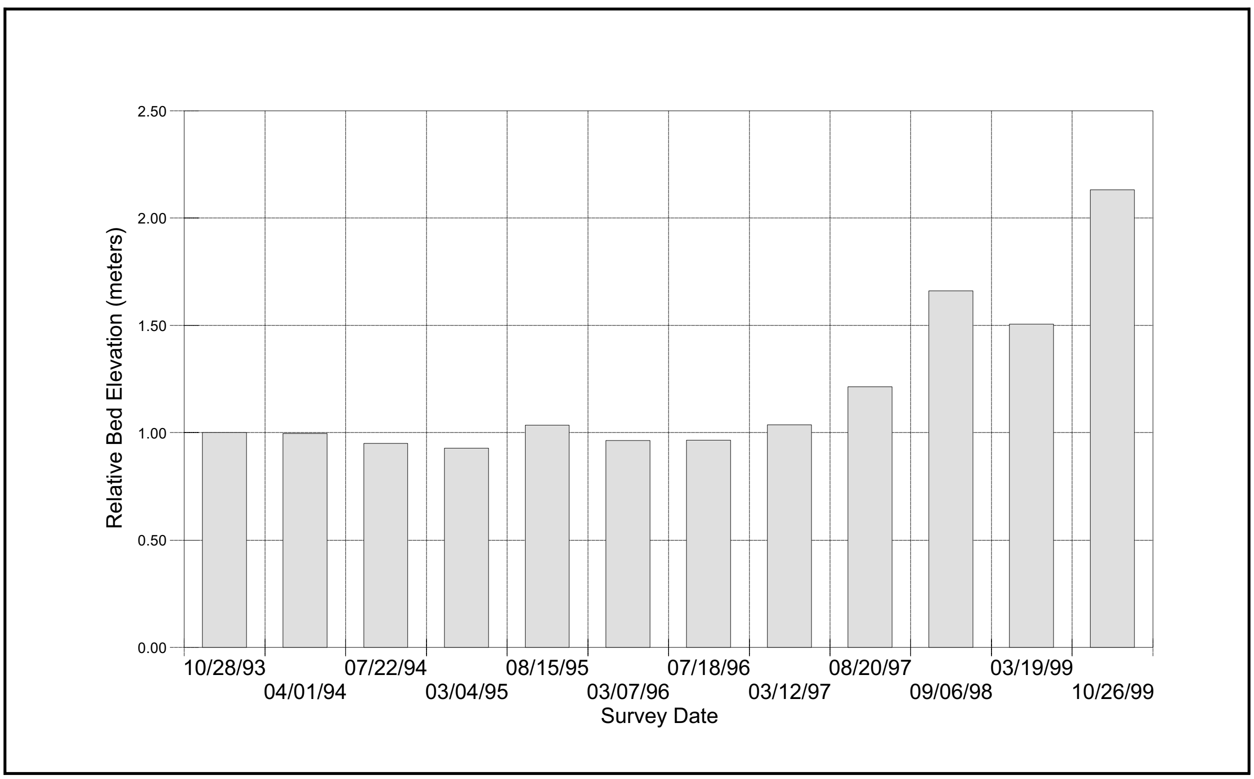


Figure 3.7. Bed elevation averaged for both transects in Reach 1, 1993-1999

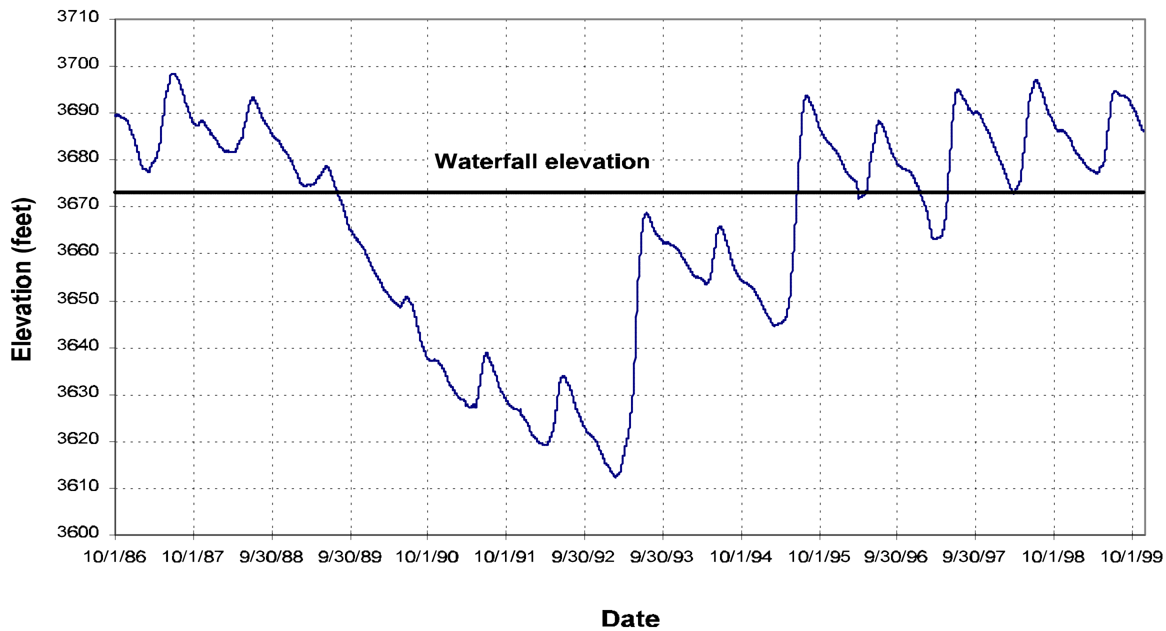


Figure 3.8. Lake Powell water surface elevation, 1986-1999.

Table 3.3. Summary of cobble bar change for bars at RM 173.7, 168.4 and 132.

Survey Date	Average Elev. (M)	Change in Elev. (m)	Max Elev. (m)	Min Elev. (m)
	Bar at RM 173.7			
04/02/96	30.48		28.90	27.13
07/08/96	30.52	3.7	28.80	27.28
08/22/97	30.41	-10.4	28.96	26.76
08/10/98	30.44	3.0	28.90	26.70
11/15/99	30.43	-1.2	28.93	26.82
	Bar at RM 168.4			
04/03/96	30.48		29.00	27.86
07/09/96	30.47	-0.9	28.99	27.46
08/22/97	30.50	2.4	28.99	27.91
07/29/98	30.54	4.3	29.11	27.84
11/16/99	30.60	6.7	29.43	28.00
	Bar at RM 132			
03/08/95	30.48		28.73	26.91
07/25/95	30.57	8.5	28.80	27.19
03/13/96	30.56	-0.9	28.68	27.04
07/10/96	30.54	-1.5	28.55	27.00
08/21/97	30.64	10.7	28.52	26.76
08/11/98	30.68	3.7	28.67	27.06
10/28/99	30.76	7.9	28.69	27.28

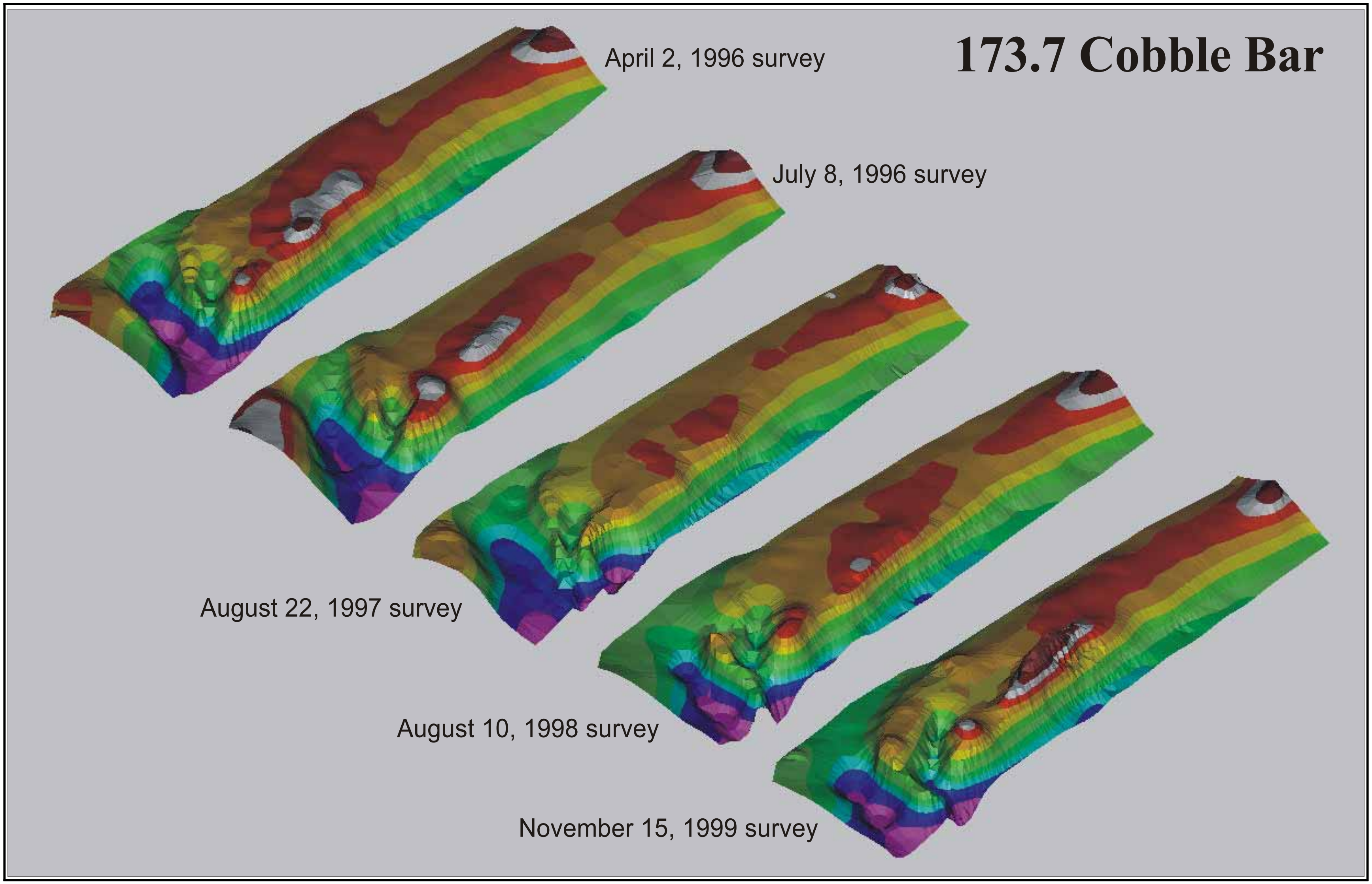


Figure 3.9. Topography of cobble bar at RM 173.7, 1993-1999

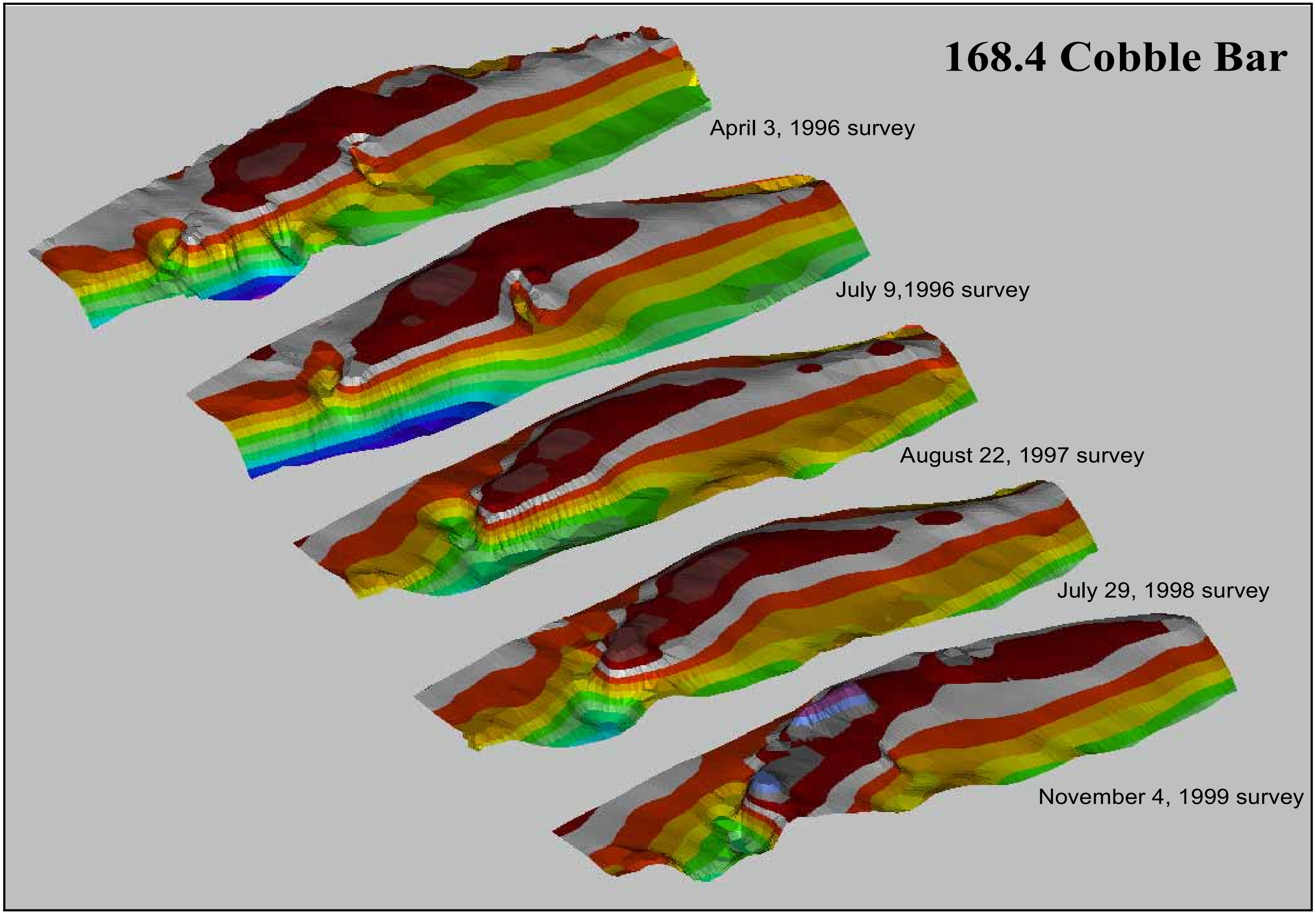


Figure 3.10. Topography of cobble bar at RM 168.4, 1993-1999.

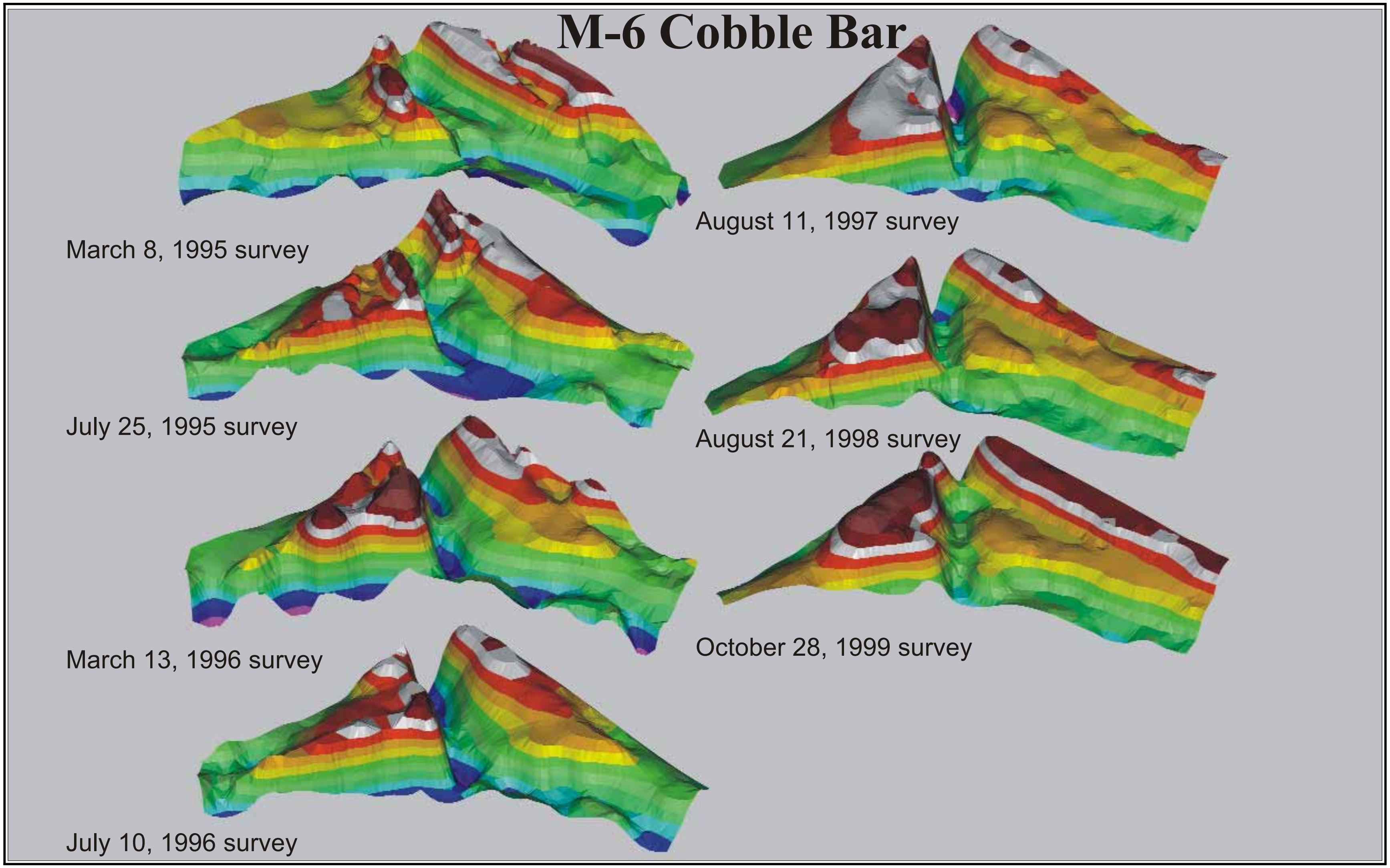


Figure 3.11. Topography of cobble bar at RM 132, 1995-1999.

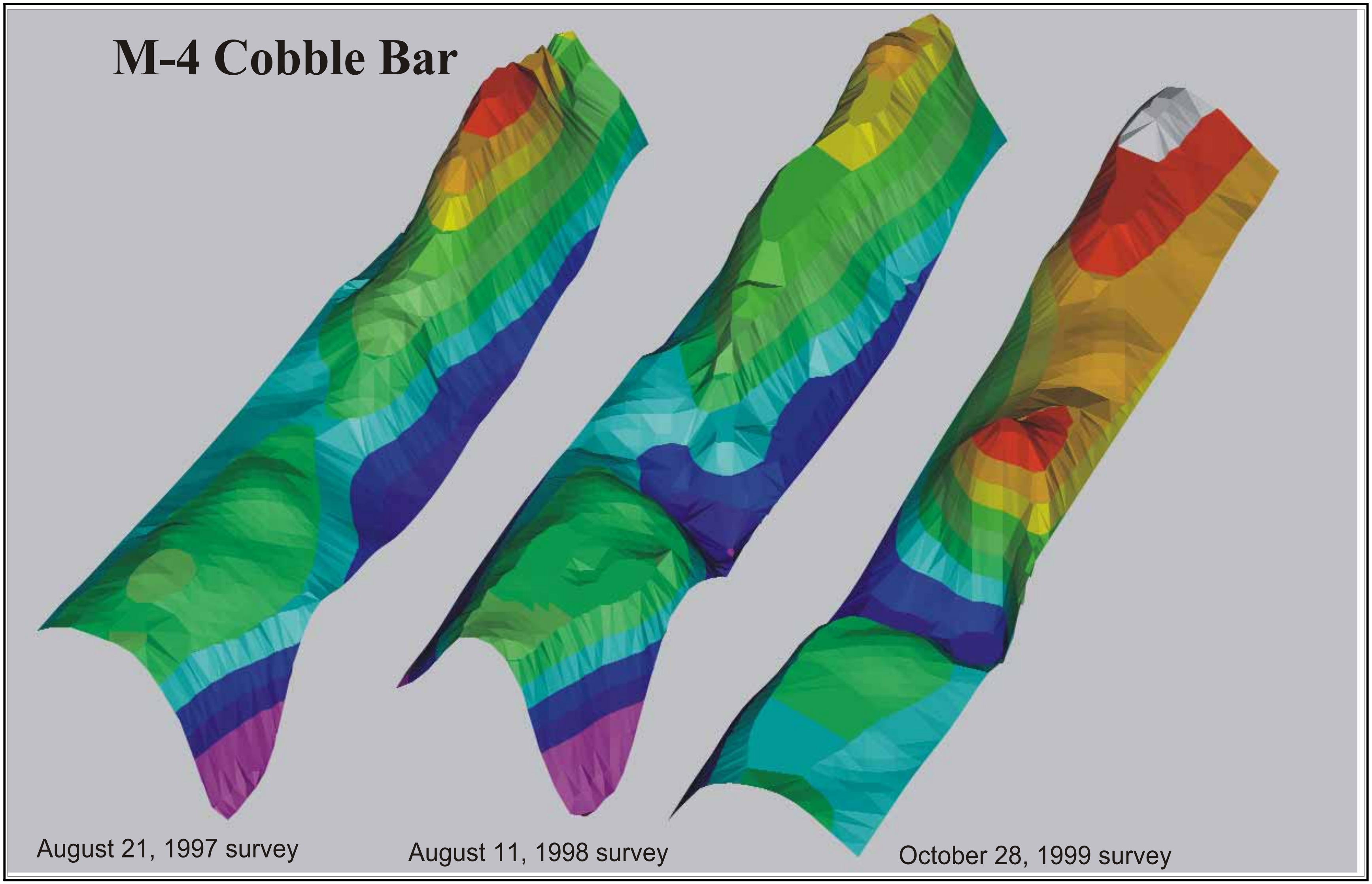


Figure 3.12. Topography of cobble bar at RM 131, 1997-1999

The cobble bar at RM 173.7 showed slight overall scour of 1.2 cm. This is within survey error so the average elevation was essentially unchanged. Both the maximum and minimum elevation increased. Figure 3.13 shows areas of deposition and scour between the 1998 and 1999 survey. The top image in each figure shows areas of deposition and the bottom image shows areas of scour. The deposition and scour has been separated to more clearly illustrate how the bar changed between the 1998 and 1999 surveys.

The cobble bars at 168.4 and 132 were depositional in 1999 and have been since 1996. Both the minimum and maximum elevations increased from 1998 to 1999 further showing deposition. Figures 3.14 and 3.15 show areas of deposition and scour for both 132 (M-6) and 168.4.

Characterization of Bed Material

Table 3.4 shows the surface substrate composition for the 1999 pre- and post-runoff surveys of the Reach 3-6 transects. The pre-runoff survey averaged 69% sand and 31% cobble. The post-runoff survey averaged 55% sand and 45% cobble. The increase in the cobble percentage in the post-runoff survey shows that some fines were flushed from the system during runoff. Figure 3.16 shows the composition of the scour and deposition that occurred at each of the Reach 3-6 transects. Most of the material moved was fines. However, there was some cobble movement at most of the transects, particularly at CS4-02. This occurred with a 7,400 cfs peak at Bluff. Figure 3.17 simply shows the percent cobble substrate for all surveys of the Reach 3-6 transects.

The cobble size distribution for each of the four surveyed cobble bars is shown in Table 3.5. In all cases, the cobble size is somewhat larger than in 1998, but as large, on average as 1996, the year with the largest cobble. In general, the cobble size is not correlated to river mile within the sample range (RM 131 - 173.7) and there are no increasing or decreasing trends.

Depth of Open Interstitial Space

Depth of open interstitial space was also measured at each cobble bar. Figures 3.18 through 3.21 show three-dimensional plots of the four cobble bars at river mile 173.7, 168.4, 132 (M-6) and 131 (M-4) for the post-runoff 1999 survey. The “posts” seen on the surface of each image represent the depth of open interstitial space as measured at that point. Each color band on the posts indicate 1-cm of embeddedness or open interstitial space. The higher posts represent areas with greater open interstitial space.

Figures 3.22 and 3.23 show the frequency distribution of depth of open interstitial space for cobble bar 173.7. The depth is expressed in centimeters in the top plot and as multiples of the d50 cobble size in the bottom plot. Similar data are shown in Figures 3.24 to 3.29 for the cobble bars at 168.4, 132 (M-6) and 131 (M4). The actual area represented by a particular depth of exceedence is shown in Figures 3.30 to 3.33. These figures may be used to put the relative size of the cobble bars in perspective. The cobble bar at 173.7 and 168.4 are over 5,000 m^2 while the bar at 131 (m-4) is only 1,000 m^2. In these plots the area represented by a single reading is the average area which is calculated by dividing the gross area by the number of readings.

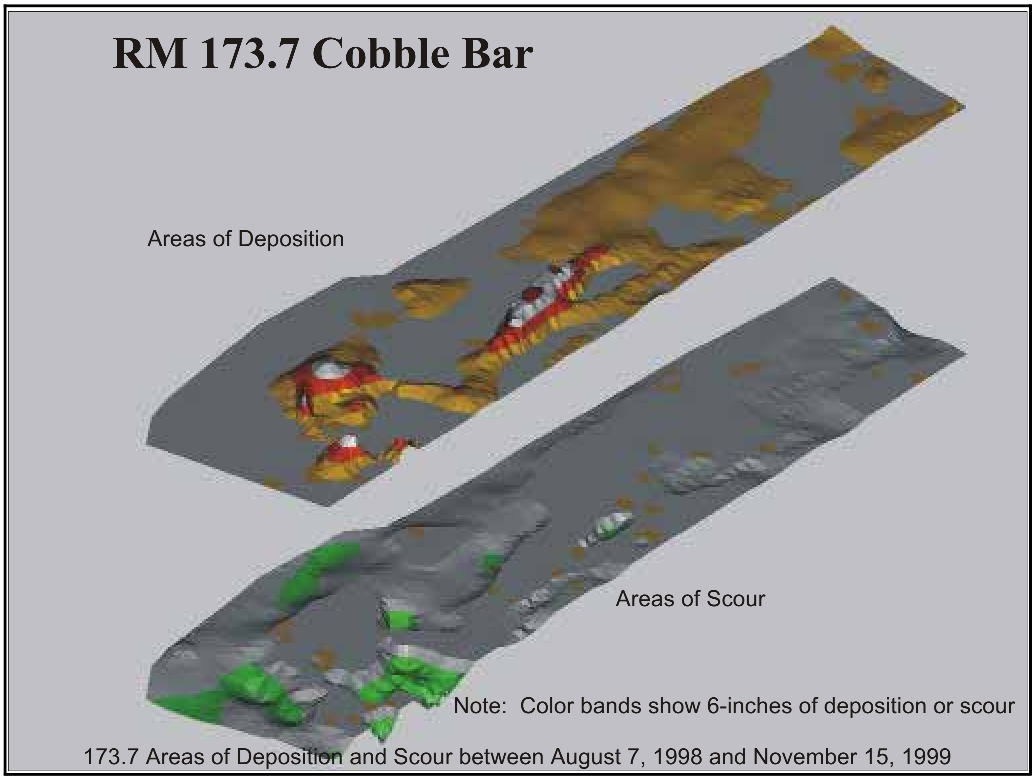


Figure 3.13. Areas of scour and deposition pre- to post-runoff for the RM 173.7 cobble bar.

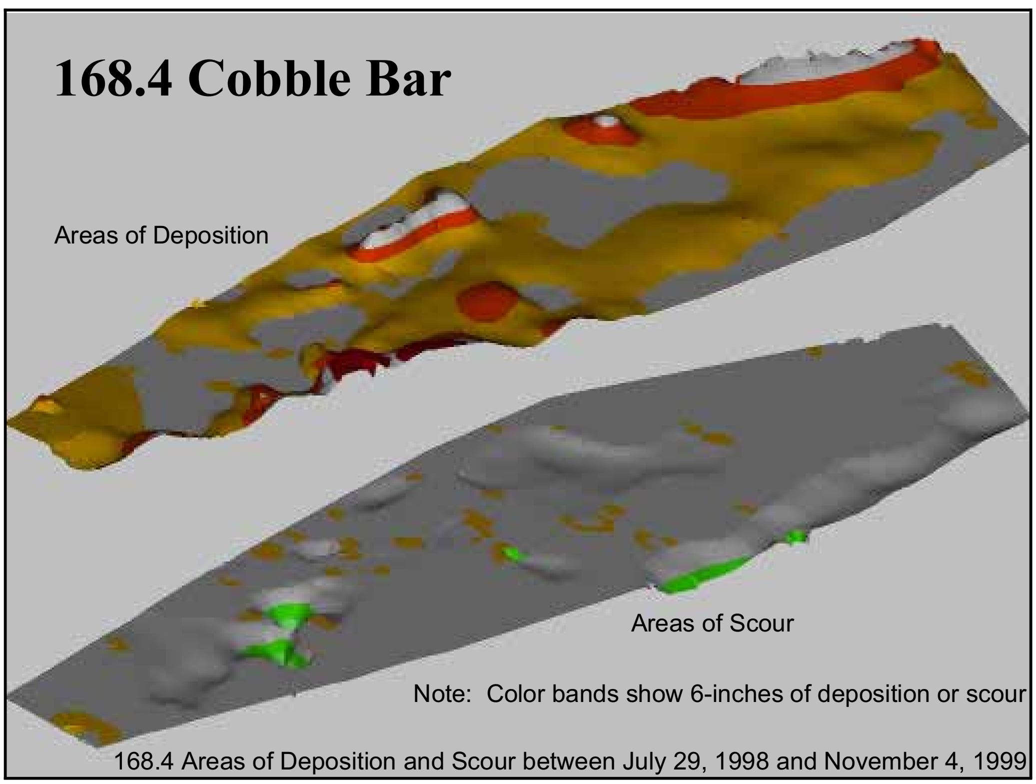


Figure 3.14. Area of scour and deposition pre- to post-runoff for the RM 168.4 cobble bar.

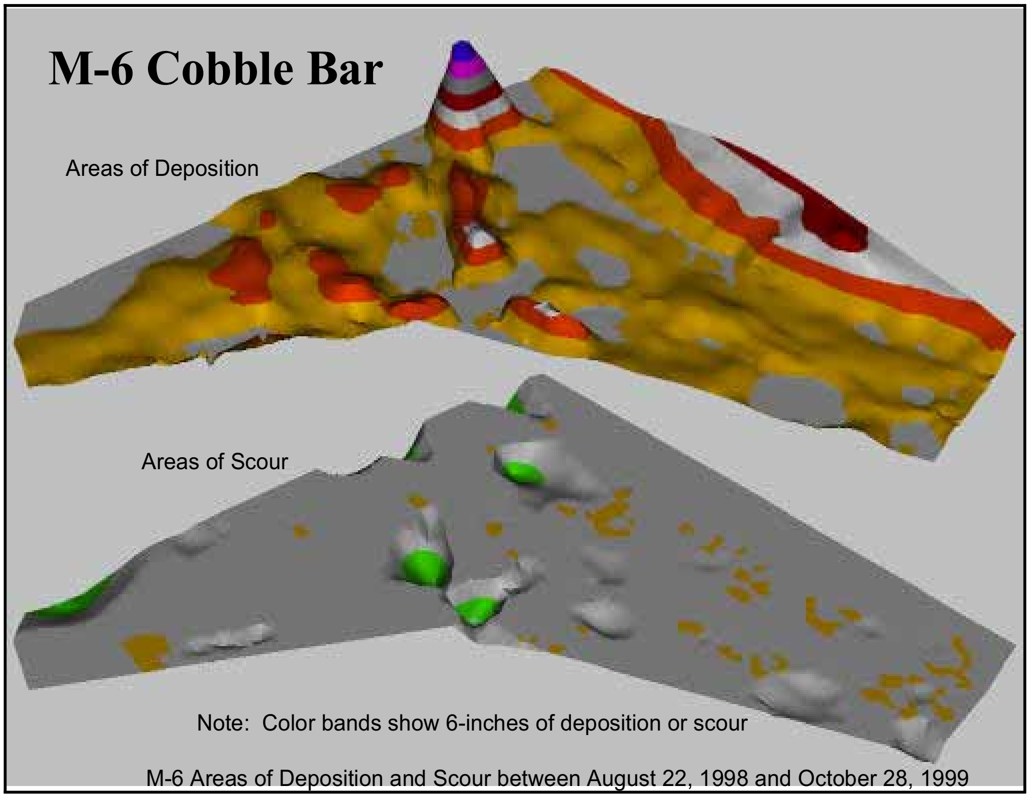


Figure 3.15. Area of scour and deposition pre- to post-runoff for the RM 132 cobble bar.

Table 3.4. Summary of percent cobble substrate, pre- and post-runoff, 1999 for Reach 3-6 transects.

Survey date	03/19/99	10/26/99
Transect	percent cobble	
CS6-02	0%	20%
CS6-03	38%	56%
CS5-01	31%	62%
CS5-02	42%	47%
CS5-03	42%	43%
CS4-01	9%	20%
CS4-02	60%	72%
CS3-01	19%	34%
CS3-02	58%	64%
CS3-03	7%	26%
Average	31%	45%

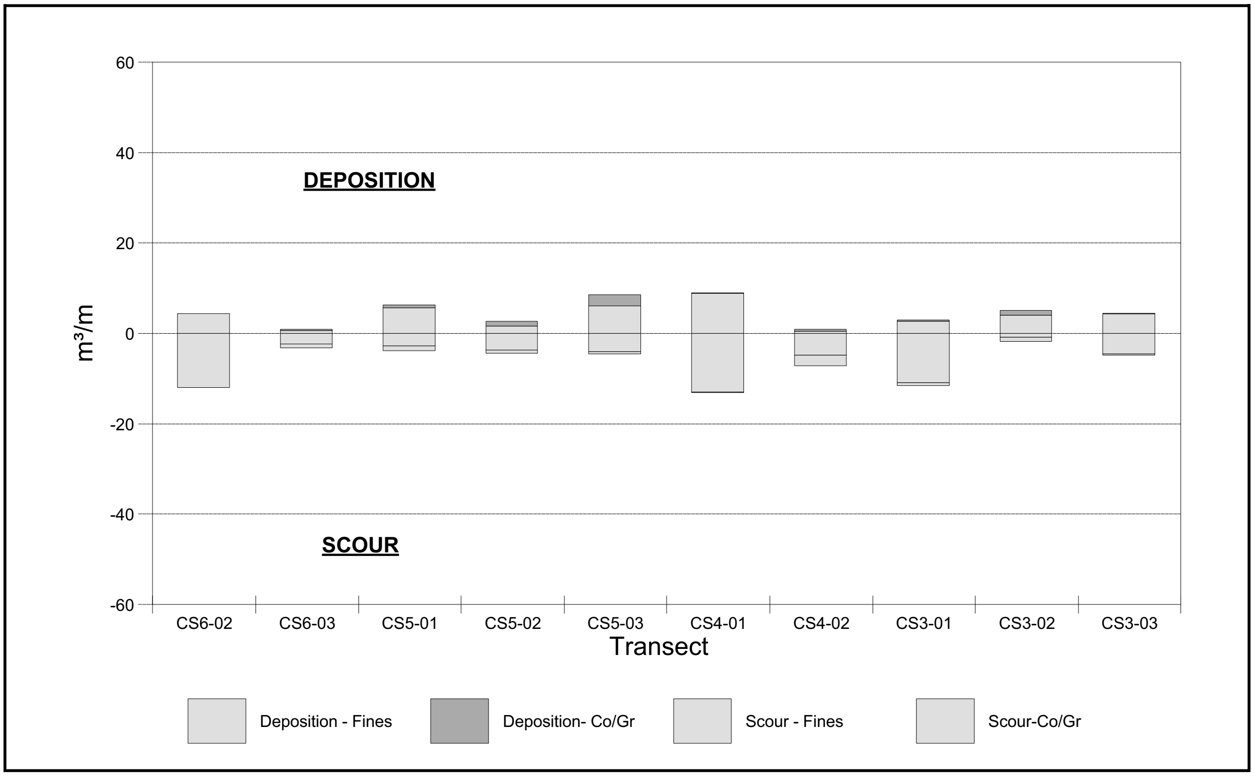


Figure 3.16. Scour and deposition composition at Reach 3-6 transects between pre- and post-runoff, 1999.

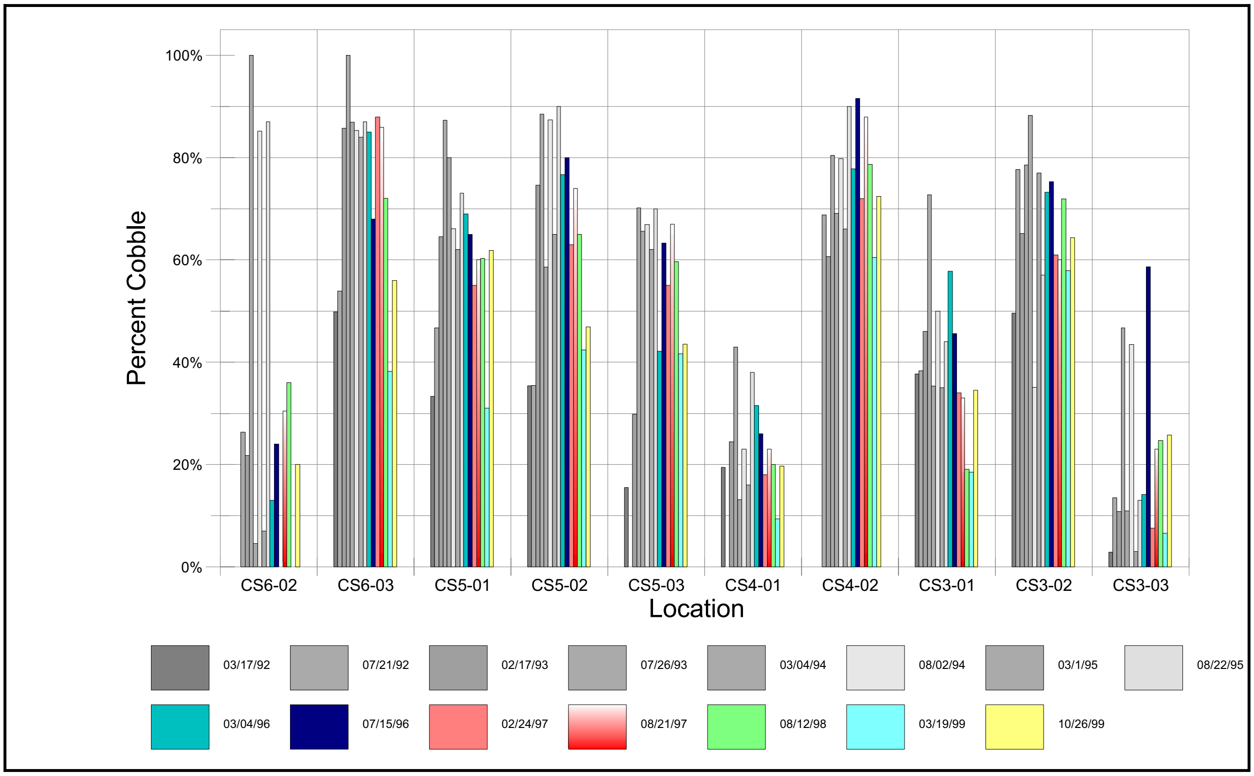


Figure 3.17. Cobble percentage at each transect, 1992-1999.

Table 3.5. Cobble size distribution for the four surveyed cobble bars.

Year	1995	1996	1997	1998	1999
Size Fraction	Cobble Size - cm				
			RM 173.7		
D84	n/a	9.93	12.57	12.02	16.68
D75	n/a	7.95	8.00	10.33	13.17
D50	n/a	4.83	3.79	6.96	8.03
D25	n/a	3.03	2.19	4.72	4.41
D16	n/a	2.59	1.69	3.89	3.33
			RM 168.8		
D84	10.97	14.65	10.45	11.24	11.91
D75	10.17	12.62	10.00	9.94	11.00
D50	7.21	8.38	6.25	6.79	7.45
D25	4.94	4.99	4.33	4.65	5.41
D16	4.57	4.58	3.65	3.64	4.64
			RM 132 (M6)		
D84	8.64	11.64	9.90	9.49	9.98
D75	7.28	10.64	8.38	8.18	8.52
D50	5.10	7.79	6.58	5.91	6.04
D25	3.35	5.54	4.88	3.70	4.08
D16	2.75	4.60	4.40	3.03	3.44
			RM 131 (M4)		
D84	6.48	10.82	7.88	8.49	9.98
D75	5.43	9.81	7.06	6.95	8.50
D50	4.17	7.96	5.20	4.64	6.64
D25	2.80	6.58	3.56	2.54	4.68
D16	2.09	5.60	2.76	1.92	4.15

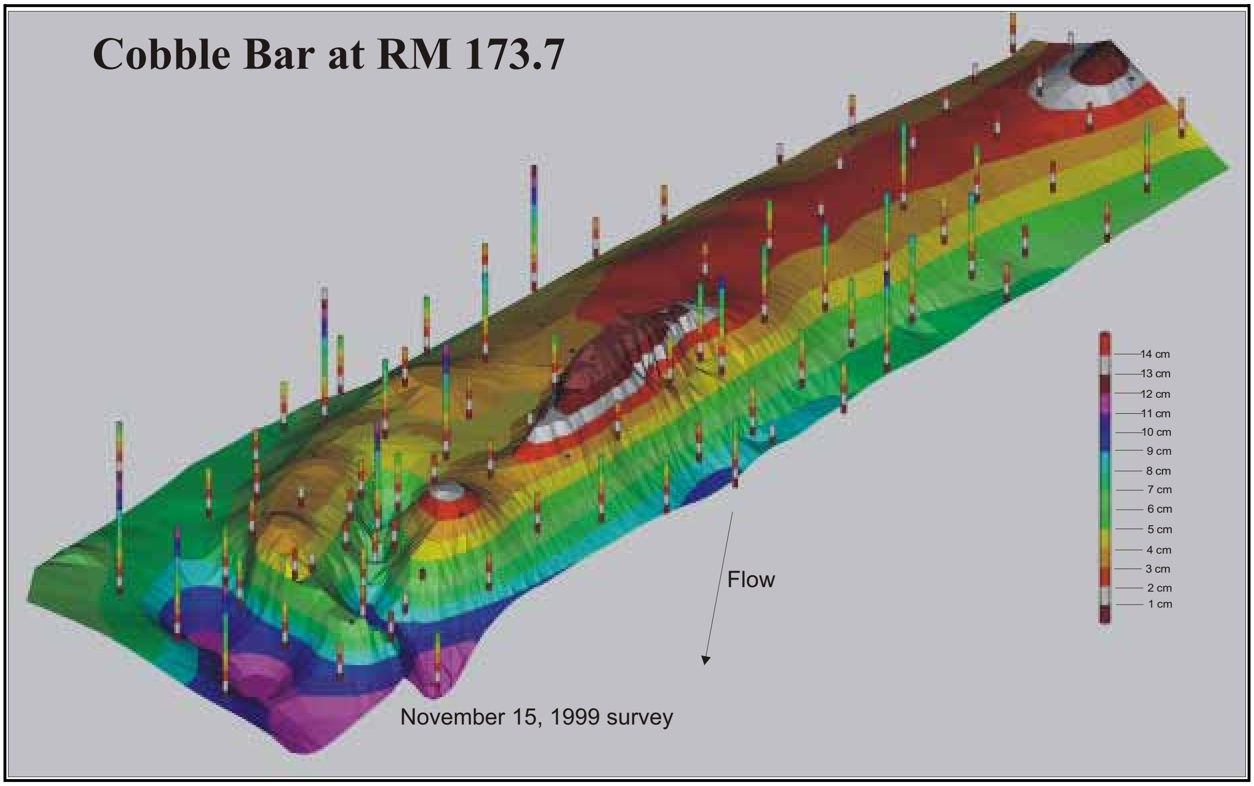


Figure 3.18. November 15, 1999 survey with embeddedness markers.

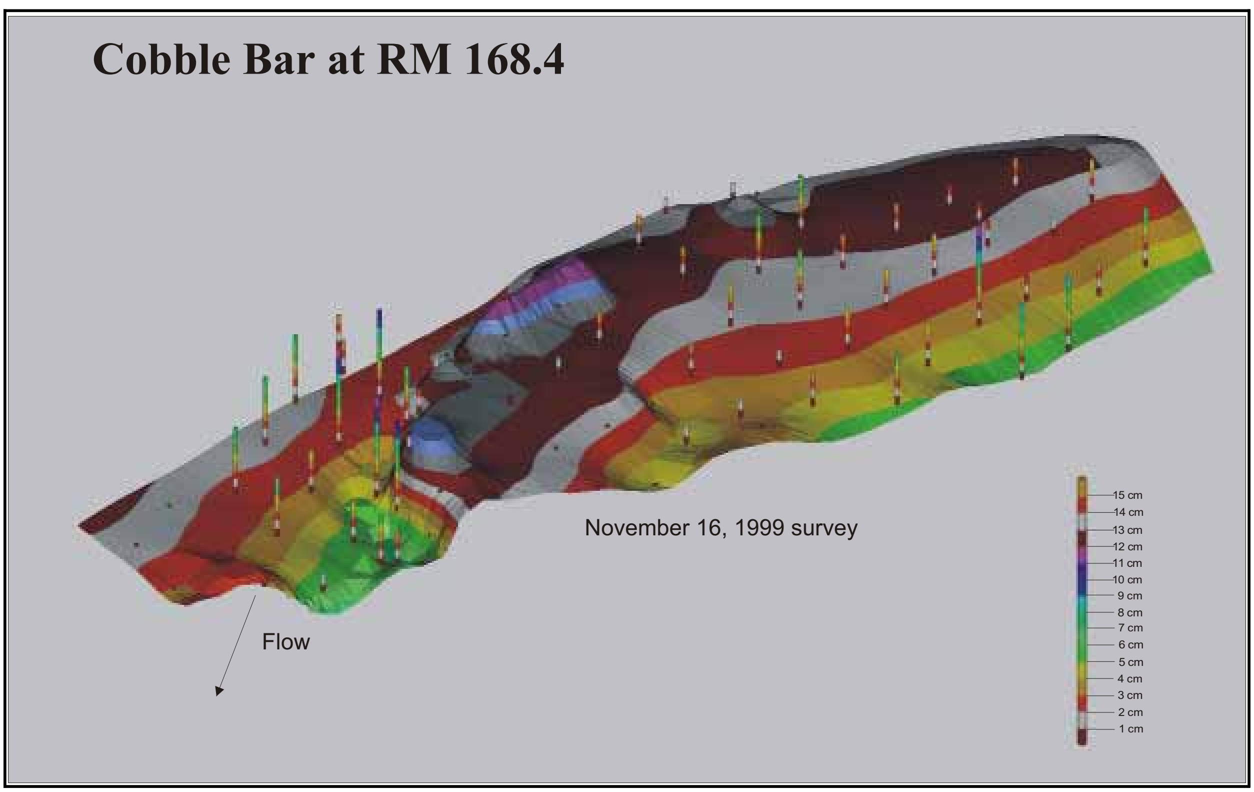


Figure 3.19. November 16, 1999 survey with embeddedness markers.

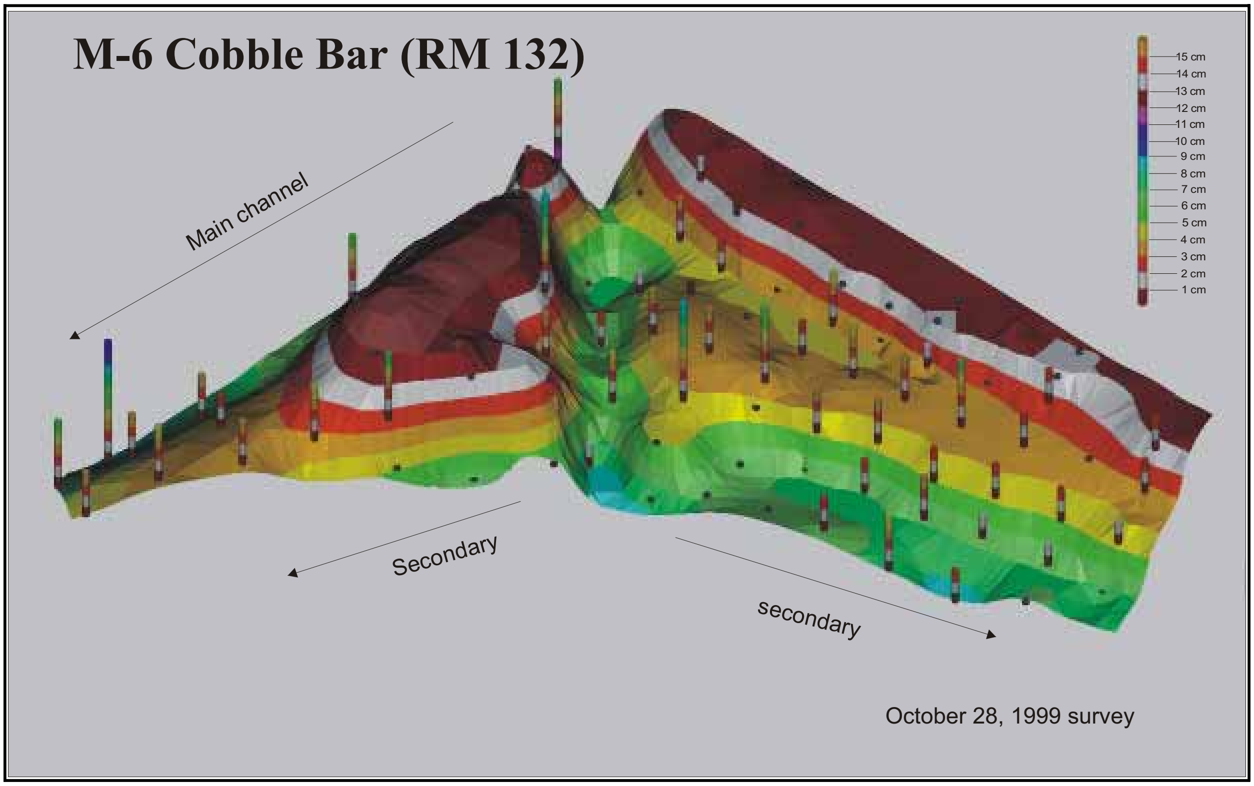


Figure 3.20. October 28, 1999 survey with embeddedness markers.

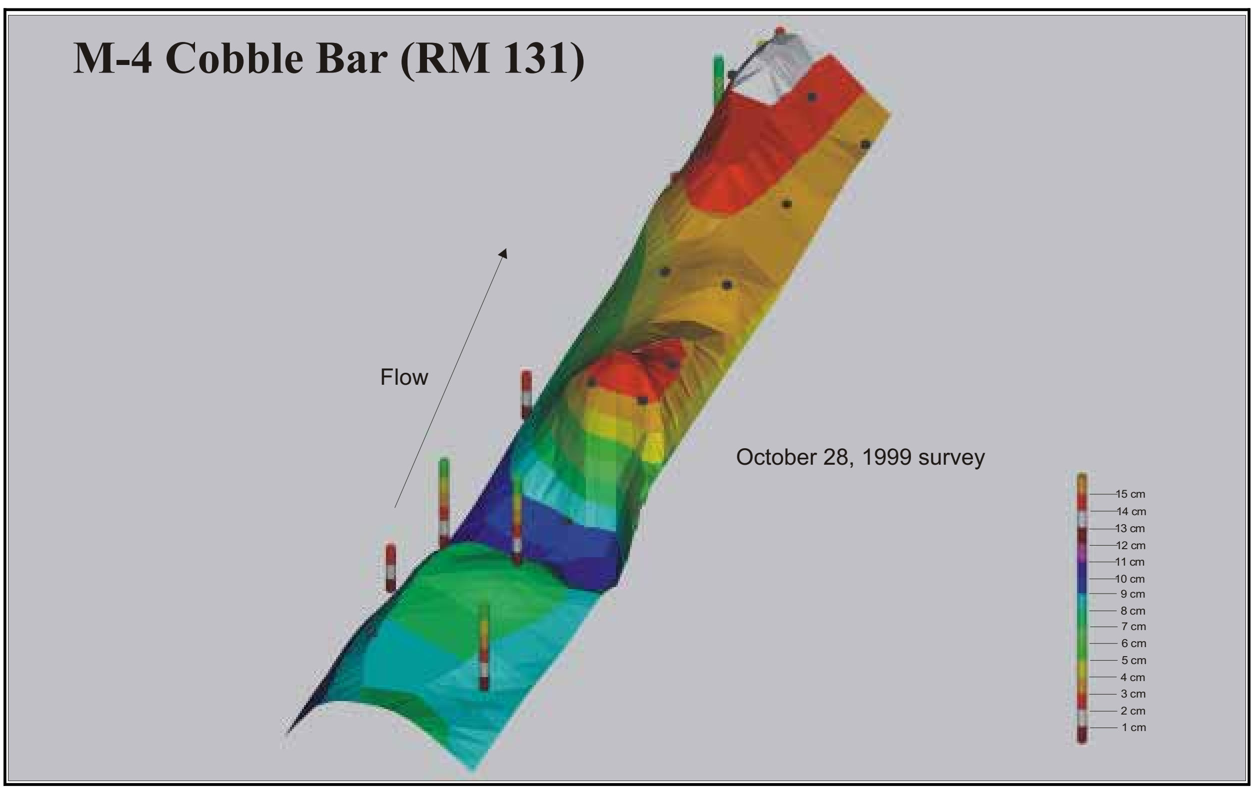


Figure 3.21. October 28, 1999 survey with embeddedness markers.

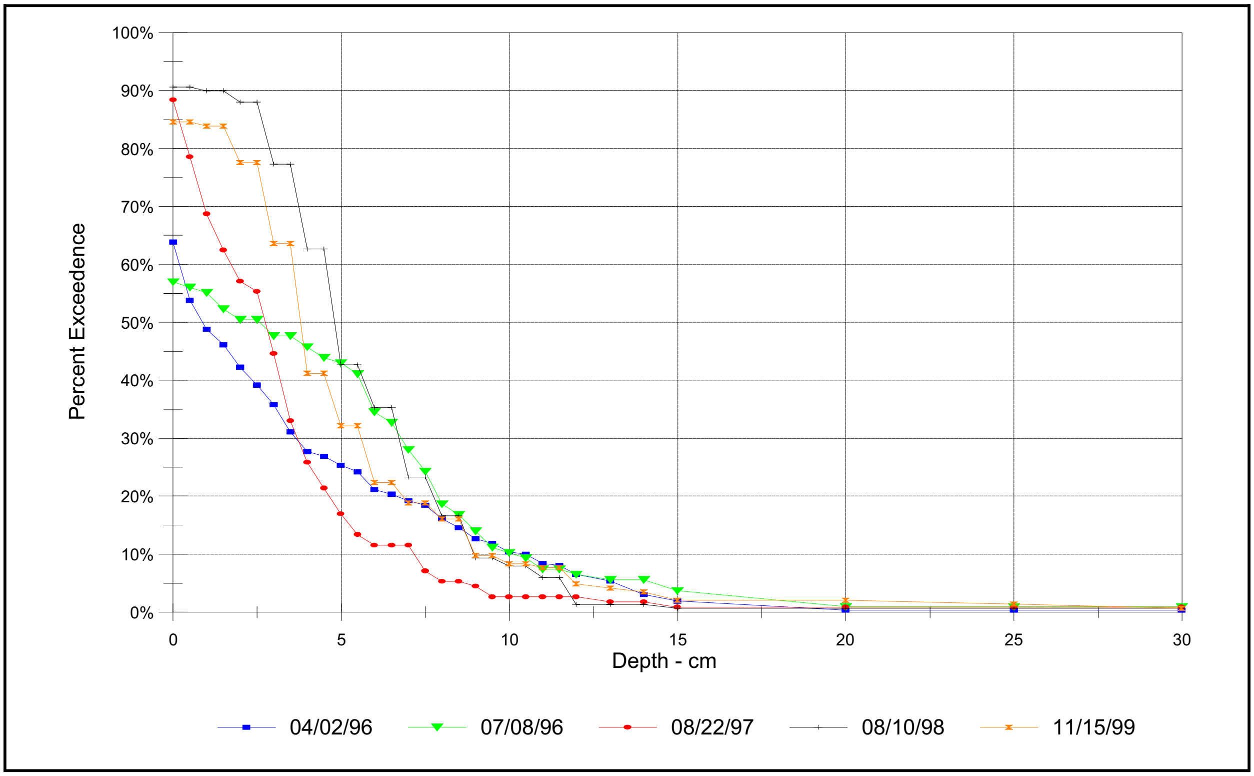


Figure 3.22. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 173.7 expressed in cm.

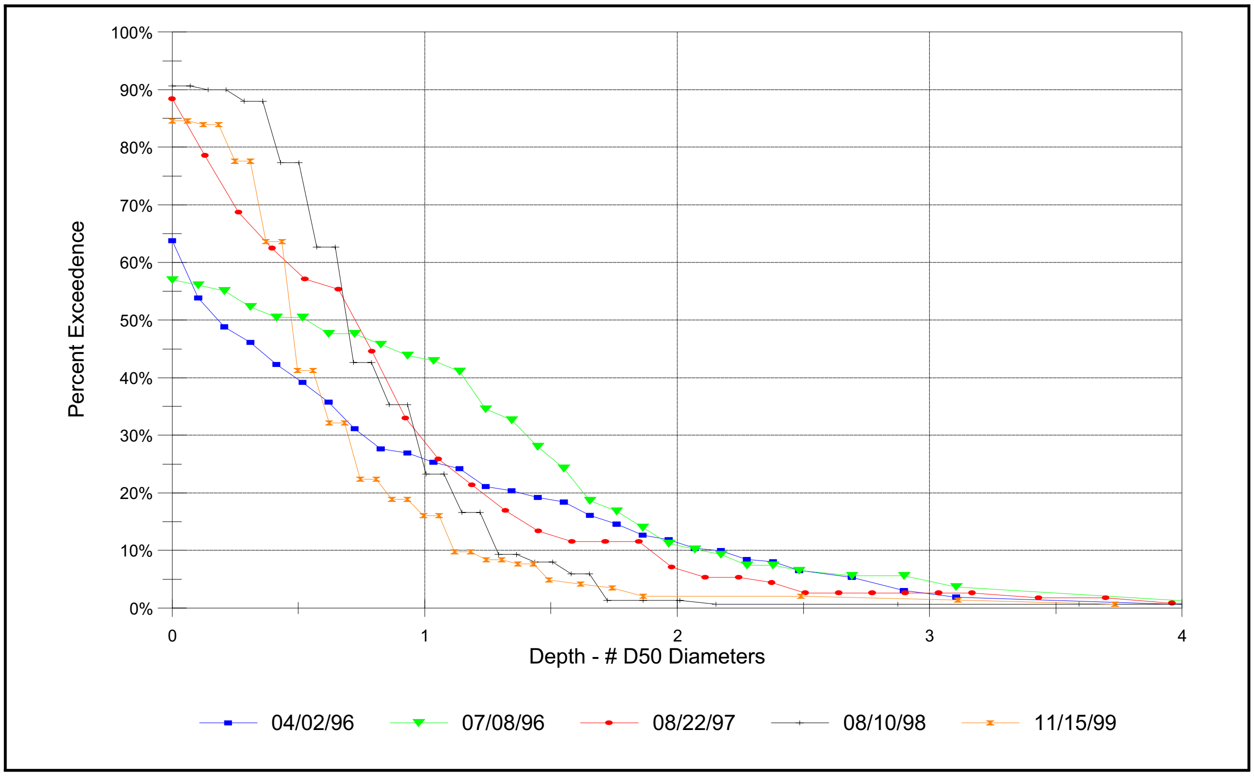


Figure 3.23. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 173.7 expressed in d50 cobble size.

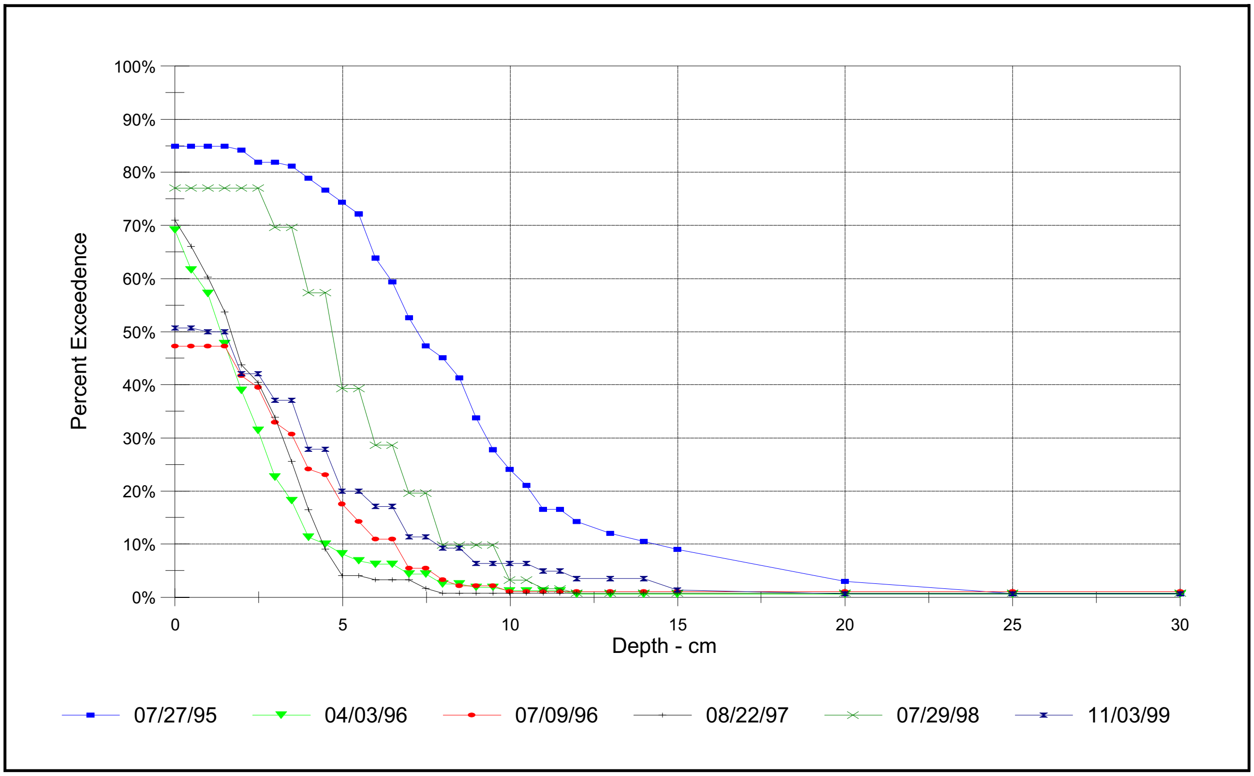


Figure 3.24. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 168.4 expressed in cm.

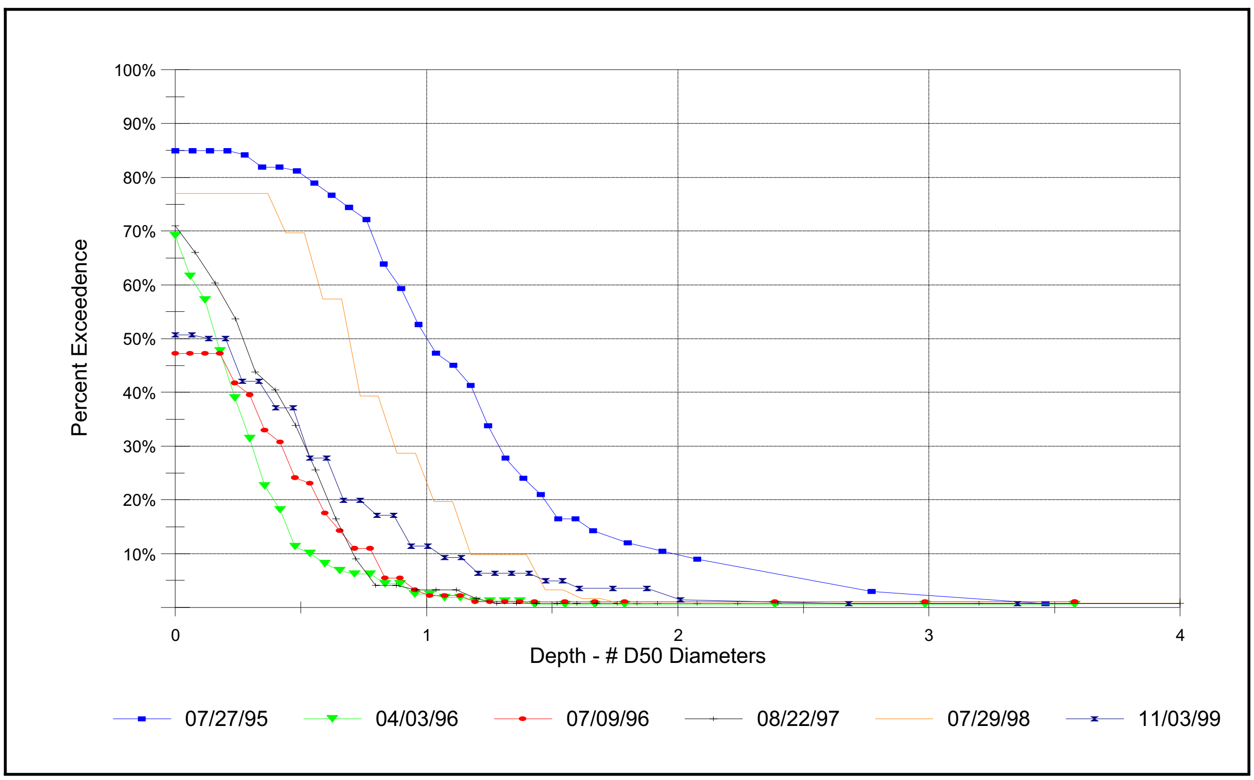


Figure 3.25. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 168.4 expressed in d50 cobble size.

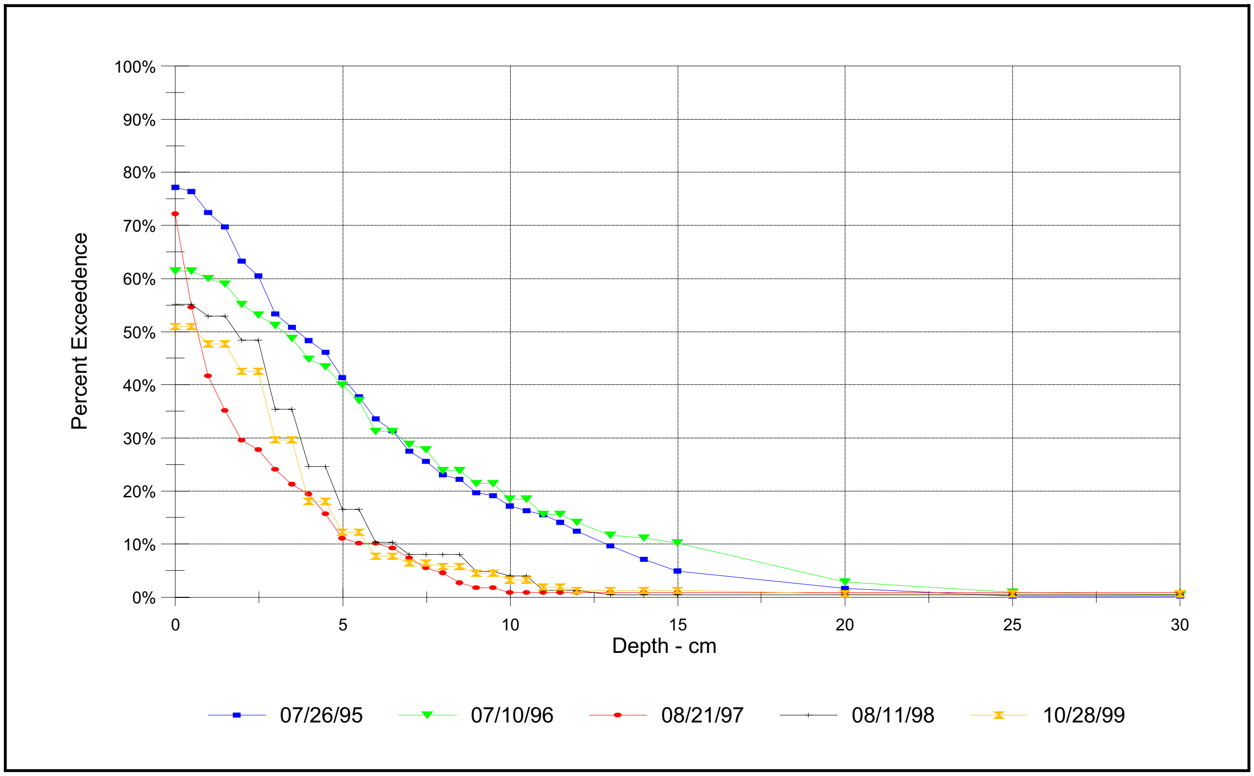


Figure 3.26. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 132 (M-6) expressed in cm.

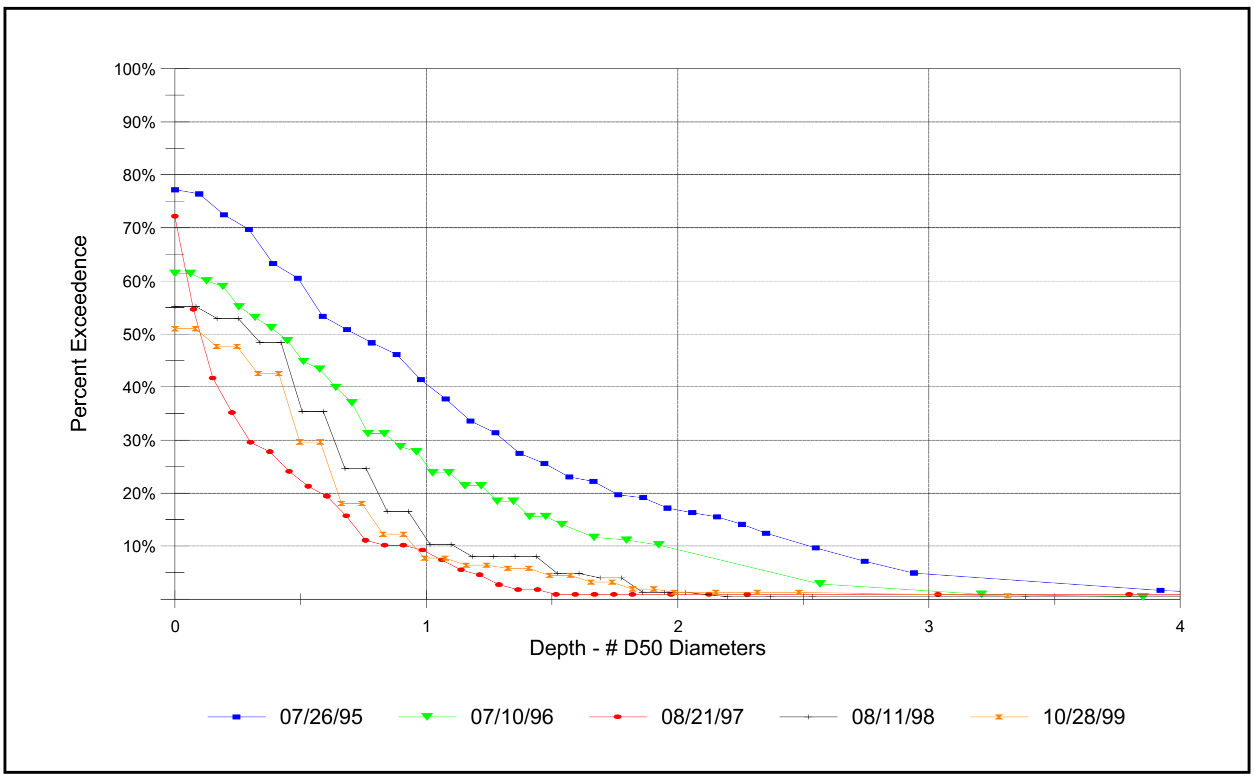


Figure 3.27. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 132 (M-6) expressed in d50 cobble size.

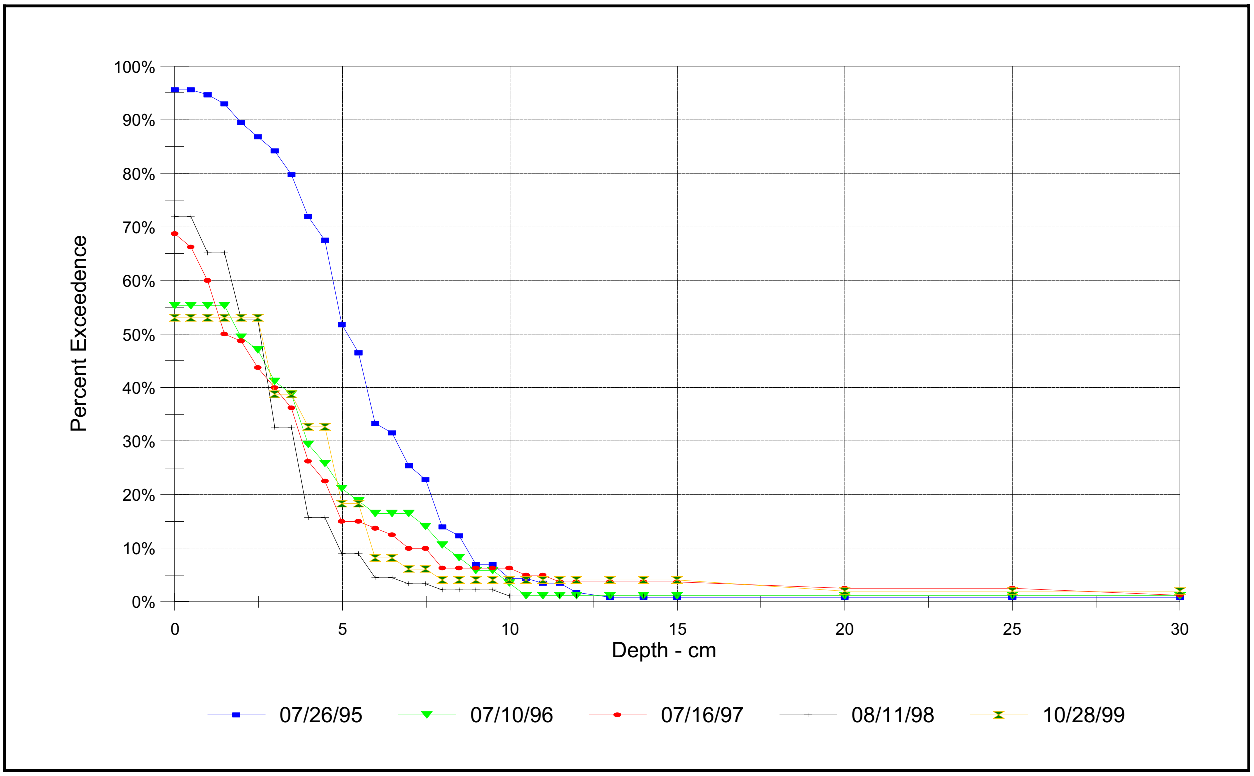


Figure 3.28. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 131 (M-4) expressed in cm.

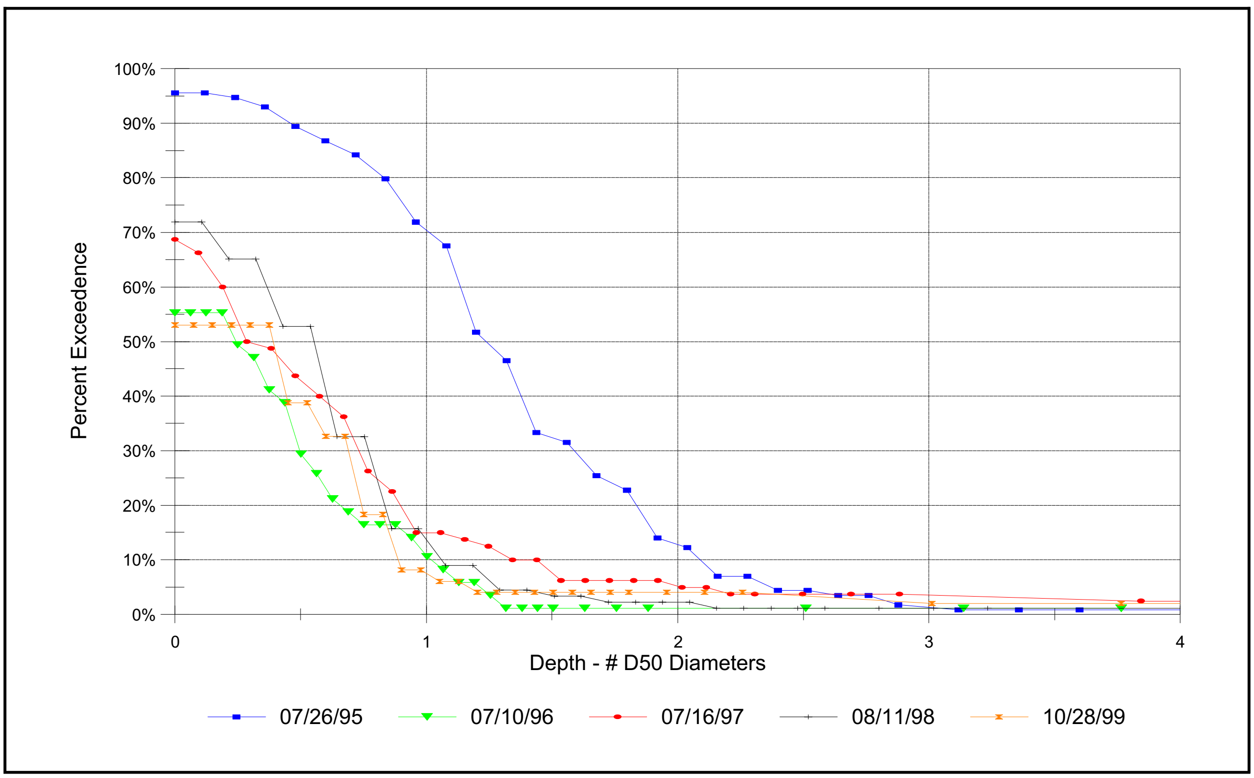


Figure 3.29. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 131 (M-4) expressed in d50 cobble size.

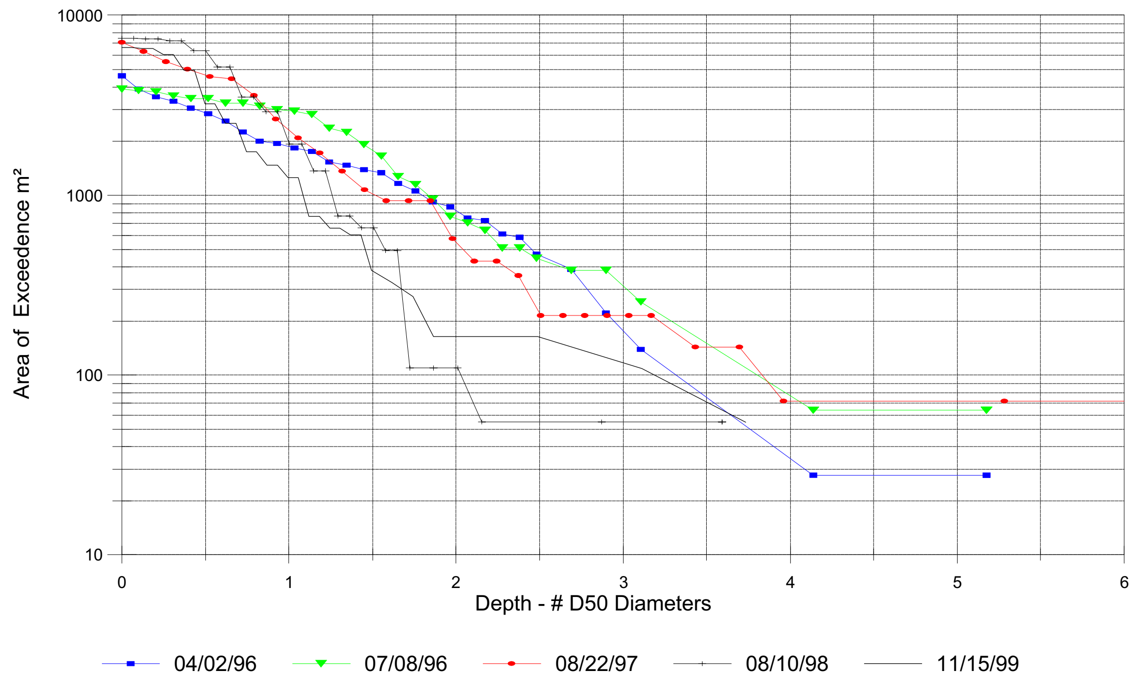


Figure 3.30. Area of Depth of Open Interstitial Space Exceedence for 173.7.

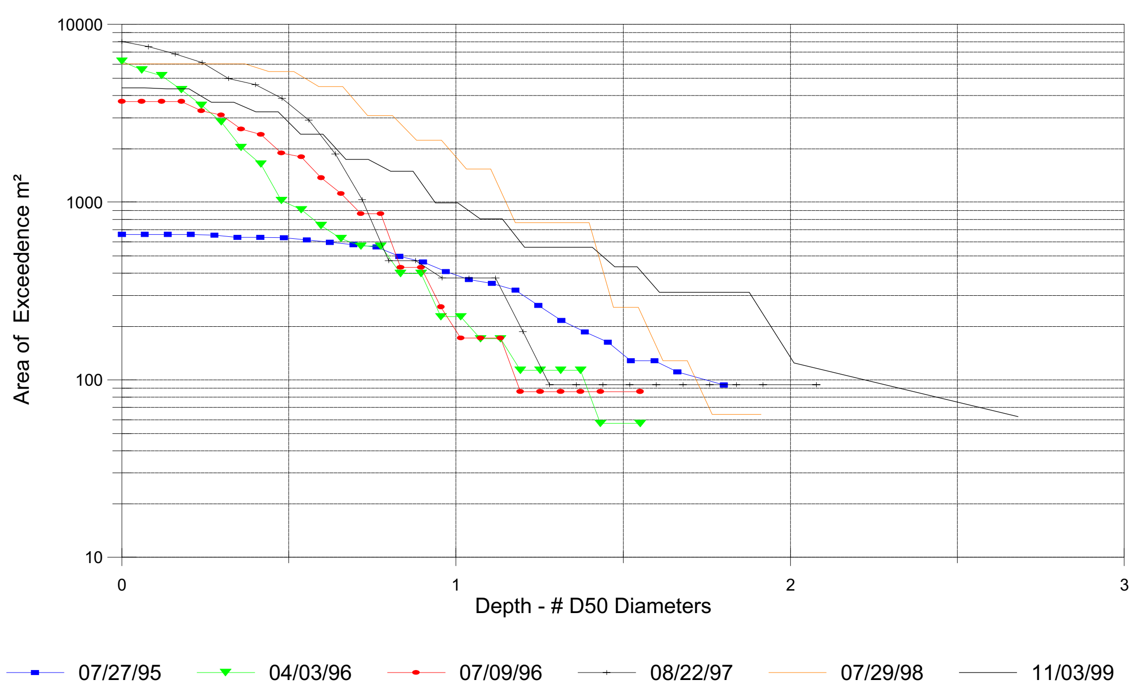


Figure 3.31. Area of Depth of Open Interstitial Space Exceedence for 168.4.

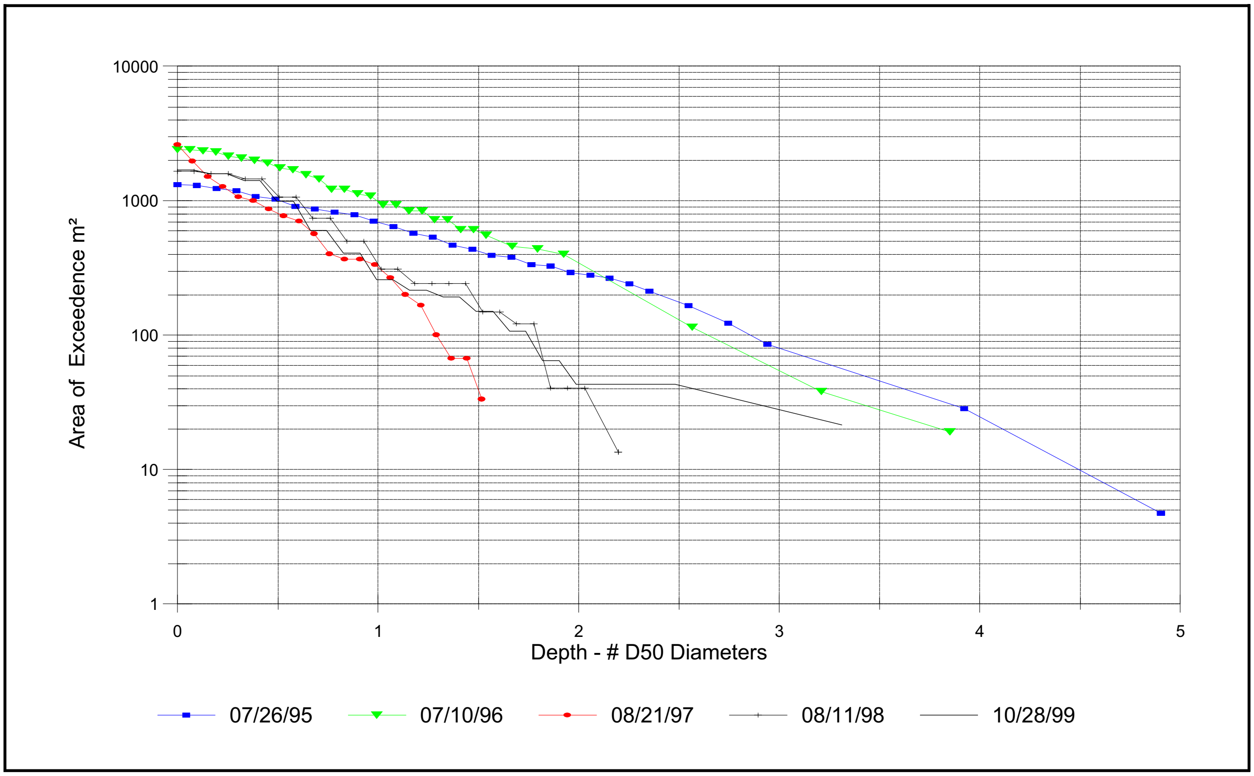


Figure 3.32. Area of Depth of Open Interstitial Space Exceedence for 132 (M-6).

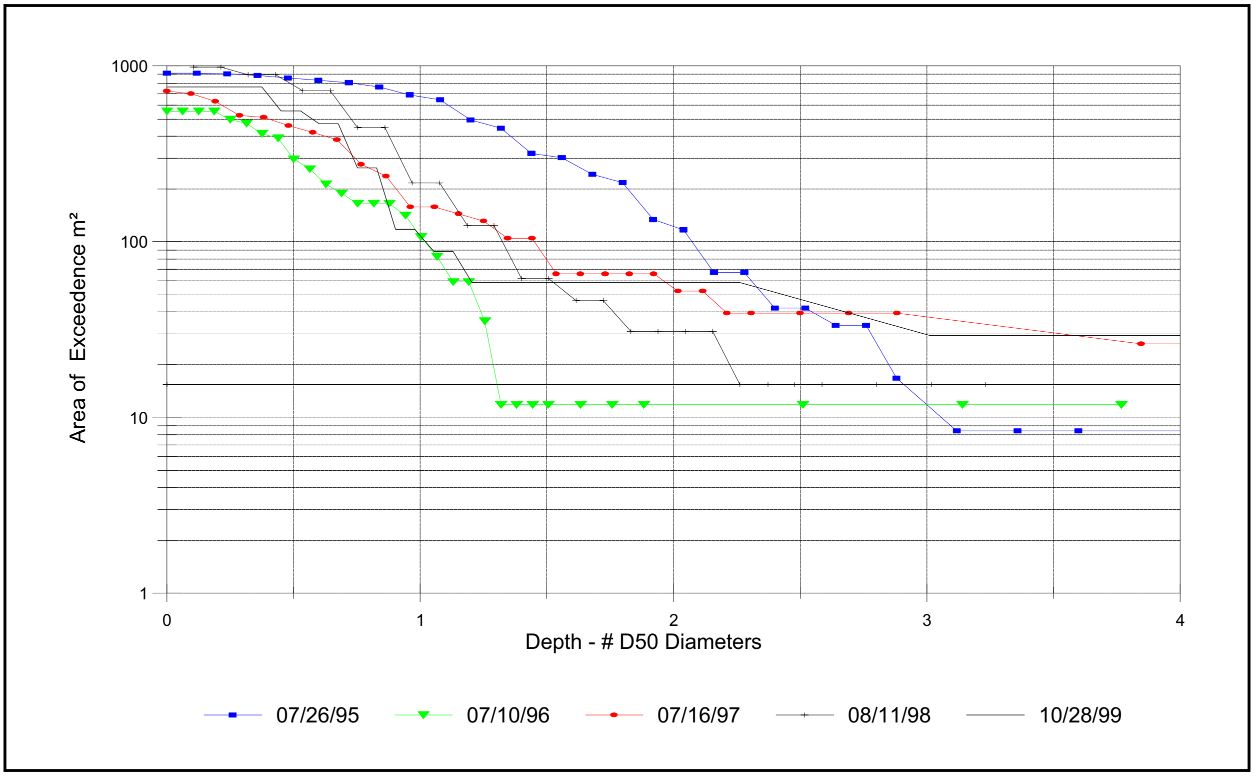


Figure 3.33. Area of Depth of Open Interstitial Space Exceedence for 131 (M-4).

Suspended Sediment Analysis

Sediment Sampling

The results of the 1999 composite sediment sampling is shown in Figure 3.34. The plot shows the concentration at each station on the day of survey. Figure 3.35 shows the historical sediment concentration versus flow at Bluff as measured by the USGS from 1930 to 1980. The Bluff suspended sediment data gathered during the 1992 to 1999 research period is also shown. The collected data is within the historical concentration range.

Turbidity Monitoring

Turbidity equipment is installed at the USGS gage at Shiprock and at a site near the Montezuma Creek Bridge. The OBS-3 turbidity probe measures the optical properties of the water by emitting an infrared beam of light and measuring the backscatter. The sediment concentration and particle size distributions affect the back scatter. The probes are calibrated to read between 0-3000 NTU's (Nephelometric Turbidity Unit) at Montezuma Creek and 0- 4000 NTU's at Shiprock. The turbidity data collected in1998 and 1999 are shown plotted with USGS gage flow in Figures 3.36 and 3.37.

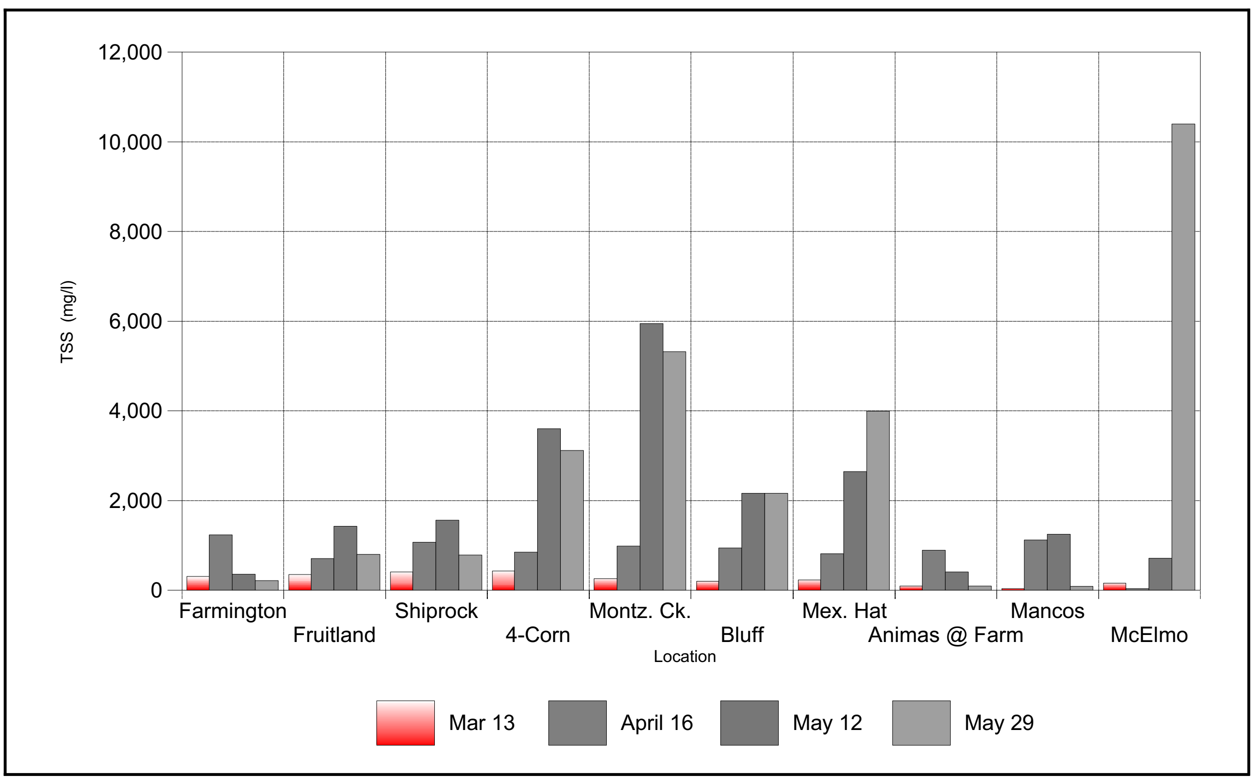


Figure 3.34. Results of 1999 Suspended Sediment Sampling

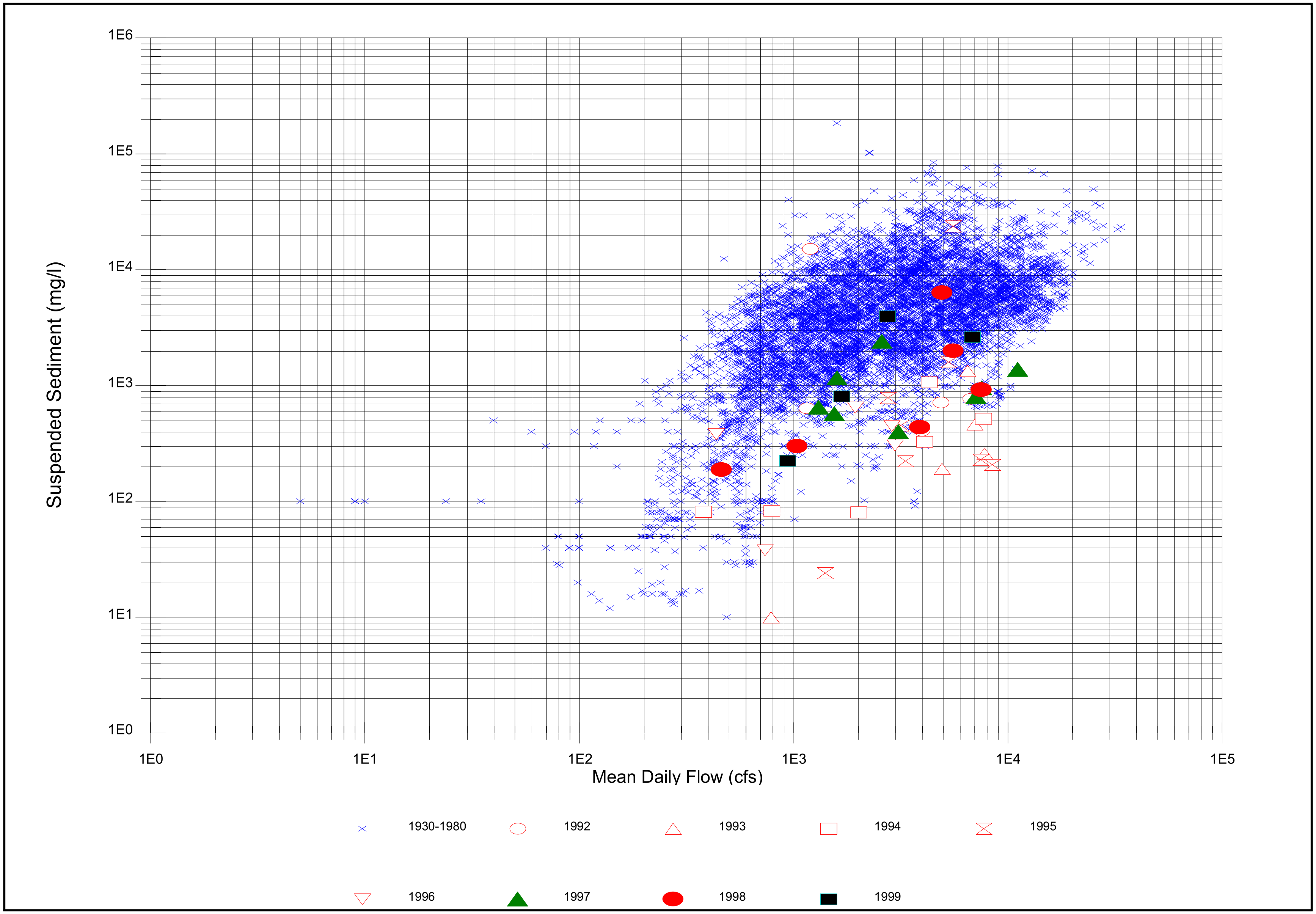


Figure 3.35. Historical Sediment Concentration at Bluff

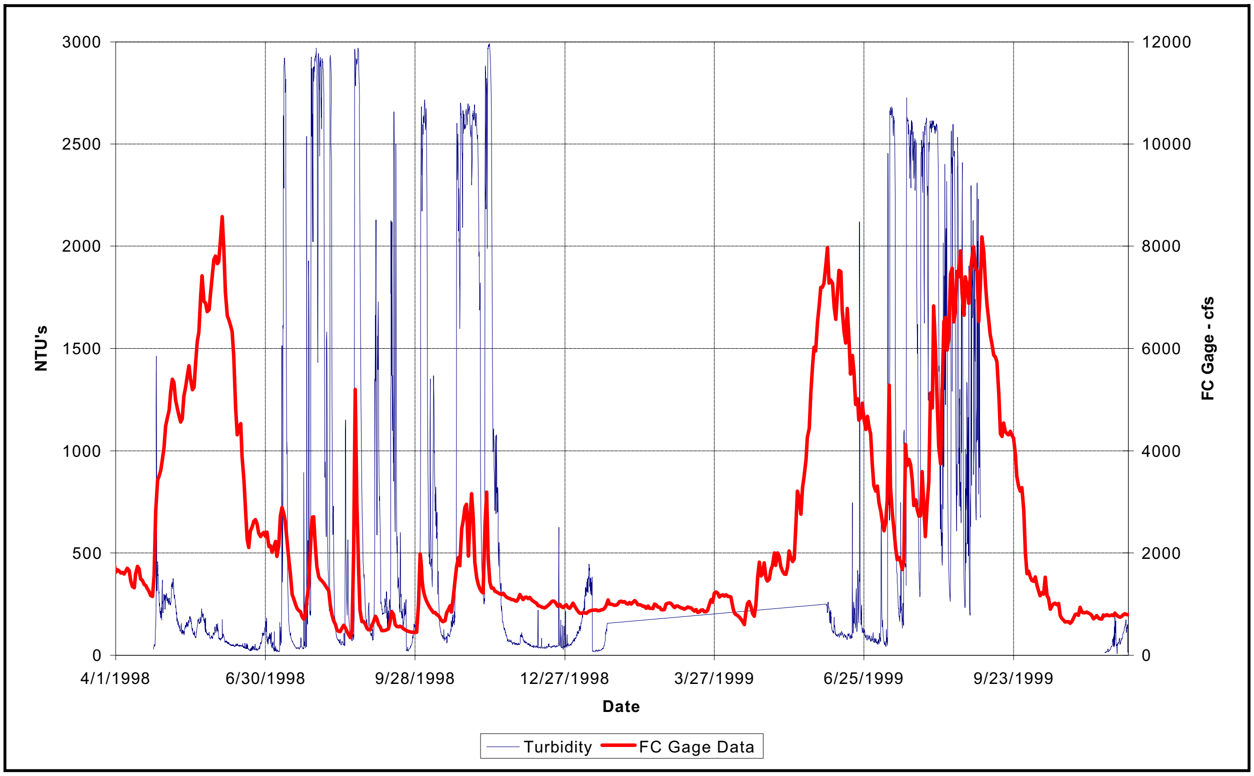


Figure 3.36. Montezuma Creek Turbidity Data and Four Corners Gage Flow

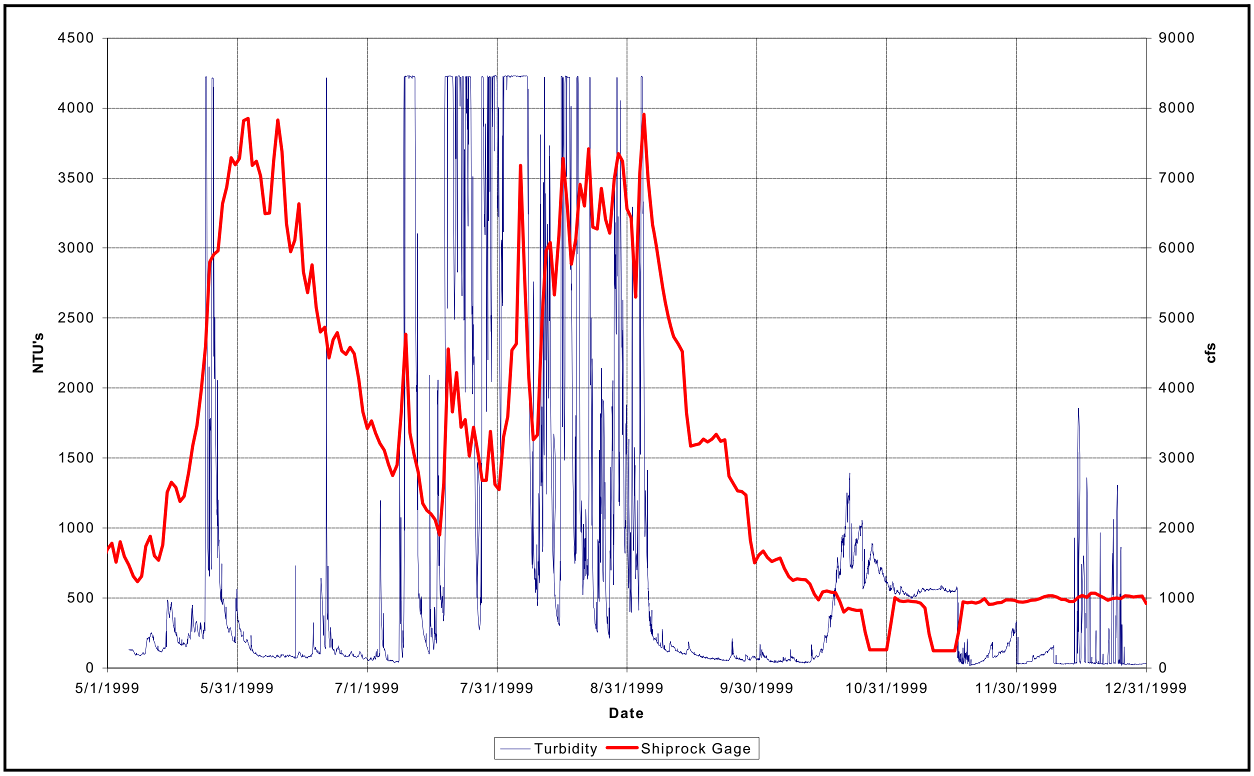


Figure 3.37. Shiprock Turbidity Data and Shiprock Gage Flow

The turbidity equipment is used to continuously monitor sediment producing events. These events can result in large inflows of sediment that can reduce or eliminate spawning areas of endangered fish. By monitoring these events, reservoir operations the next year may be modified to provide flushing flows in an attempt flush the sediment through the system. These sediment producing events have been defined as storm event days. The definition of a storm event day is flow based. The following algorithm is used to determine Storm Event Days.

The storm event day calculation for Bluff is shown below. The subscripted numbers are day indicators. A 0 represents day 0 (today), -1 represents the previous day (yesterday), +1 represents the following day (tomorrow).

$Gain_0 = Bluff_0 - Animas_{-1} - Archuleta_{-2}$
    If $[Gain_0 - AverageGain_{(-2, -1, 0, 1, 2)} > 150 \text{ cfs}]$
        Then If $[Bluff_0 - AverageBluff_{(-2, -1, 0, 1, 2)} > 150 \text{ cfs}]$
            Then If $[Gain_0 - AverageGain_{(-2, -1, 0, 1, 2)} > 3000 \text{ cfs}]$
            Storm Event Day Flag = 2
            Storm Event Day Flag =1
        Storm Event Day Flag = 0
    Storm Event Day Flag = 0

Where,
    $Gain_0$ = The flow gain in cfs between Archuleta and Bluff.
    $Bluff_0$ = The flow at Bluff today
    $Animas_{-1}$ = The Animas contribution to the San Juan in cfs yesterday.
    $Archuleta_{-2}$ = The flow at Archuleta two days ago in cfs.
    $AverageGain_{(-2, -1, 0, 1, 2)}$ = The average gain over a 5-day period.
    $AverageBluff_{(-2, -1, 0, 1, 2)}$ = The average flow at Bluff over a 5-day period.

The above algorithm may be described as follows. The gain in flow between Bluff and Archuleta is determined after subtracting the Animas contribution. All other tributaries are ignored. The flow of the Animas is lagged one day and the flow at Archuleta is lagged two days. If this average gain is more than 150 cfs than the 5-day average and the average flow at Bluff is more than 150 cfs than the 5-day average, the day is flagged a storm event day. If the Gain is greater than 3,000 cfs, the day is given extra weight and counted as two days. A perturbating year is determined by summing the storm event days between July 25 and the end of February. If the number of storm event days is greater than 12 then the year is flagged as a perturbating year and additional flushing releases from Navajo may be necessary the following season.

The turbidity data were analyzed to see if it could be used to estimate storm event days and produce results similar to the flow based method described in the previous paragraph. The average daily turbidity data from Shiprock and Montezuma Creek were combined to produce a semi-complete data set. Even with combining the data there are 38-days of missing data between January 22 and February 28, 1999. On days with concurrent data, the station with the highest turbidity was used. The results of this analysis are shown in Table 3.6. The second column in the table shows the number of days that exceed 2600 NTU's. The third column shows the flow based sediment event days. For 1999, 2600 NTU's appears to be a good approximation of a storm event day turbidity based definition. This value was determined by iteratively adjusting the NTU level until the number of days exceeding a given NTU value reasonably corresponded to the flow based definition. The last column in the table shows the number of days where both methods produced sediment event days on the same date. Both methods would flag 1999 as perturbating years because of exceeding 12 sediment event days. However, the nature of the runoff in 1999, with the high summer flows probably mitigated a portion of the sediment flow days. The final test of perturbation is the condition of the backwaters, addressed in the backwater monitoring data.

Turbidity and Suspended Sediment Concentration

Turbidity monitors such as those installed at Shiprock and Montezuma Creek may be calibrated to read suspended solids directly. However, since turbidity sensors respond differently to varying size, composition, and shape of suspended particles, it is nearly impossible to do so accurately in an environment such as the San Juan River. The particles suspended in San Juan river water vary greatly in size and presumably shape and composition depending on the source of the suspended particles. In an attempt to develop a relationship between suspended sediment and turbidity, water samples were taken at the Shiprock and Montezuma Creek sites at the time of equipment service. The turbidity was then plotted against the concentration. These data are shown in Figure 3.38. Any pair of points with a NTU greater than 4000 were thrown out. The r^2 for the combined set of data as plotted is 0.59. The r^2 for the Shiprock data is .83 and for the Montezuma Creek data is 0.63. In general, the correlation is high enough to allow a reasonable prediction of sediment load based on turbidity. Since sediment sampling is not included in the long range monitoring plan, only turbidity data will be collected in the future.

Table 3.6. Flow based Sediment Event Days and Turbidity based Sediment Days.

Year	Days > 2600 NTU's	Flow Based Sediment Event Days	Concurrent Days
1999	17	15	8

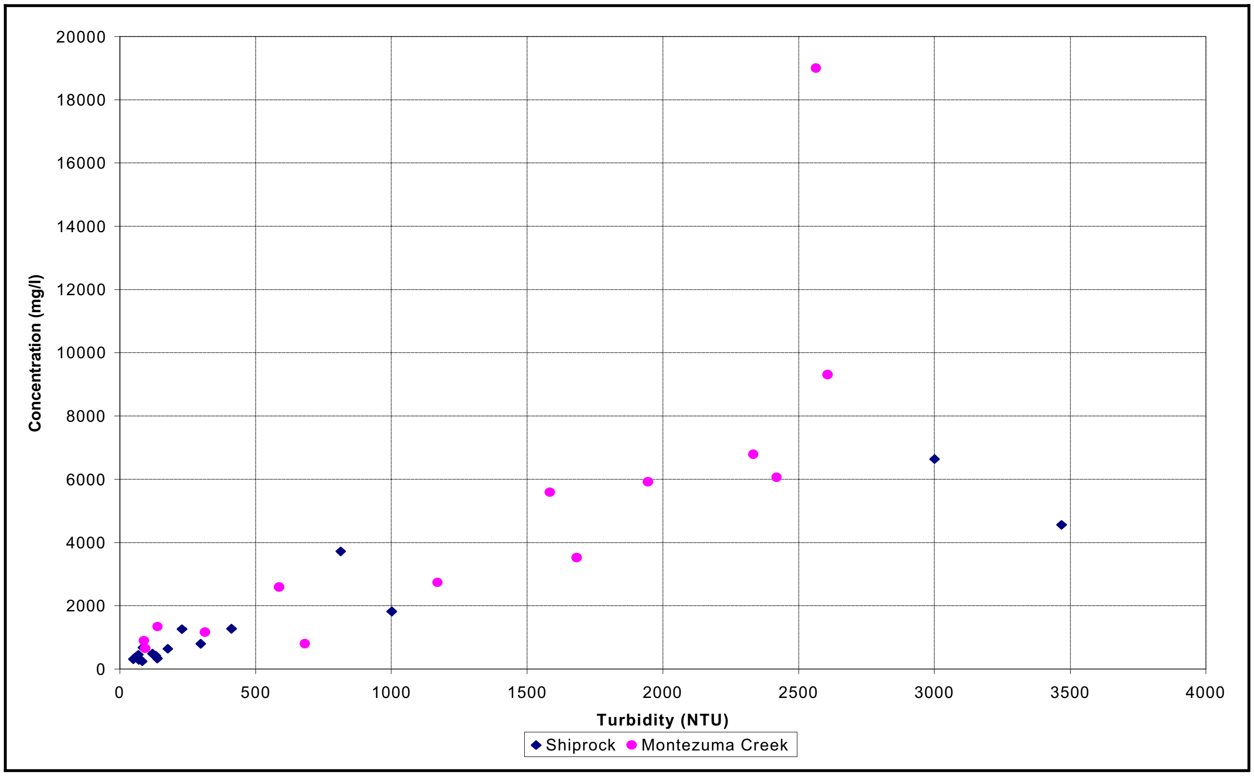


Figure 3.38. Montezuma Creek and Shiprock Turbidity versus Concentration.

CHAPTER 4. WATER QUALITY

METHODS

Water Temperature

Nine temperature recorders were originally installed in the San Juan and Animas rivers in July and August of 1992 at the locations shown in Table 4.1. Each station consisted of a temperature sensor, lead wires and an OMNIDATA DP-230 data pod. The temperature was sampled every 10 minutes and stored every 24 hours as a maximum, minimum and mean temperature for the day. Table 2.2 also shows the periods of record at each site. The missing data were caused by equipment problems. Due to equipment problems and other maintenance challenges, the temperature recorders were replaced in July 1999 with the Optic StowAway temperature loggers. These are manufactured by Onset Computer Corporation and are factory sealed, submersible units that communicate via an optic interface. The temperature sensor is embedded in the body of the unit, eliminating any external wires. Water temperature is currently recorded every 15-minutes. The "in place" phrase in Table 4.1 indicates that StowAway's are monitoring temperature at the indicated sites.

Water Chemistry

Twelve water quality monitoring sites (Table 4.2) were identified as necessary to characterize water quality in the San Juan River and key tributaries. Sampling interval are quarterly (trimonthly) in February, May, August, and November. This temporal spacing was adopted to ensure water sampling occurs during spring runoff in the upper portion of the San Juan River basin and during winter base flows.

Chemical analyses performed are listed in Table 4.3. Parameters listed in left column were measured quarterly. In addition, field measurements of water temperature, pH, redox potential, specific conductance, and dissolved oxygen were made. Annually, during low-flow periods in February, water samples were analyzed for all parameters listed in Table 4.3.

RESULTS

Water Temperature

The plot of the 1999 StowAway temperature data is shown in Figure 4.1. Maximum, minimum and average plots are shown for Archuleta and Montezuma Creek in Figures 4.2 and 4.3. The missing data in Figures 4-2 and 4-3 is the interval between getting the new temperature equipment installed and the old equipment running out of data storage space and/or power. There is a lot of water temperature data missing from 1998 due to equipment problems and thus max, min and average plots are not shown for the other stations. The new equipment appears to be operating well and should provide a more consistent and reliable record.

Table 4.1. Water temperature monitoring locations and period of record.

Location	RM	Period of Record
Near Navajo Dam	225	7/9/1999 to 11/17/99 (in place)
Archuleta - San Juan at USGS Gage Location	218.6	7/23/92 to 11/17/99 (in place)
Blanco - San Juan at US-64 Bridge	207.1	8/7/92 to 2/28/95 (missing 11/21 - 12/9/92)
Bloomfield - San Juan at Highway 44 Bridge	195.6	2/27/93 to 7/17/98
Lee Acres - San Juan at Lee Acres Bridge	188.9	8/8/92 to 12/2/92, 2/26/93 to 4/15/93, 5/27/93 to 9/6/94, 3/9/95 to 10/10/95
Farmington - San Juan at USGS Gage Location	180.1	8/5/92 to 1/16/96, 7/8/99 to 11/15/99 (in place)
Shiprock - San Juan at USGS Gage Location	148.0	7/8/99 to 11/16/99 (in place)
Four Corners - San Juan at USGS Gage Location	119.4	10/7/94 to 3/11/96*, 7/9/99 to 11/16/99 (in place)
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 11/16/99 (in place)
Mexican Hat - San Juan near Bluff Gage Location	52.1	7/9/99 to 11/16/99 (in place)
Cedar Hill - Animas at USGS Gage nr Cedar Hill	n/a	8/7/92 to 9/22/98
Farmington - Animas at USGS Gage Location	n/a	8/5/92 to 4/14/97, 5/7/97 to 8/26/97, 10/15/97 to 6/4/98, 7/8/99 to 11/15/99 (in place)
USGS Data - San Juan at Archuleta	218.6	10/1/50 - 9/30/68 with some missing data
USGS Data - San Juan at Shiprock	148.0	10/1/51 - 9/30/86,9/7/91 - 3/3/93 with some missing data
USGS Data - Animas	n/a	10/1/52 - 9/30/90 with some missing data

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

Table 4.2. San Juan River water quality monitoring sites.

Station Name	USGS ID	USGS Record	BIA Record
San Juan River near Archuleta Bridge	9355500	1958 -1984	1991-1999
Animas River @ Farmington	9364500	1958 -1992	1991-1999
San Juan River @ Farmington	9365000	1974 -1991	1991-1999
LaPlata River near Farmington	9367500	1977-1991	1994-1999
San Juan River @ Shiprock	9368000	1958 -1992	1991-1999
Mancos River near Four Corners	9371005		1991-1999
San Juan River @ Four Corners	9371010	1977-1990	1991-1999
San Juan River @ Montezuma Creek	9378610		1991-1999
San Juan River @ Bluff	9379495		1991-1999
San Juan River near Bluff (@ Mex. Hat)	9379500	1974 -1993	1991-1999

Table 4.3. San Juan River Monitoring Program water quality parameters.

Quarterly	Annually
Arsenic (total & dissolved)	Aluminum (total & dissolved)
Calcium (dissolved)	Barium (total & dissolved)
Copper (total & dissolved)	Manganese (total & dissolved)
Lead (total & dissolved)	Nickel (total & dissolved)
Magnesium (dissolved)	Potassium (total & dissolved)
Mercury (total & dissolved)	Strontium (total & dissolved)
Sodium (dissolved)	Orthophosphate (total & dissolved)
Selenium (total, dissolved, & total recoverable)	Chloride (dissolved)
Zinc (total & dissolved)	Ammonia (dissolved)
Alkalinity (HCO_3)	Nitrate (dissolved0
Hardness	Nitrite (dissolved)
TDS	Silica (total & dissolved)
TSS	Sulfate (dissolved)
Turbidity	

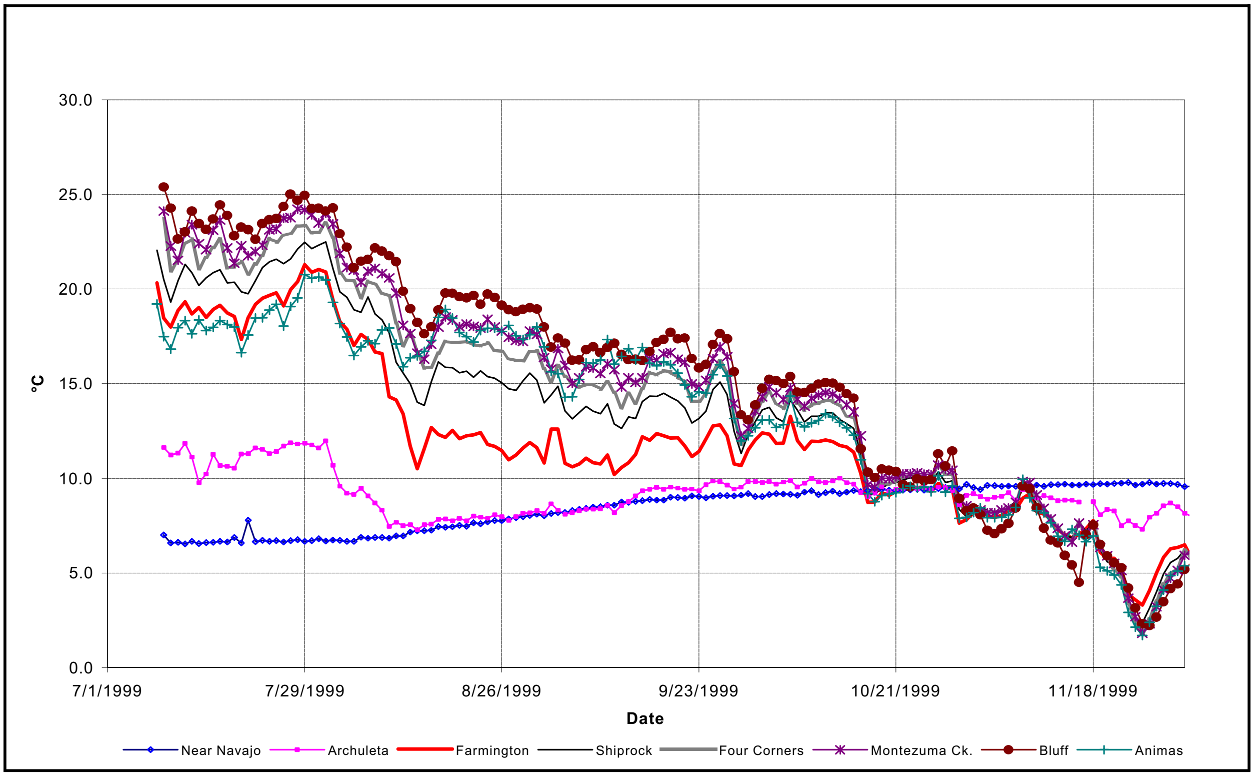


Figure 4.1. San Juan Basin Water Average Daily Temperature Data

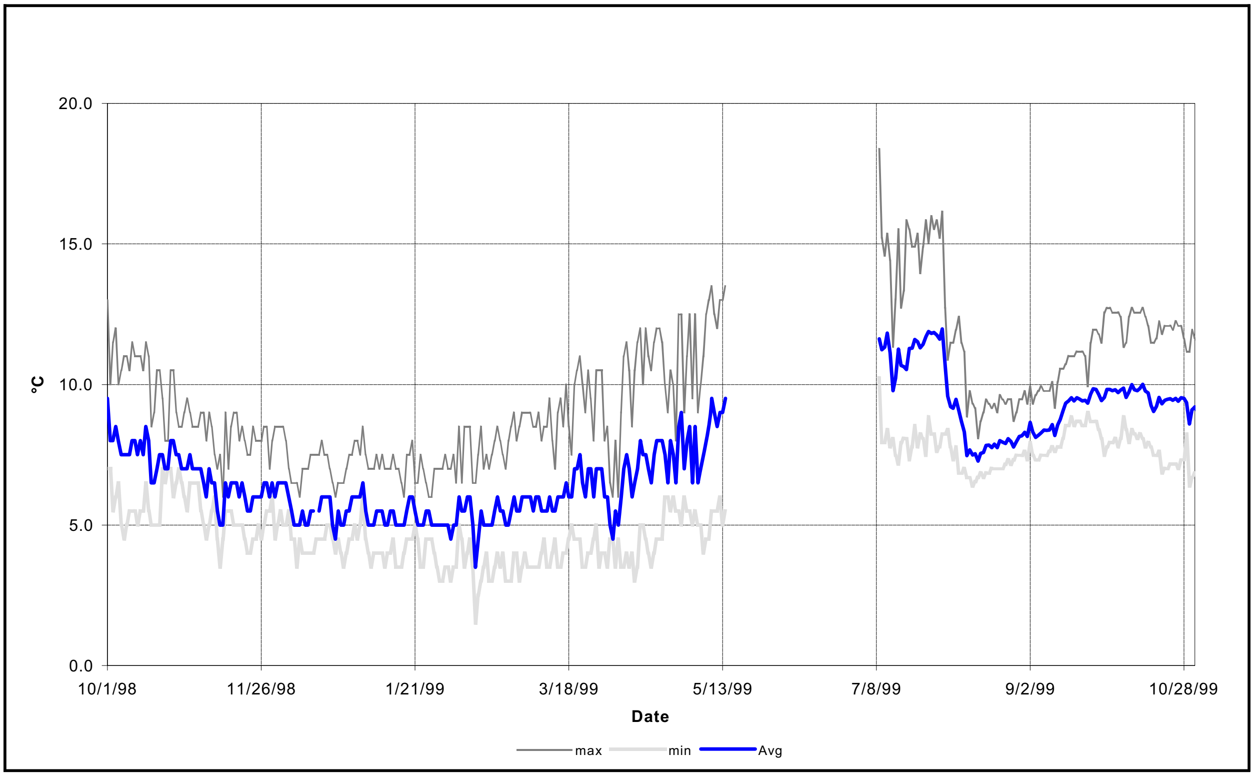


Figure 4.2. Archuleta Maximum, Minimum and Average Daily Water Temperatures

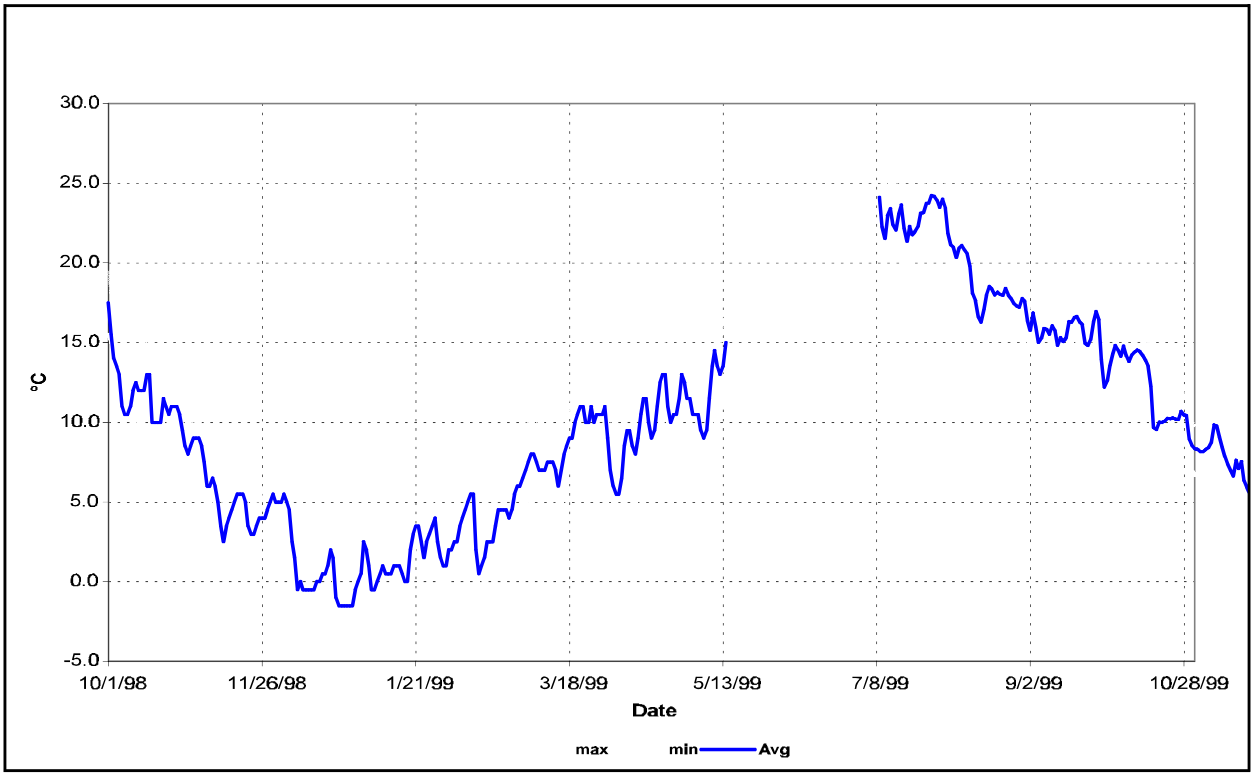


Figure 4.3. Montezuma Creek Maximum, Minimum and Average Daily Water Temperatures

Water Chemistry

Tables 4.4 through 4.13 summarize the water quality data for the 10 permanent stations, comparing the 1994-1998 statistics to those for 1999. In each case the minimum, maximum, mean and standard deviation is given for each parameter in Table 4.3.

Table 4.4. Water chemistry data for San Juan River at Archuleta Bridge

San Juan River at Archuleta Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	31	43	99	74.8	9.5	4	54	78	69.8	10.8
Alkalinity (mg/l)	31	43	99	75.2	9.6	4	54	78	69.8	10.8
Arsenic dissolved (µg/l)	59	0.3	2.5	2	0.8	4	0.9	1	1	0.1
Arsenic total (µg/l)	59	0.5	642	13.2	83.3	4	0.5	5	1.9	2.1
Calcium dissolved (mg/l)	31	25.1	33.6	29.3	2.6	4	27.2	30	28.3	1.3
Copper dissolved (µg/l)	31	1	21	3.8	3.7	4	2	4	2.9	1.1
Copper total (µg/l)	31	1	41	8	10.4	4	1.5	5	3.4	1.5
Hardness ((mg/l)	31	83	112	96.4	8.6	4	90	98	93.5	3.7
Mercury dissolved (µg/l)	59	0.1	0.5	0.1	0.1	4	0.1	0.1	0.1	0
Mercury total (µg/l)	59	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	31	4.9	6.9	5.6	0.5	4	5.4	5.7	5.5	0.2
Sodium dissolved (mg/l)	8	10.7	15.3	12.9	1.5	4	11.9	13.2	12.6	0.7
Lead dissolved (µg/l)	59	0.1	5.7	0.6	0.9	4	0.1	1.6	0.5	0.8
Lead total (µg/l)	59	0.1	19.2	1.4	2.7	4	0.2	1	0.5	0.4
Selenium dissolved (µg/l)	59	0.5	0.5	0.5	0	4	0.5	0.5	0.5	0
Selenium total (µg/l)	59	0.5	3	0.5	0.3	4	0.5	1	0.6	0.3
Selenium total recoverable (µg/l)	9	0.5	0.5	0.5	0	4	0.5	0.5	0.5	0
Total dissolved solids (mg/l)	29	90	280	163.4	41.1	4	130	150	135	10
Total suspended solids (mg/l)	58	1	57	9.5	10.3	4	2.5	2.5	2.5	0
Turbidity (NTU)	56	0	33	6	5.4	4	2.1	8.3	4.9	3
Zinc dissolved (µg/l)	59	5	70	7.4	9.2	4	5	5	5	0
Zinc total (µg/l)	59	5	360	27.5	54.8	4	5	10	7.5	2.9
Temperature (°C)	59	3.4	19.9	8.1	3	4	6.1	9.3	7.6	1.3
pH	59	7.2	9	8.2	0.4	4	7.6	8.1	7.8	0.2
Conductance (µmhos/cm)	59	200	1210	260	128.8	4	210	250	230	18.9
Redox Potential (mv)	59	223	527	380	69.3	4	228	479	365	105
Oxygen dissolved (mg/l)	58	5.4	14.3	10.5	1.5	4	9.1	11.2	10.1	0.9

Table 4.5. Water Chemistry data for Animas River at Farmington

Animas River at Farmington	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	30	43	167	116.8	34.5	4	86	171	126.8	35.2
Alkalinity (mg/l)	30	43	167	117.6	34.7	4	86	171	126.8	35.2
Arsenic dissolved (µg/l)	59	0.3	2.5	1.9	0.8	4	0.7	2	1.2	0.6
Arsenic total (µg/l)	59	0.5	13	2.6	1.8	4	0.5	4	2	1.6
Calcium dissolved (mg/l)	30	27.6	96.1	68.6	21.7	4	37.7	101	71.1	28.3
Copper dissolved (µg/l)	30	1	9	4	2.2	4	2	4.1	3.3	1
Copper total (µg/l)	30	2.5	68	14.8	15.1	4	1.5	13	7.9	5.5
Hardness ((mg/l)	30	85	304	217.7	71.2	4	117	319	224.8	91.8
Mercury dissolved (µg/l)	59	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	59	0.1	0.9	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	30	3.8	19.2	11.3	4.2	4	5.6	16.2	11.4	5.1
Sodium dissolved (mg/l)	7	6	34.6	25.9	9.3	4	7.3	37.7	22.1	15.1
Lead dissolved (µg/l)	59	0.1	4.5	0.6	0.6	4	0.1	0.3	0.2	0.1
Lead total (µg/l)	59	0.5	80	14.3	18.7	4	0.5	43.2	11.4	21.2
Selenium dissolved (µg/l)	59	0.5	3	0.6	0.3	4	0.5	0.5	0.5	0
Selenium total (µg/l)	59	0.5	4	0.6	0.5	4	0.5	1	0.6	0.3
Selenium total recoverable (µg/l)	9	0.5	0.5	0.5	0	4	0.5	1	0.6	0.3
Total dissolved solids (mg/l)	29	110	520	320.7	120	4	180	500	330	154.5
Total suspended solids (mg/l)	58	1	2170	144.3	331.2	4	2.5	166	82.6	88.4
Turbidity (NTU)	56	0.9	1240	74.9	195.7	4	2.8	87	38.4	42.1
Zinc dissolved (µg/l)	59	5	40	9.6	7.4	4	5	20	10	7.1
Zinc total (µg/l)	59	5	430	89.1	86.6	4	10	100	52.5	44.3
Temperature (°C)	59	-0.2	27.3	11.5	7	4	5.2	16.3	11.5	5
pH	59	7.5	8.9	8.2	0.3	4	7.8	8.5	8.2	0.3
Conductance (µmhos/cm)	59	200	970	550	180.6	4	280	720	500	209.5
Redox Potential (mv)	59	253	545	395	66.2	4	357	482	412	51.9
Oxygen dissolved (mg/l)	58	3.7	13.2	9.5	2.1	4	7.6	11.1	9.5	1.7

Table 4.6. Water Chemistry data for San Juan River at Farmington Bridge

San Juan River at Farmington Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	29	49	143	103	23.4	4	84	110	100	11.6
Alkalinity (mg/l)	29	49	143	103.3	23	4	84	110	100	11.6
Arsenic dissolved (µg/l)	59	0.3	5	2.1	0.9	4	0.9	2	1.2	0.5
Arsenic total (µg/l)	59	0.5	7	2.6	1.2	4	1	2.5	1.9	0.6
Calcium dissolved (mg/l)	29	28.8	83.5	54.3	15.4	4	32.8	55.9	49.5	11.2
Copper dissolved (µg/l)	29	1	10	4	2.5	4	1	5	3.2	2
Copper total (µg/l)	29	2.5	50	17.1	12.3	4	2.5	10	5.4	3.3
Hardness ((mg/l)	29	91	265	171.8	48.6	4	105	178	157.5	35.1
Mercury dissolved (µg/l)	59	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	59	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	29	4.6	13.9	8.8	2.5	4	5.6	9.4	8.2	1.8
Sodium dissolved (mg/l)	6	27.5	46.7	36.6	7.1	4	12.2	37	26	11.8
Lead dissolved (µg/l)	59	0.1	4	0.6	0.6	4	0.1	0.2	0.2	0.1
Lead total (µg/l)	59	0.5	105	12	16.3	4	0.5	19.3	6	8.9
Selenium dissolved (µg/l)	59	0.5	2	0.5	0.2	4	0.5	1	0.6	0.3
Selenium total (µg/l)	59	0.5	2.5	0.6	0.3	4	0.5	1	0.8	0.3
Selenium total recoverable (µg/l)	9	0.5	0.5	0.5	0	4	0.5	0.5	0.5	0
Total dissolved solids (mg/l)	29	140	450	293.4	87.4	4	190	330	265	59.7
Total suspended solids (mg/l)	58	2.5	2660	244.8	397.8	4	14	424	166	180.2
Turbidity (NTU)	56	2.5	1880	110.4	265.2	4	13	116	44.1	48.5
Zinc dissolved (µg/l)	59	5	30	7.7	5.8	4	5	5	5	0
Zinc total (µg/l)	59	5	320	63.1	53.5	4	5	100	43.7	45
Temperature (°C)	59	-0.3	24.3	10.6	6.3	4	5.5	14.8	9.9	3.9
pH	59	7.2	8.8	8.1	0.3	4	7.8	8.5	8.1	0.3
Conductance (µmhos/cm)	59	200	700	430	118.4	4	270	620	420	144.3
Redox Potential (mv)	59	252	535	400	61.3	4	384	477	431	38
Oxygen dissolved (mg/l)	58	0	12.5	8.9	2.2	4	6.8	9.7	8.6	1.3

Table 4.7. Water chemistry data for La Plata River near Farmington

La Plata River near Farmington	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	21	111	370	230	57.6	4	197	290	240.3	45.8
Alkalinity (mg/l)	21	111	370	230	57.6	4	198	290	240.5	45.5
Arsenic dissolved (µg/l)	50	0.2	5	2.3	0.9	4	1	2.5	1.9	0.8
Arsenic total (µg/l)	50	0.5	29	4.2	5.4	4	2	7	4.1	2.3
Calcium dissolved (mg/l)	21	65.4	507	175.4	97.3	4	108	339	212.3	96.9
Copper dissolved (µg/l)	21	1	20	9.1	5.8	4	4	8	5.8	1.7
Copper total (µg/l)	21	2.5	136	24	30	4	1.5	39	18.1	17.9
Hardness ((mg/l)	21	279	2120	778.5	419.6	4	461	1410	901	389.6
Mercury dissolved (µg/l)	50	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	50	0.1	1.7	0.2	0.3	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	21	18.1	208	82.7	44.6	4	46.4	136	89.9	37.6
Sodium dissolved (mg/l)	1	118	118	118	.	4	56.7	453	238.9	177
Lead dissolved (µg/l)	50	0.1	1	0.4	0.2	4	0.1	0.5	0.3	0.2
Lead total (µg/l)	50	0.3	408	17.7	60.5	4	0.5	18.2	5.5	8.5
Selenium dissolved (µg/l)	50	0.5	4	1.2	0.9	4	0.5	1	0.6	0.3
Selenium total (µg/l)	50	0.5	10	1.5	1.7	4	0.5	3	1.1	1.3
Selenium total recoverable (µg/l)	5	0.5	2	1.1	0.6	4	0.5	2	1	0.7
Total dissolved solids (mg/l)	21	80	3240	1263.3	679.4	4	900	3220	1905	985.3
Total suspended solids (mg/l)	50	2	65600	2100	9689.7	4	2.5	1870	497.6	916.2
Turbidity (NTU)	50	0.6	18900	588.5	2692.6	4	0.1	430	108.4	214.4
Zinc dissolved (µg/l)	50	5	20	6.3	3.8	4	5	10	8.8	2.5
Zinc total (µg/l)	50	5	1850	86	273.9	4	10	70	25	30
Temperature (°C)	50	-0.3	32.2	12.8	8.7	4	2.3	24.9	14	10.5
pH	50	7.4	8.5	8.1	0.2	4	7	8.2	7.8	0.5
Conductance (µmhos/cm)	50	270	3740	1660	691.4	4	1040	3590	2180	1116.2
Redox Potential (mv)	50	239	498	390	61	4	287	460	391	75.2
Oxygen dissolved (mg/l)	49	3.1	12.8	8.8	2.2	4	7.1	10.4	8.6	1.7

Table 4.8. Water chemistry data for San Juan River at Shiprock Bridge

San Juan River at Shiprock Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	55	17	165	108.4	29.6	8	47	139	105.8	28
Alkalinity (mg/l)	55	17	166	109.8	30.1	8	47	139	105.8	28
Arsenic dissolved (µg/l)	114	0.5	2.5	2	0.7	8	0.6	1	0.9	0.2
Arsenic total (µg/l)	113	1	44	4.2	5.9	8	0.5	9	3.9	3.7
Calcium dissolved (mg/l)	55	30.8	96.3	59.9	16.8	8	36.8	74.2	57.3	14.1
Copper dissolved (µg/l)	55	1	18	4.9	3.4	8	1.5	6	3.3	1.6
Copper total (µg/l)	55	2.5	155	28.7	32.5	8	3	65	27.9	25.7
Hardness ((mg/l)	55	98	317	195.9	56.9	8	115	248	186.3	49.6
Mercury dissolved (µg/l)	114	0.1	0.3	0.1	0	8	0.1	0.1	0.1	0
Mercury total (µg/l)	114	0.1	1.6	0.1	0.2	8	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	55	5.2	18.6	11.2	3.8	8	5.7	15.1	10.5	3.6
Sodium dissolved (mg/l)	8	13	58.5	41.4	13.5	8	21.8	48	33.3	11.6
Lead dissolved (µg/l)	114	0.1	18	1	2.5	8	0.1	0.9	0.3	0.3
Lead total (µg/l)	113	0.5	323	26.7	45.4	8	1	65.8	21.4	28
Selenium dissolved (µg/l)	114	0.5	1	0.5	0.1	8	0.5	0.5	0.5	0
Selenium total (µg/l)	114	0.5	3	0.6	0.4	8	0.5	2	0.8	0.5
Selenium total recoverable (µg/l)	18	0.5	1	0.6	0.2	8	0.5	2	0.9	0.5
Total dissolved solids (mg/l)	54	130	550	343.1	107.3	8	220	430	313.8	82.1
Total suspended solids (mg/l)	112	2.5	17700	1057.8	3091.6	8	28	3280	895	1443.1
Turbidity (NTU)	110	3.8	11100	546	1730.3	8	11.2	1800	430.7	743.5
Zinc dissolved (µg/l)	114	5	50	7.3	6.1	8	5	20	7.5	5.4
Zinc total (µg/l)	114	5	1380	121.3	229.4	8	10	490	136.3	160.5
Temperature (°C)	114	0.1	26.1	12.2	6.9	8	7.2	18.6	12.1	5.2
pH	114	7.7	9	8.3	0.3	8	7.7	9	8.2	0.5
Conductance (µmhos/cm)	114	240	830	520	150	8	330	650	510	130.2
Redox Potential (mv)	114	250	544	407	64.8	8	404	484	428	32.1
Oxygen dissolved (mg/l)	112	3.6	13.9	9.5	2.4	8	7.9	11.7	9.8	2

Table 4.9. Water chemistry data for Mancos River near Four Corners

Mancos River near Four Corners	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	25	92	360	169.2	57	4	107	215	167	48.7
Alkalinity (mg/l)	25	92	360	172.4	56.6	4	107	215	167	48.7
Arsenic dissolved (µg/l)	48	0.3	5	2.1	0.9	4	1	4	2.2	1.3
Arsenic total (µg/l)	48	1	37	5.2	7.2	4	1	28	9.1	12.7
Calcium dissolved (mg/l)	25	43.6	201	129.1	49.8	4	66.5	211	167.6	68
Copper dissolved (µg/l)	25	2.5	19	8.7	5.5	4	6	20	11.3	6.7
Copper total (µg/l)	25	2.5	198	33	44.2	4	1.5	107	42.1	46
Hardness ((mg/l)	25	165	1040	617.7	276.6	4	283	1110	778.8	364.4
Mercury dissolved (µg/l)	48	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	48	0.1	0.5	0.1	0.1	4	0.1	2	0.6	1
Magnesium dissolved (mg/l)	25	13.7	136	71.8	37.5	4	28.4	145	87.3	56
Sodium dissolved (mg/l)	2	22	143	82.5	85.6	4	35.2	206	121.1	77.5
Lead dissolved (µg/l)	48	0.1	1	0.4	0.2	4	0.1	1	0.4	0.4
Lead total (µg/l)	48	0.2	77	10.8	17.8	4	0.4	78.6	20.1	39
Selenium dissolved (µg/l)	48	0.5	30	7.5	6.3	4	2	15	9.3	5.9
Selenium total (µg/l)	48	0.5	30	7.4	5.9	4	4	15	11	5
Selenium total recoverable (µg/l)	9	2	16	8	5.1	4	3	14	9.8	5
Total dissolved solids (mg/l)	24	240	2100	1135.8	538.1	4	440	2040	1407.5	696.1
Total suspended solids (mg/l)	47	2.5	6320	621.1	1221.5	4	12	33500	8650	16574.1
Turbidity (NTU)	47	3.9	2300	296.4	503.8	4	12.5	18500	4732.5	9180.1
Zinc dissolved (µg/l)	48	5	40	7.1	6.2	4	5	20	10	7.1
Zinc total (µg/l)	48	5	330	58.7	76.7	4	5	2300	596.2	1136.2
Temperature (°C)	48	-0.2	32.3	12.2	8.5	4	2.8	24.2	14	9.3
pH	48	7.8	8.8	8.2	0.2	4	7.8	8.4	8.1	0.3
Conductance (µmhos/cm)	48	380	2450	1510	589.6	4	650	2330	1610	745.9
Redox Potential (mv)	48	4	548	400	87.9	4	375	484	426	44.7
Oxygen dissolved (mg/l)	47	4.8	12.7	9.3	2	4	6	11.9	9.2	2.7

Table 4.10. Water chemistry data for San Juan River at Four Corners Bridge

San Juan River at Four Corners Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	30	67	165	113.7	23.9	4	88	141	111.5	22
Alkalinity (mg/l)	30	67	165	114.4	24.2	4	88	141	112	21.9
Arsenic dissolved (µg/l)	59	0.5	2.5	2	0.7	4	0.5	2	1.1	0.6
Arsenic total (µg/l)	59	1	19	3.5	3.3	4	1	9	4.8	3.3
Calcium dissolved (mg/l)	30	31.7	99.9	64.8	18.9	4	37.8	78.7	59	16.8
Copper dissolved (µg/l)	30	1	11	5	2.7	4	4	6	5	0.8
Copper total (µg/l)	30	2.5	130	23.3	26.3	4	6	65	39.3	25.1
Hardness ((mg/l)	30	103	340	220.4	69.6	4	117	274	198.5	65
Mercury dissolved (µg/l)	59	0.1	0.3	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	59	0.1	0.8	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	30	5.8	23.8	14.2	5.7	4	5.5	18.7	12.4	5.6
Sodium dissolved (mg/l)	7	14	60.1	45.6	16.3	4	23.9	54.4	38.1	14
Lead dissolved (µg/l)	59	0.1	7	0.6	0.9	4	0.1	0.7	0.3	0.3
Lead total (µg/l)	59	0.5	271	22.4	46.3	4	1	52.7	15.6	24.8
Selenium dissolved (µg/l)	59	0.5	2	0.8	0.5	4	0.5	2	1	0.7
Selenium total (µg/l)	59	0.5	4	1	0.7	4	0.5	2	1.1	0.6
Selenium total recoverable (µg/l)	9	0.5	1	0.8	0.3	4	0.5	2	1.1	0.6
Total dissolved solids (mg/l)	29	110	640	391	137.4	4	240	480	340	108.6
Total suspended solids (mg/l)	59	2.5	11700	673.4	1972.5	4	20	3990	1100	1930.8
Turbidity (NTU)	57	2	7900	401.4	1319.9	4	8.5	2000	543.6	973.1
Zinc dissolved (µg/l)	59	5	30	6.9	4.7	4	5	5	5	0
Zinc total (µg/l)	59	5	920	84.3	143.8	4	20	230	97.5	97.1
Temperature (°C)	59	0	26.3	12.3	7.4	4	4.6	17.9	12.4	6.4
pH	59	7.5	8.8	8.2	0.3	4	7.9	8.7	8.2	0.4
Conductance (µmhos/cm)	59	250	870	580	179.7	4	370	710	530	148.4
Redox Potential (mv)	59	256	592	409	64.6	4	385	488	433	42.3
Oxygen dissolved (mg/l)	58	4.3	12.7	9.3	2	4	7.4	12.2	9.8	2.4

Table 4.11. Water chemistry data for San Juan River at Montezuma Creek Bridge

San Juan River at Montezuma Creek Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	27	59	192	122.8	31.4	4	93	149	117	23.3
Alkalinity (mg/l)	27	59	192	123.6	31.7	4	93	149	117	23.3
Arsenic dissolved (µg/l)	55	0.5	2.5	2	0.8	4	0.9	2	1.2	0.5
Arsenic total (µg/l)	55	1	21	3.5	3.6	4	1	9	3.6	3.6
Calcium dissolved (mg/l)	27	33.9	132	73.9	25.8	4	39.9	88	65.6	19.8
Copper dissolved (µg/l)	27	2	15	5.4	3.5	4	2	4.3	3.6	1.1
Copper total (µg/l)	27	2.5	120	25.6	29.3	4	1.5	57	23.4	25.8
Hardness ((mg/l)	27	111	465	269	102.8	4	127	323	232	82.6
Mercury dissolved (µg/l)	55	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	55	0.1	0.8	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	27	6.5	40.5	20.5	9.6	4	6.7	25.1	16.6	8.2
Sodium dissolved (mg/l)	3	16	196	87.2	95.7	4	18.6	59	39.8	19.3
Lead dissolved (µg/l)	55	0.1	4	0.5	0.5	4	0.1	0.2	0.2	0.1
Lead total (µg/l)	55	0.5	129	18.4	27	4	0.5	50.8	13.4	25
Selenium dissolved (µg/l)	55	0.5	4	0.9	0.6	4	0.5	2	1.1	0.6
Selenium total (µg/l)	55	0.5	3	1	0.7	4	0.5	6	2.4	2.5
Selenium total recoverable (µg/l)	9	0.5	1	0.7	0.3	4	0.5	2	1.1	0.6
Total dissolved solids (mg/l)	25	170	800	456.4	176.1	4	220	560	377.5	159.7
Total suspended solids (mg/l)	54	2.5	9100	683.3	1544.6	4	16	3320	975.5	1581.2
Turbidity (NTU)	54	3.9	6900	356.8	1007.8	4	7.2	1600	466.4	764.3
Zinc dissolved (µg/l)	55	5	60	7.2	7.9	4	5	20	8.8	7.5
Zinc total (µg/l)	55	5	540	82.7	110.9	4	5	220	93.8	104.8
Temperature (°C)	55	-0.2	27.8	12.7	7.4	4	5.6	18.4	12.5	6.7
pH	55	7.7	8.7	8.2	0.2	4	7.7	8.6	8.2	0.4
Conductance (µmhos/cm)	55	280	1160	670	224.3	4	350	810	580	205.7
Redox Potential (mv)	55	250	516	403	65.1	4	385	459	422	30.7
Oxygen dissolved (mg/l)	54	5.1	12.3	9	1.9	4	7.2	11.6	9.5	2.2

Table 4.12. Water chemistry data for San Juan River at Bluff Bridge

San Juan River at Bluff Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	57	47	175	122.6	31.9	8	94	146	116.9	19.6
Alkalinity (mg/l)	57	47	175	122.7	31.9	8	94	146	116.9	19.6
Arsenic dissolved (µg/l)	114	0.5	2.5	2.1	0.7	8	1	2	1.1	0.4
Arsenic total (µg/l)	113	1	20	4.3	4.5	8	0.5	10	2.9	3.2
Calcium dissolved (mg/l)	57	32.3	121	74	22.3	8	41.4	91.2	65.7	18.6
Copper dissolved (µg/l)	57	1	13	6.1	3.2	8	2	6.7	3.9	1.5
Copper total (µg/l)	57	2.5	200	34	37.8	8	1.5	50	21	20.7
Hardness ((mg/l)	57	106	507	271	94.1	8	134	337	233.4	77.7
Mercury dissolved (µg/l)	114	0.1	0.5	0.1	0	8	0.1	0.1	0.1	0
Mercury total (µg/l)	114	0.1	0.7	0.1	0.1	8	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	57	6.2	49.8	21.1	9.7	8	7.3	26.5	16.8	7.8
Sodium dissolved (mg/l)	10	18	83	55.4	24.2	8	18.3	62.3	40.3	19.3
Lead dissolved (µg/l)	114	0.1	4	0.6	0.7	8	0.1	0.2	0.2	0.1
Lead total (µg/l)	113	0.5	144	23.1	32.8	8	0.5	35	9.4	15.2
Selenium dissolved (µg/l)	114	0.5	3	0.9	0.6	8	0.5	2	0.9	0.5
Selenium total (µg/l)	114	0.5	8	1.2	1.1	8	0.5	2	1.1	0.6
Selenium total recoverable (µg/l)	18	0.5	1	0.7	0.2	8	0.5	1	0.9	0.2
Total dissolved solids (mg/l)	54	160	990	489.3	181.9	8	230	560	388.8	145
Total suspended solids (mg/l)	114	1	9820	903.4	1822.8	8	12	2390	787	1024.5
Turbidity (NTU)	112	2	7900	570.9	1327.7	8	8.1	1500	356.1	552.2
Zinc dissolved (µg/l)	114	5	40	7.4	5.8	8	5	20	6.9	5.3
Zinc total (µg/l)	114	5	650	104.6	142.5	8	5	150	66.9	66.2
Temperature (°C)	114	-0.3	29.4	12.4	7.7	8	5	18.9	12.3	6.6
pH	114	7.7	8.6	8.2	0.2	8	7.9	8.6	8.2	0.3
Conductance (µmhos/cm)	114	280	1150	690	228	8	360	820	600	191.1
Redox Potential (mv)	114	4	535	401	84.4	8	366	468	425	40.2
Oxygen dissolved (mg/l)	112	5.4	12.7	9	2	8	7.6	12.4	9.7	2.1

Table 4.13. Water chemistry data for San Juan River at Mexican Hat Bridge

San Juan River at Mexican Hat Bridge	1994-1998					1999				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	30	71	180	130.3	28.4	4	91	146	119.5	23.3
Alkalinity (mg/l)	30	71	180	130.3	28.4	4	91	146	119.5	23.3
Arsenic dissolved (µg/l)	59	0.5	2.5	2	0.7	4	0.7	2	1.2	0.6
Arsenic total (µg/l)	59	1	50	5	7.1	4	1	7	2.9	2.8
Calcium dissolved (mg/l)	30	32.7	112	75.5	23.7	4	42.5	90.5	67	19.6
Copper dissolved (µg/l)	30	2	13	5.6	3.3	4	3	5	3.8	1
Copper total (µg/l)	30	2.5	170	23.9	31.2	4	1.5	40	13.6	17.7
Hardness ((mg/l)	30	108	460	278.7	99.8	4	138	331	238.3	79.5
Mercury dissolved (µg/l)	59	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	59	0.1	1.1	0.2	0.2	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	30	6.3	43.8	21.9	10.1	4	7.8	25.6	17.3	7.7
Sodium dissolved (mg/l)	7	15	77.5	55.4	21	4	17.9	61.7	41.2	20.2
Lead dissolved (µg/l)	59	0.1	1	0.4	0.2	4	0.1	0.2	0.2	0.1
Lead total (µg/l)	59	0.5	327	23.1	51.9	4	0.5	31.4	8.2	15.5
Selenium dissolved (µg/l)	59	0.5	2	0.9	0.6	4	0.5	1	0.8	0.3
Selenium total (µg/l)	59	0.5	5	1.2	0.9	4	0.5	2	1	0.7
Selenium total recoverable (µg/l)	9	0.5	2	1.1	0.6	4	0.5	2.5	1.8	0.9
Total dissolved solids (mg/l)	29	170	800	493.1	179.7	4	250	570	400	143.1
Total suspended solids (mg/l)	59	1	16090	1328.9	2793.5	4	2.5	2770	849.1	1312.2
Turbidity (NTU)	57	1	11000	755.6	1825.1	4	4.9	825	254	389.4
Zinc dissolved (µg/l)	59	5	100	8.5	13.1	4	5	5	5	0
Zinc total (µg/l)	59	5	1620	111.6	230	4	5	130	57.5	62.8
Temperature (°C)	59	-0.2	29.8	12.6	7.9	4	5.5	19.1	12.5	6.7
pH	59	7.7	8.6	8.2	0.2	4	7.7	8.6	8.1	0.5
Conductance (µmhos/cm)	59	270	1050	700	220.1	4	380	820	610	196.1
Redox Potential (mv)	59	245	537	403	70.6	4	367	475	421	46
Oxygen dissolved (mg/l)	58	5.8	12.9	9.1	2	4	7.2	11.4	9.4	1.9

CHAPTER 5. HABITAT STUDIES

HABITAT QUANTITY

Habitat quantity was determined using airborne videography as previously described by Bliesner and Lamarra (1998). Habitat types mapped can be seen in Table 5.1 with habitat categories summarized into seven general categories. Mapping occurred between November 19 and December 11, 1998 between RM 2 and RM 180. Flows during the habitat mapping ranged between 1,300 and 900 cfs. Run habitats had the most surface area with 84.7 % of the wetted area of the San Juan River. Riffles were second most dense (8.54 %) followed by shoals (3.96 %) and slack waters (1.82 %). Backwaters made up only 0.25 % of the surface area of habitats (Figure 5.1). The spatial distribution of these same general categories can be seen in Figure 5.2. Low velocity and backwater habitats were distributed throughout the river but are in highest magnitude between RM 130 and 145 as well as below RM 20. Shoals 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 mostly found between RM 20 and RM 80 and are associated with riffle complexes. Habitat diversity, expressed as the Shannon-Weaver index (Shannon and Weaver, 1949) based on habitat counts, can be seen in Figure 5.3. The river wide habitat diversity has been increasing since October 1996 and is currently at its highest average value.

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 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 1998), the magnitude of backwater habitats are influenced by location in the river, flow magnitude, and summer storm events. In order to simplify the analysis, only mapping runs between 800 and 1,200 cfs are used in a comparison of temporal trends. These data are shown in Figure 5.4 for both surface area and the number of backwaters. The data indicated that after reaching a maximum surface area of 143,000 m^2 (373 backwaters), there has been a decrease down to 43,000 m^2 (164 backwaters). The loss of the 100,000 m^2 or 200 backwaters has primarily occurred in Reaches 3 and 4 (Figure 5.5).

HABITAT QUALITY

The depths of backwaters is an important attribute relative to use by native endangered species. In the San Juan system, backwater depths are effected by sediment laden summer storms. Bed sediment depths in backwaters have been periodically measured since August 1995. A good example of the influence of storms can be seen during August, September, and November 1995. Seven storms during the summer and fall of 1995 deposited an average of 0.5 meters of sediment in backwaters (Figure 5.6). Since 1995, summer sediment depths have ranged river wide between 0.2 and 0.4 meters in depth. In the fall of 1997, sediment depths again reached almost 0.6 meters.

The December 1999 monitoring of backwater sediment depths indicated that sediment depths were the second shallowest (average 0.14 meters and SD of 0.04 meters) since the August 1995 sampling. The deepest sediment depths were in Reach 2 (average 0.22 meters and SD of 0.03 meters) and the shallowest in Reach 4 (average 0.09 and SD of 0.03).

Table 5.1. Seven general categories of habitat types on the San Juan River

LOW VELOCITY	RUN	RIFFLE	BACKWATER	SHOAL	SLACKWATER	VEGETATION ASSOCIATED HABITAT
pool	shoal/run	riffle	backwater	sand shoal	slackwater	overhanging vegetation
debris pool	run	shore riffle	backwater pool	cobble shoal	pocket water	inundated vegetation
rootwad pool	scour run	riffle chute	embayment			
eddy	shore run	shoal/riffle				
edge pool	undercut run	chute				
riffle eddy	run/riffle	rapid				

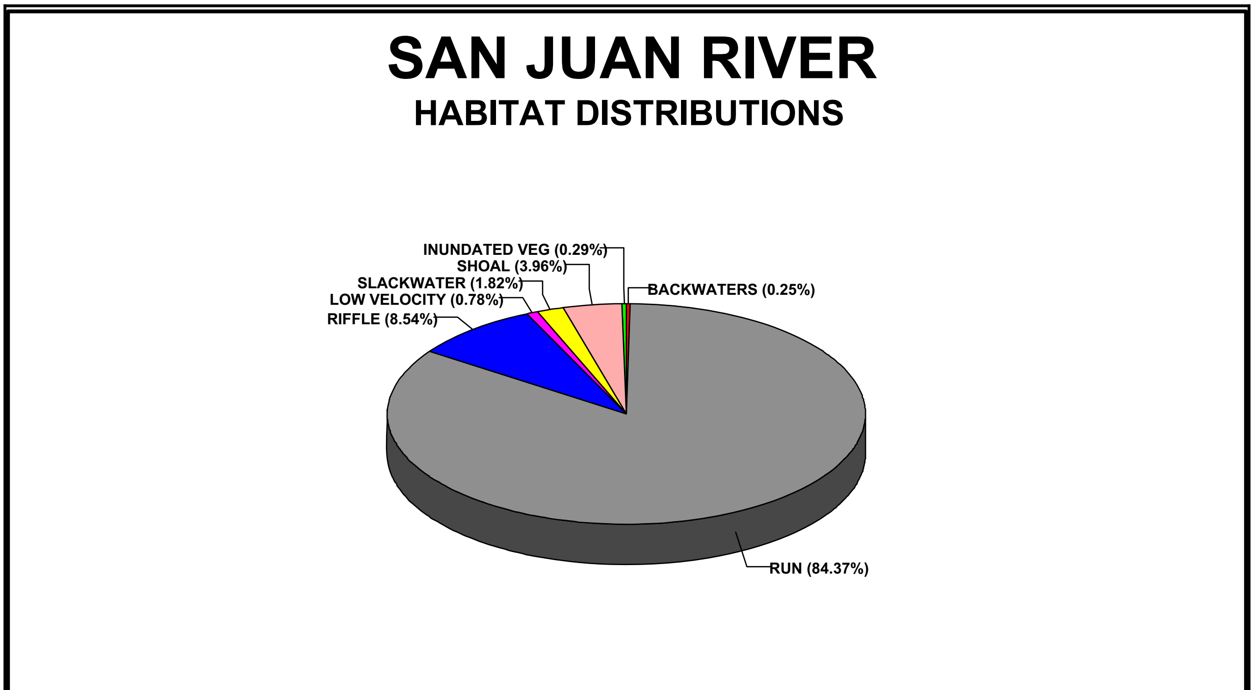


Figure 5.1. The percent distribution of general habitats in the San Juan River during November-December 1998.

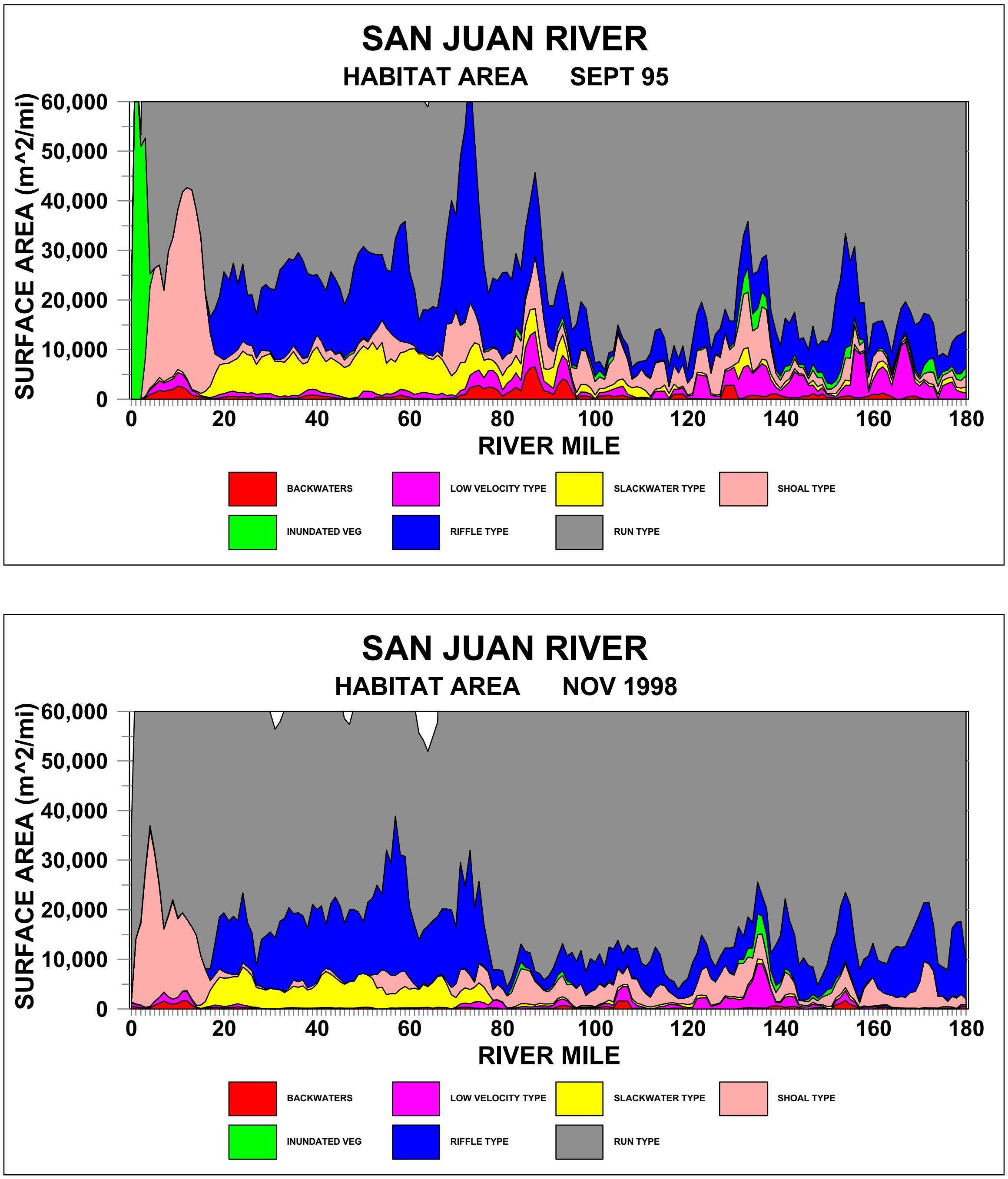


Figure 5.2. The spatial distribution of habitats in the San Juan River, November - December 1998. Run habitats are not shown.

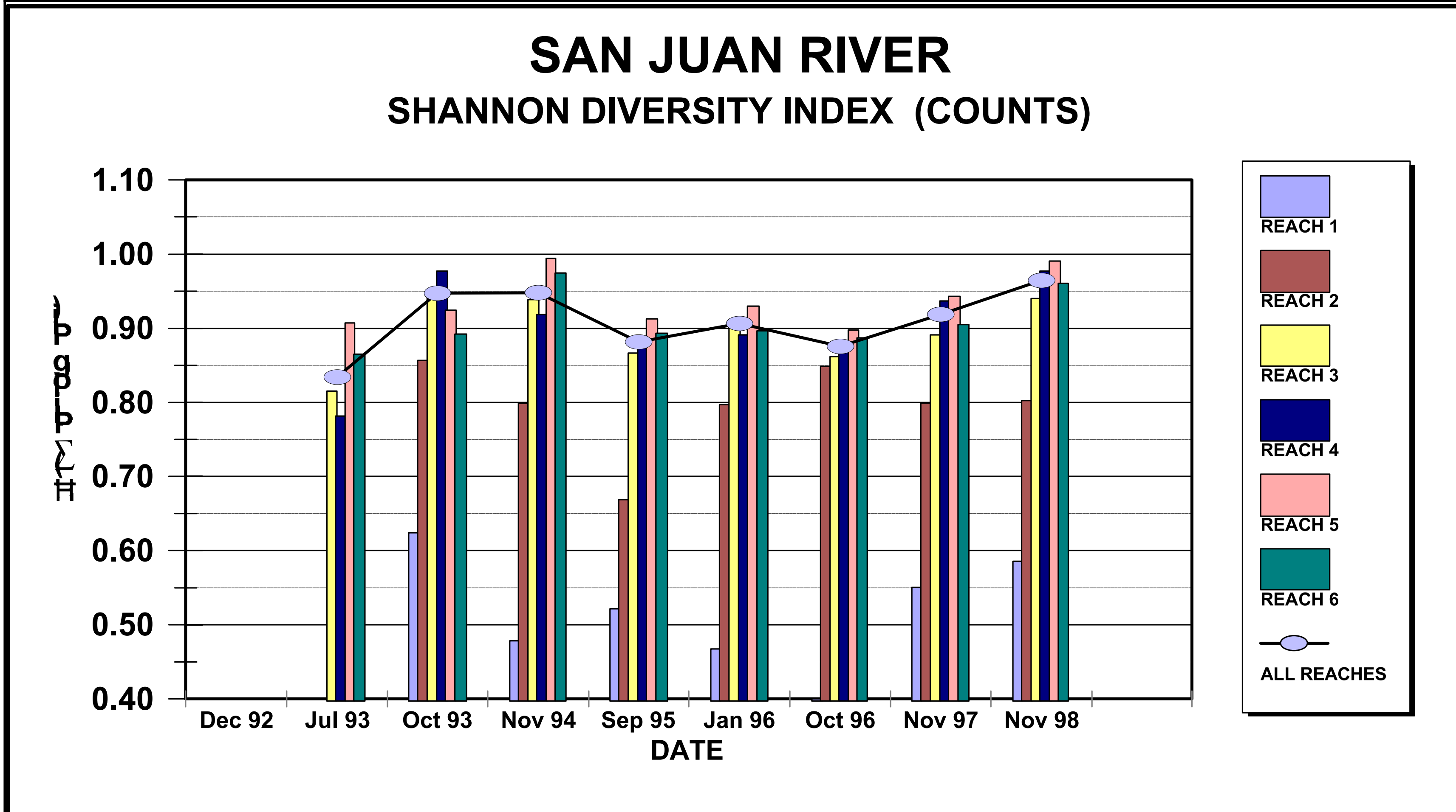


Figure 5.3. **The habitat diversity values for the San Juan River (Reaches 1-6) and the overall river-wide average for November 1998 compared to previous trips where flows were between 800-1,200 cfs.**

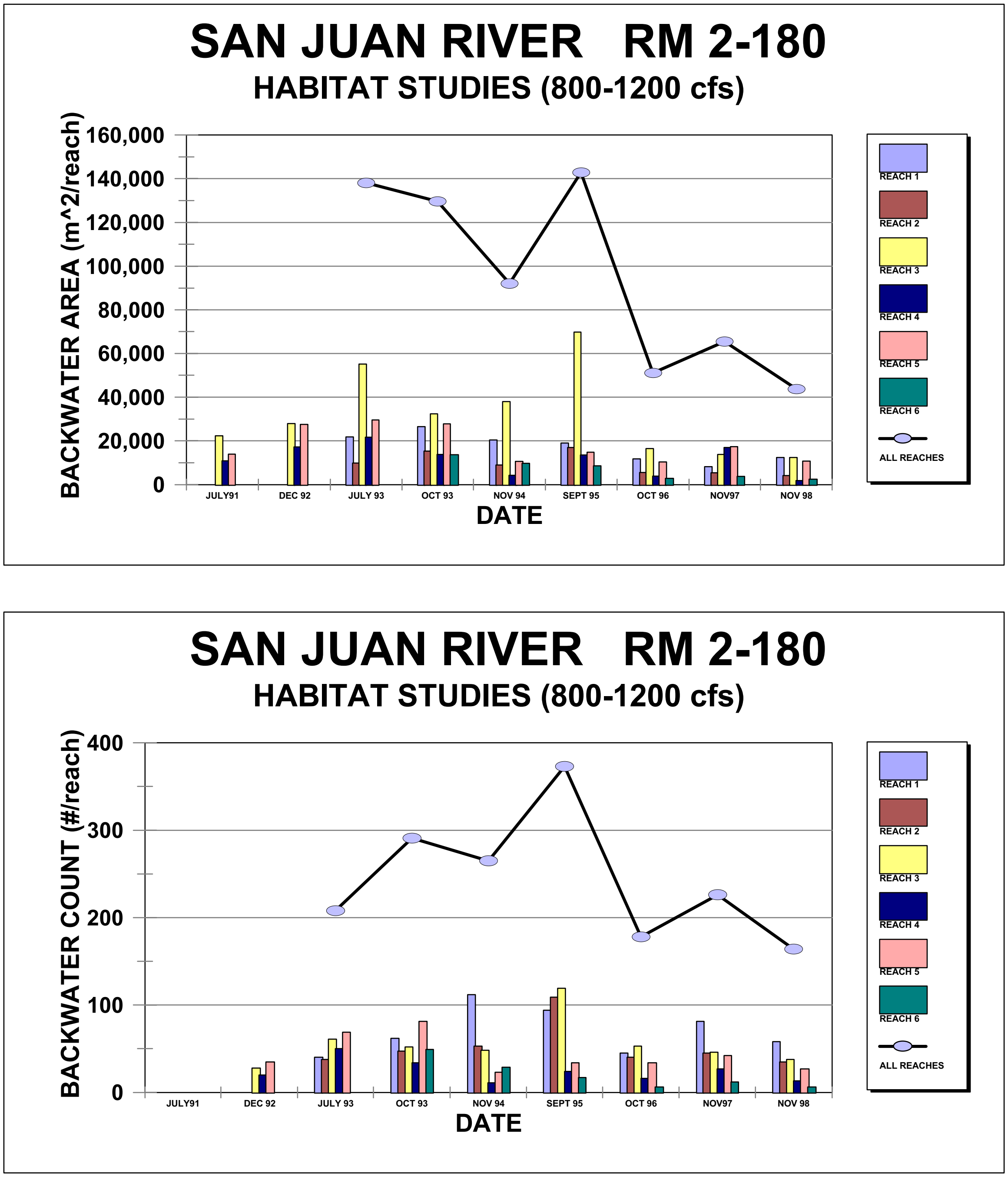
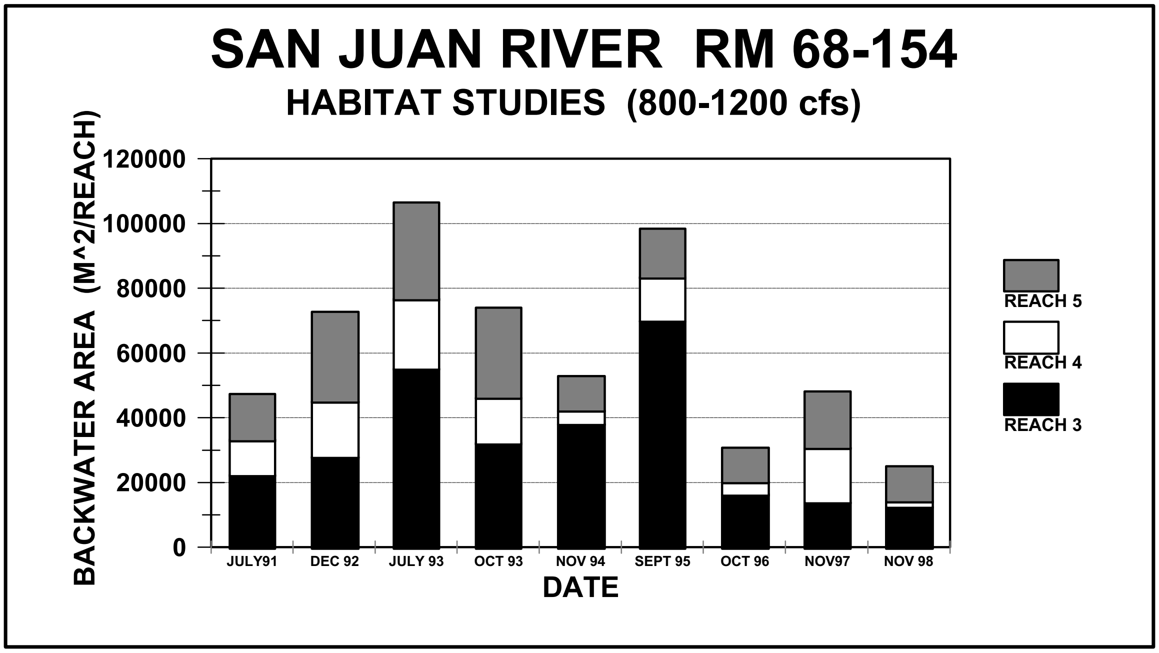


Figure 5.4. The surface area (above) and counts (below) of backwater habitats in the San Juan River between July 1991 and November 1998. Data are for each reach and RM 2 through 180.



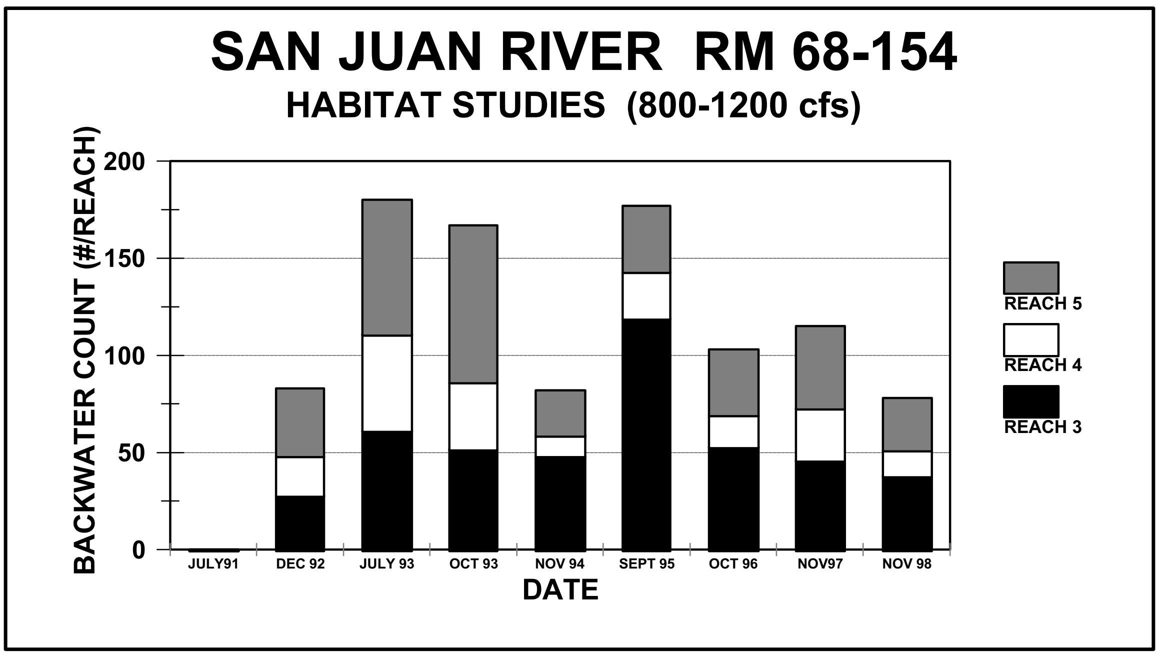


Figure 5.5. The surface area of backwaters (above) and counts (below) for three reaches in the San Juan River between July 1991 and November 1998.

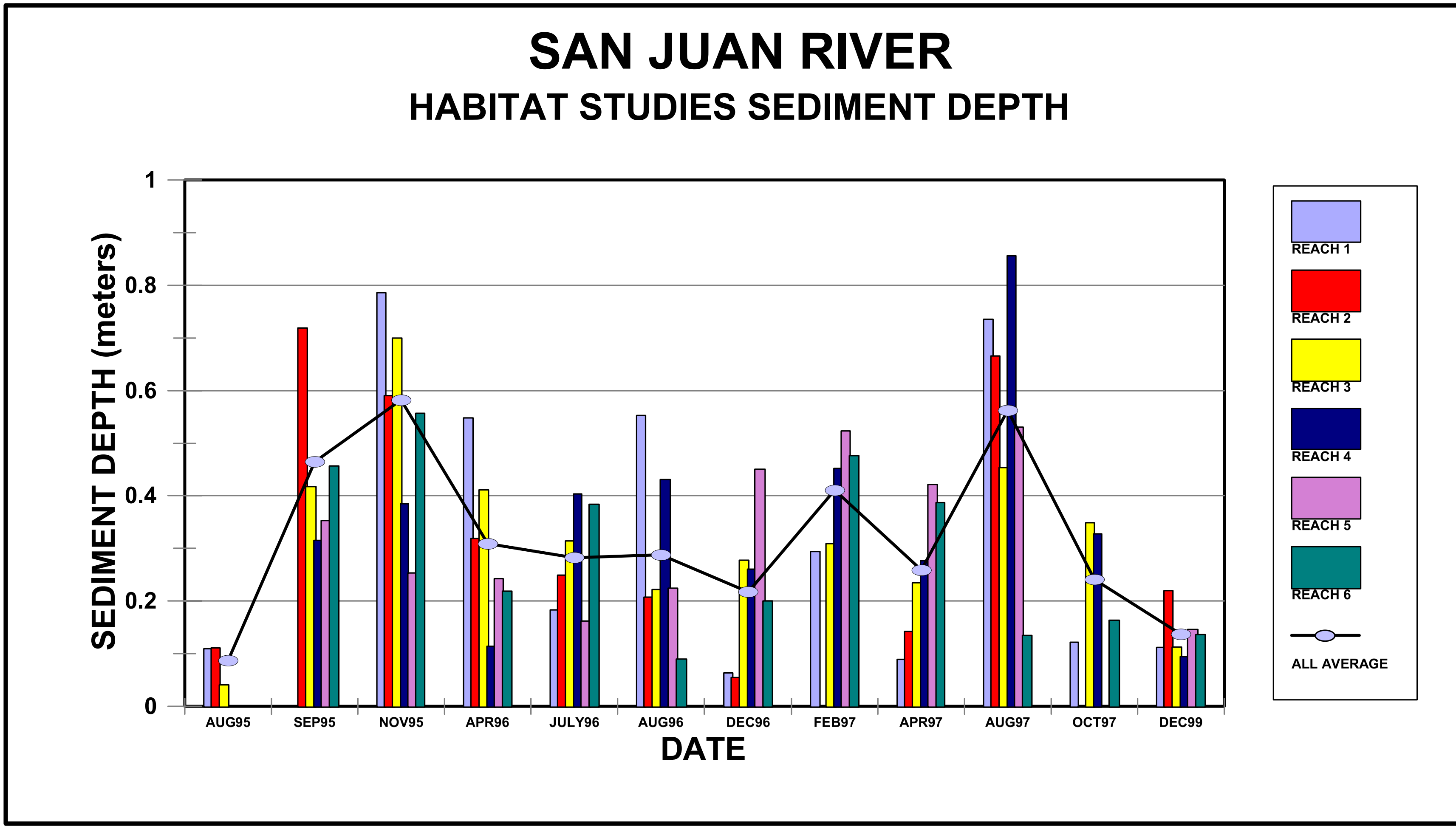
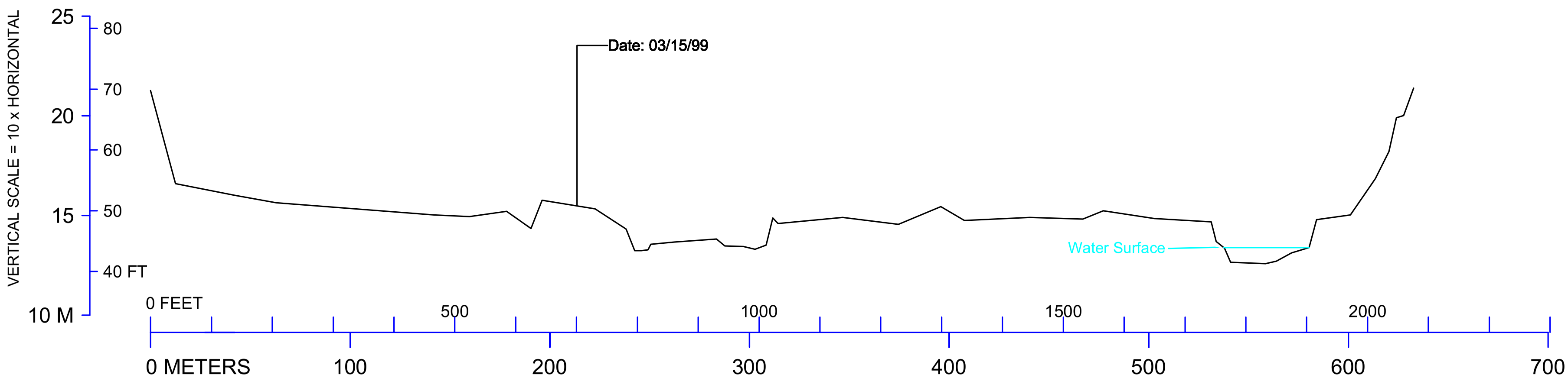
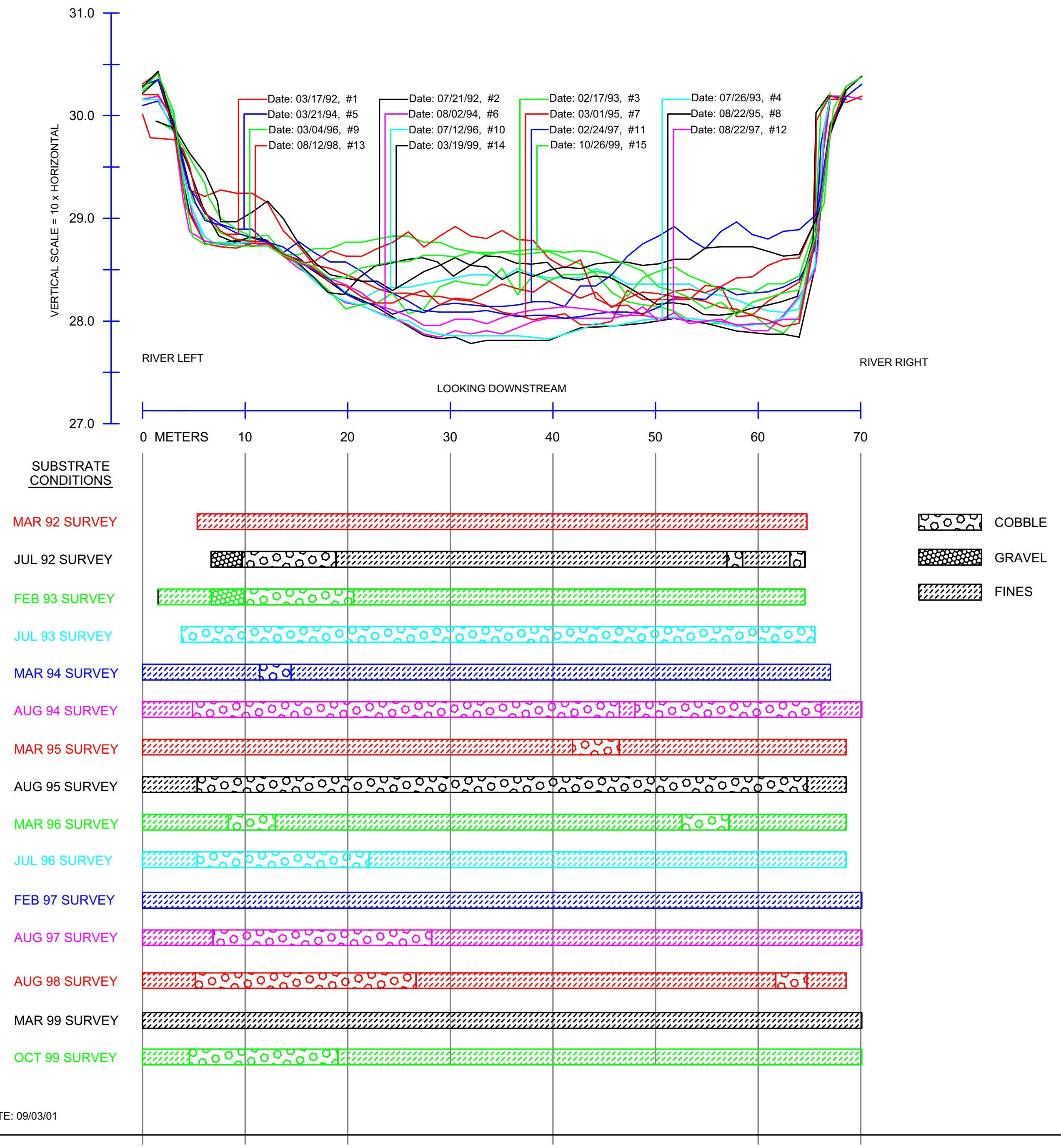


Figure 5.6. **The depth of sediments (meters) in backwater habitats of the San Juan River.**

Valley Wide Cross-Section CS6-01 (RM 175.0)
USGS 7.5 Min Quadrangle: Kirtland, NM



TRANSECT CS6-02 (RT01)
PHOTO 357-67
FRUITLAND QUAD.



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TRANSECT CS6-02 (RT01)
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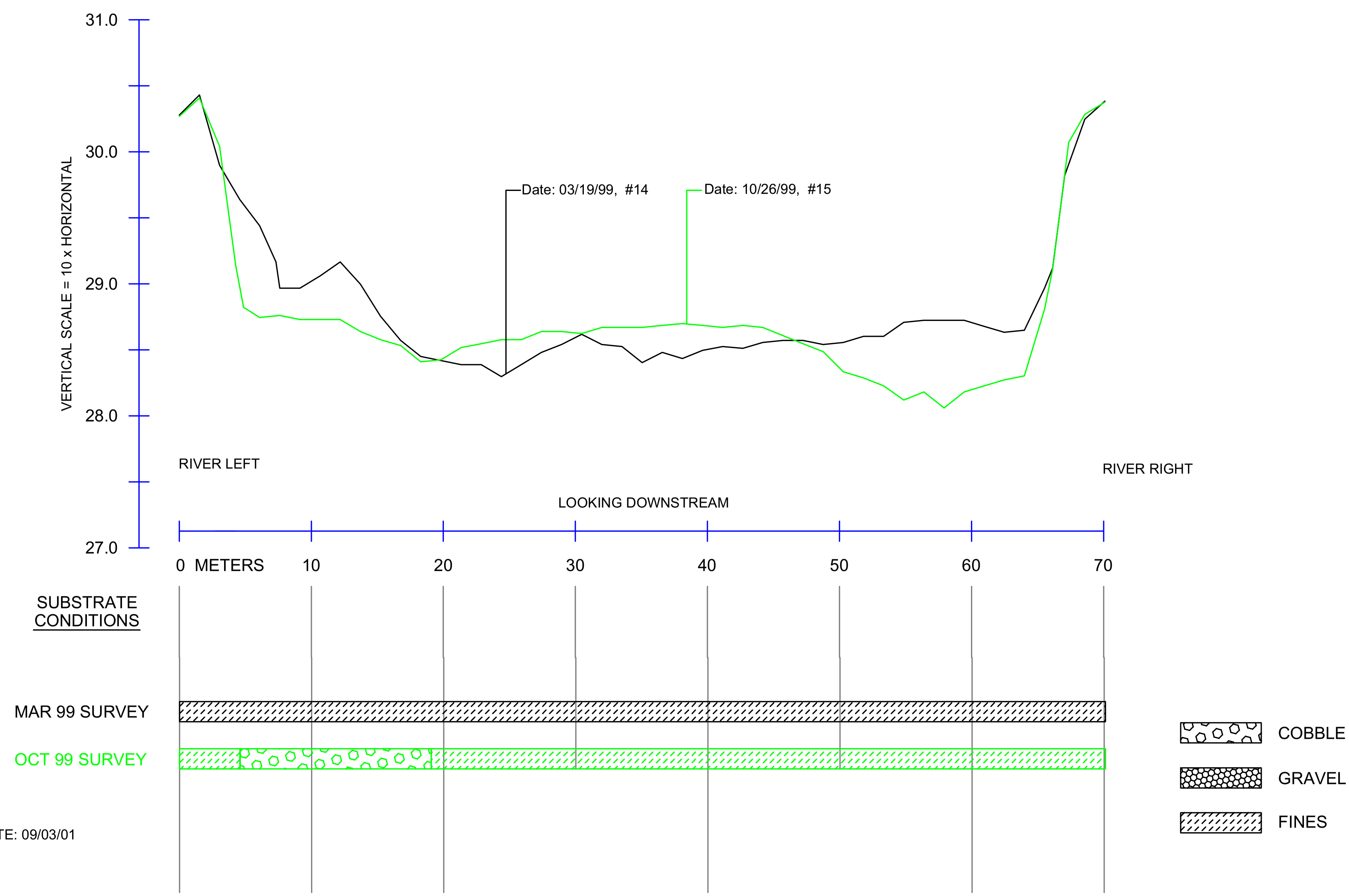
FRUITLAND QUAD.



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TRANSECT CS6-03 (RT02)
PHOTO 357-46 NHAP
QUAD: CHIMNEY ROCK

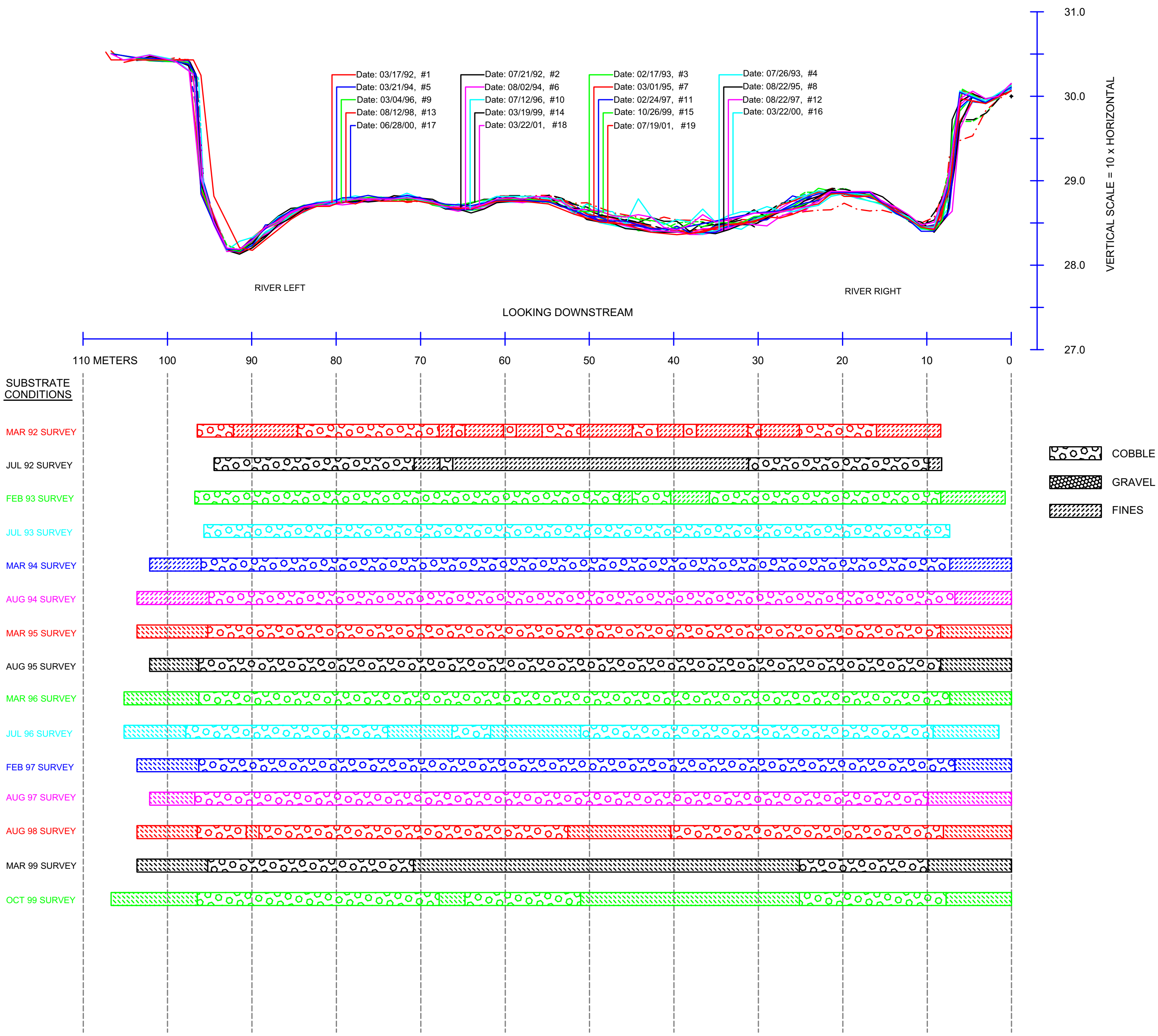

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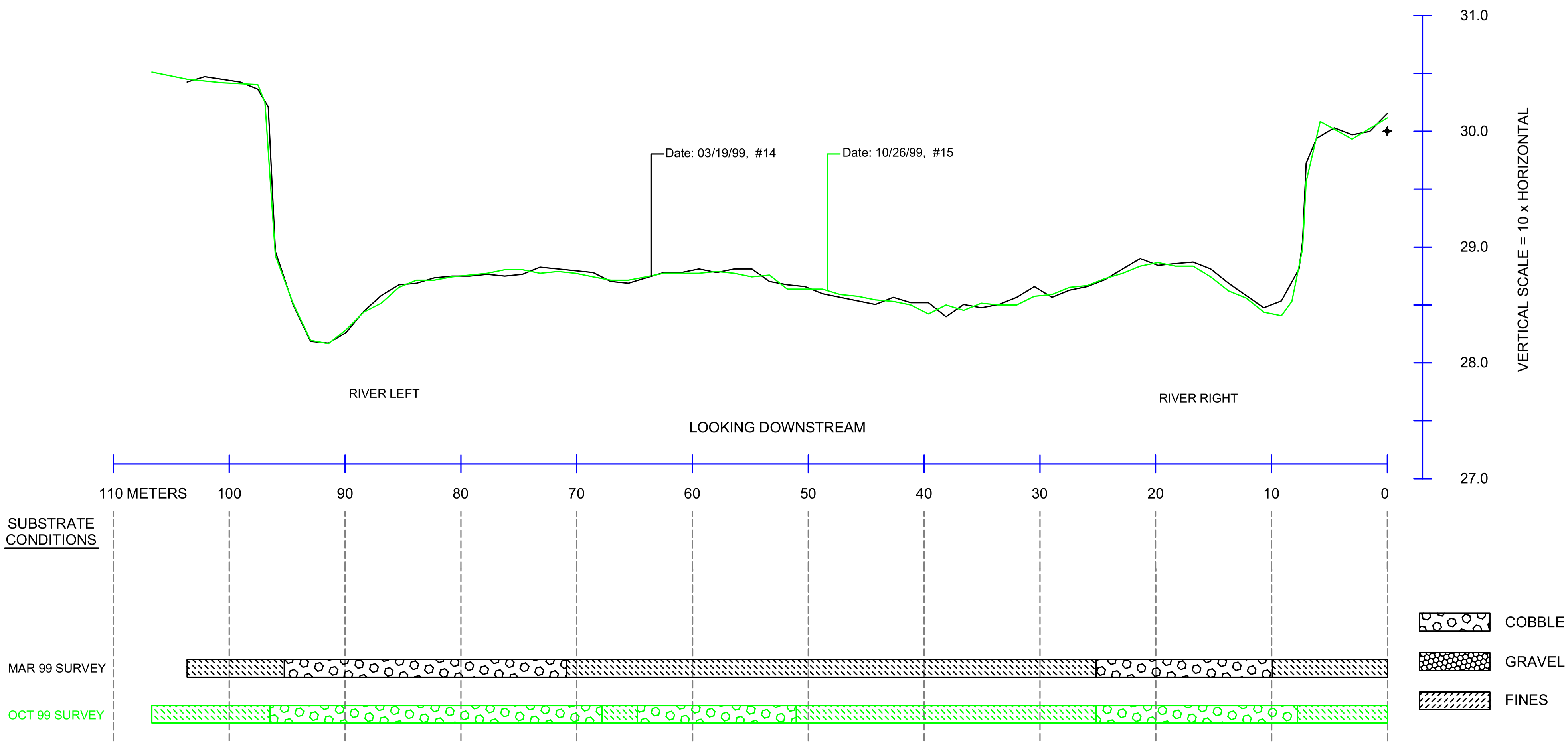
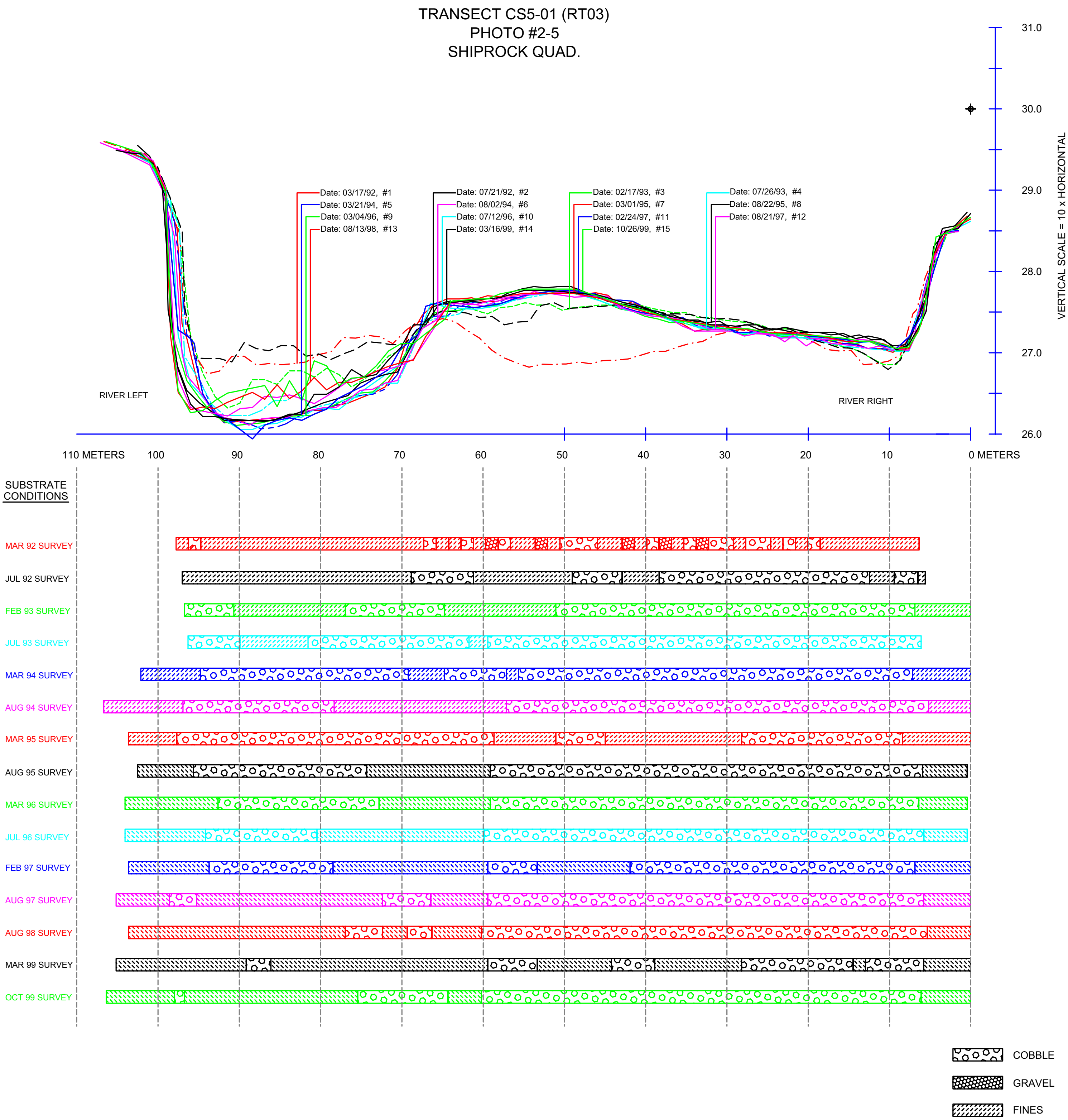
PHOTO 357-46 NHAP
QUAD: CHIMNEY ROCK





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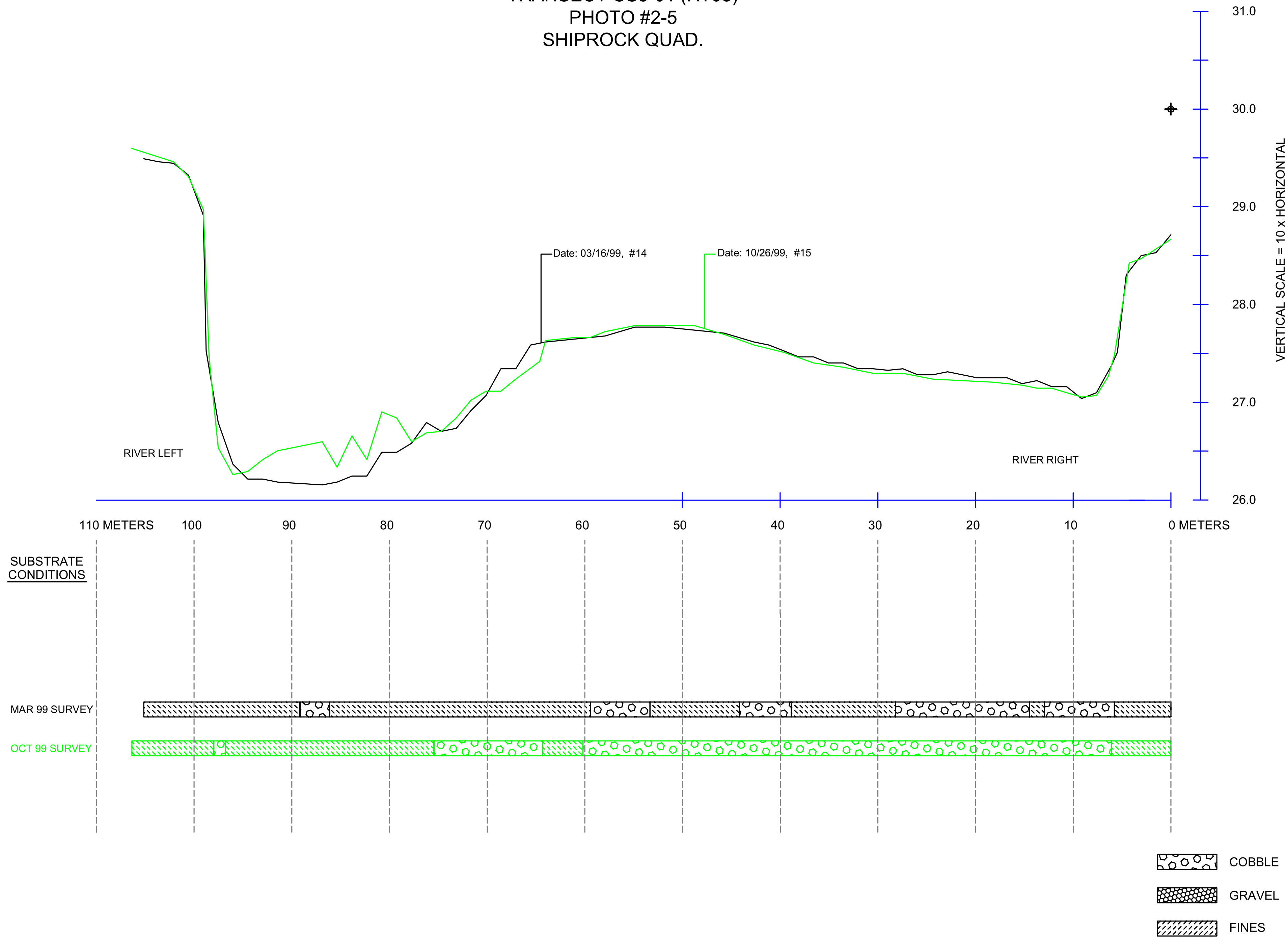
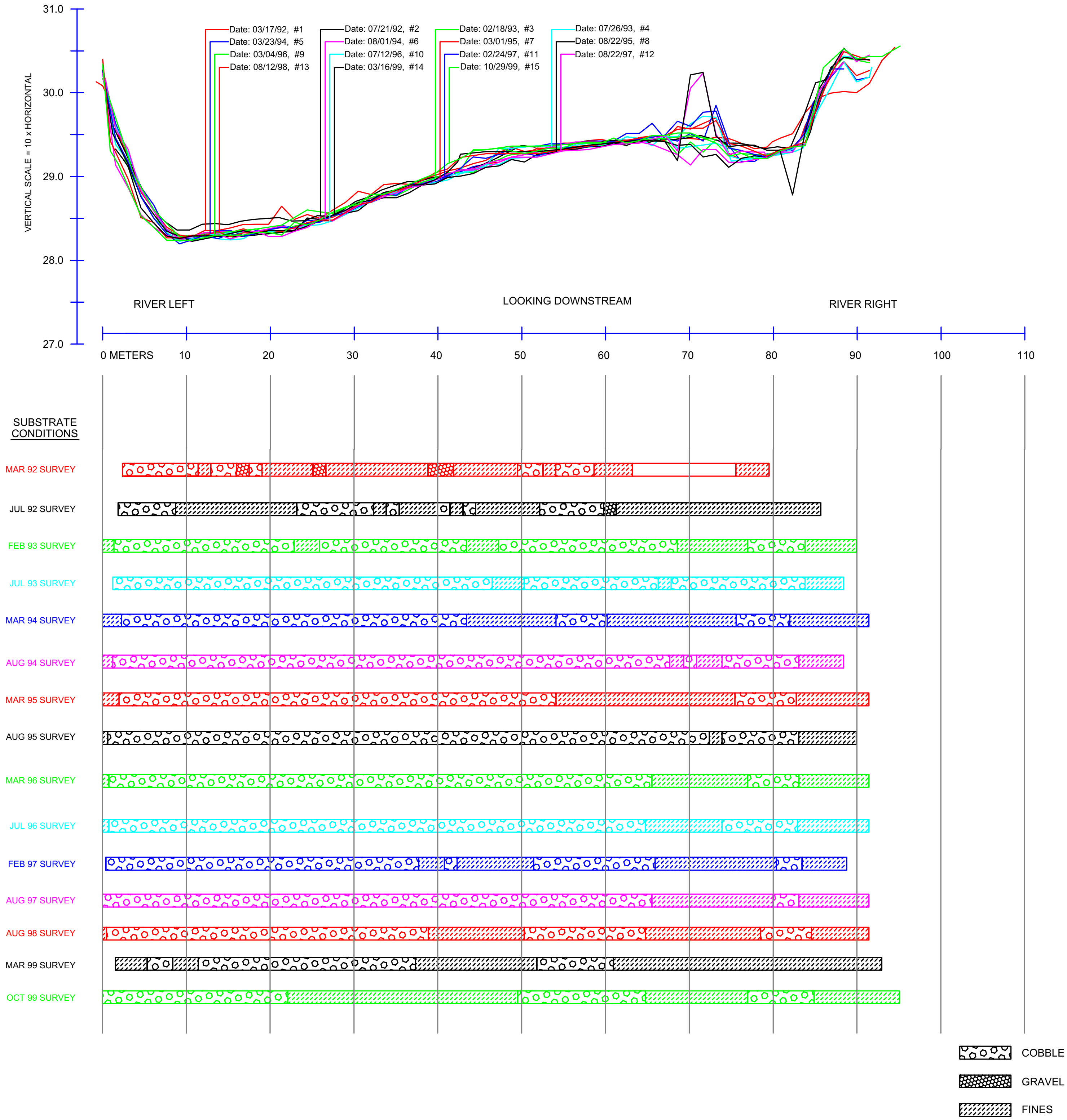
TRANSECT CS5-01 (RT03)
PHOTO #2-5
SHIPROCK QUAD.



TRANSECT CS5-02 (RT04)
PHOTO 3-7
CANAL CREEK QUAD.



FILE: RT04-GIS.DWG DATE: 09/04/01

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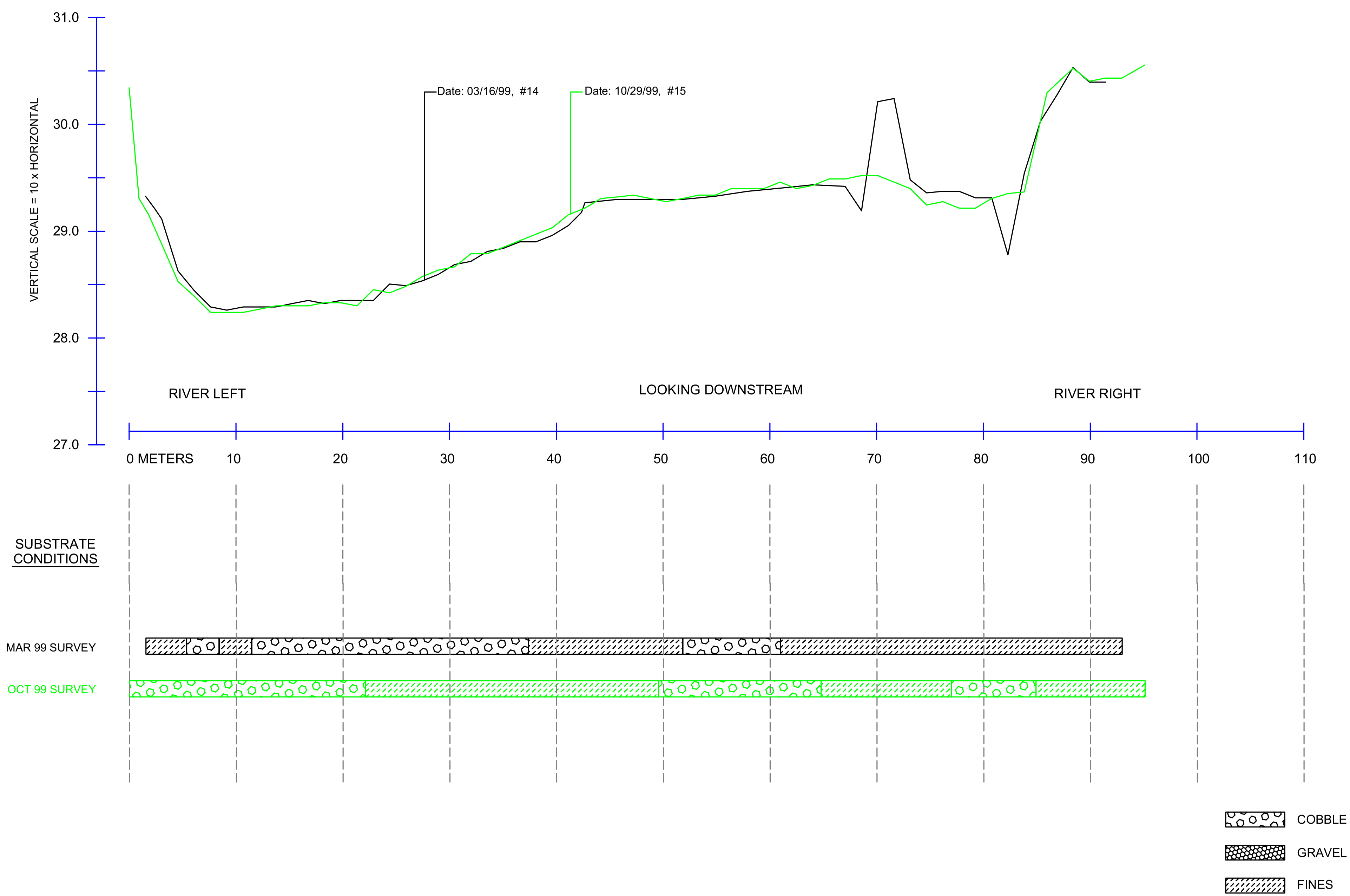
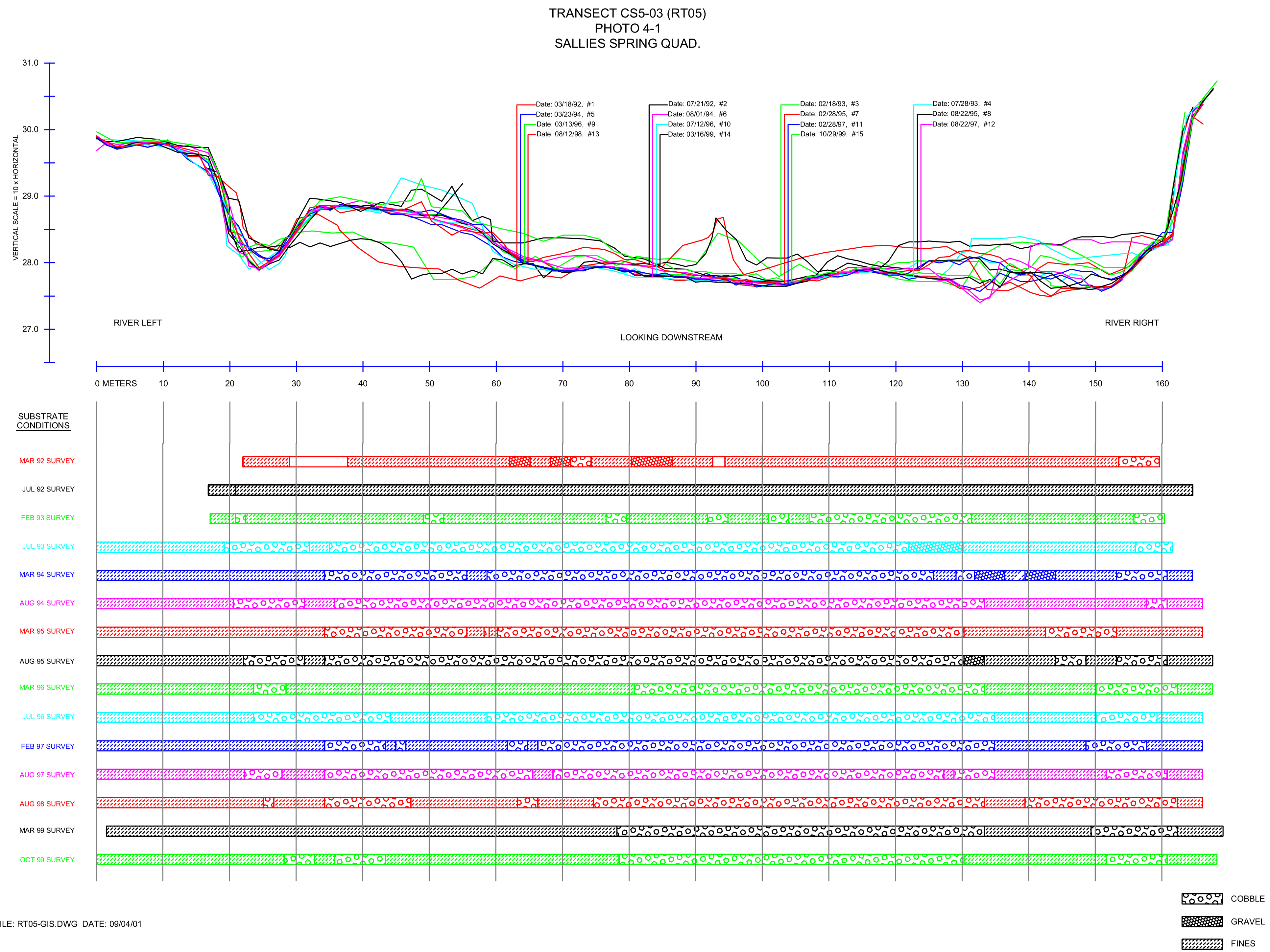
PHOTO 3-7
CANAL CREEK QUAD.





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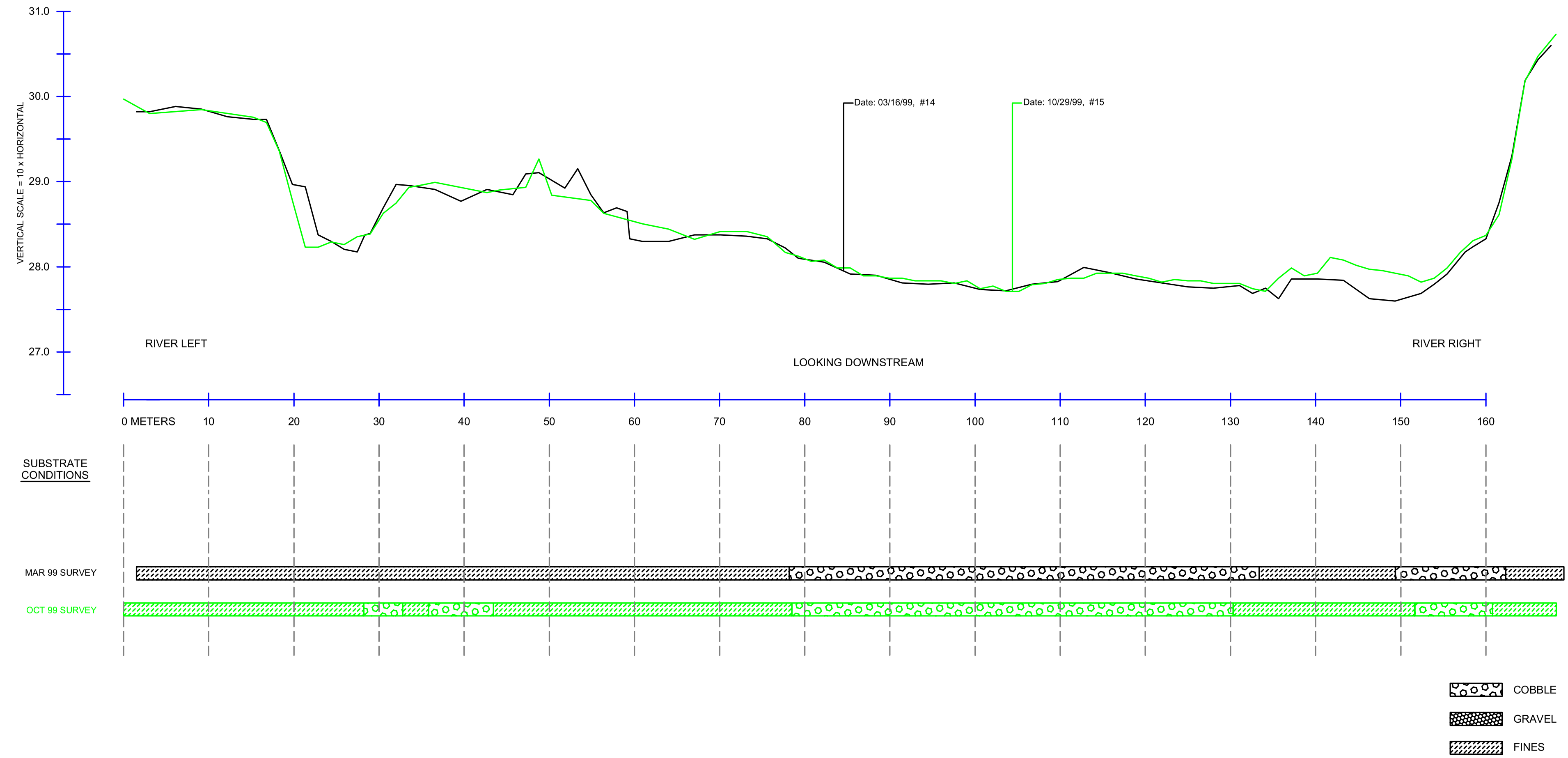
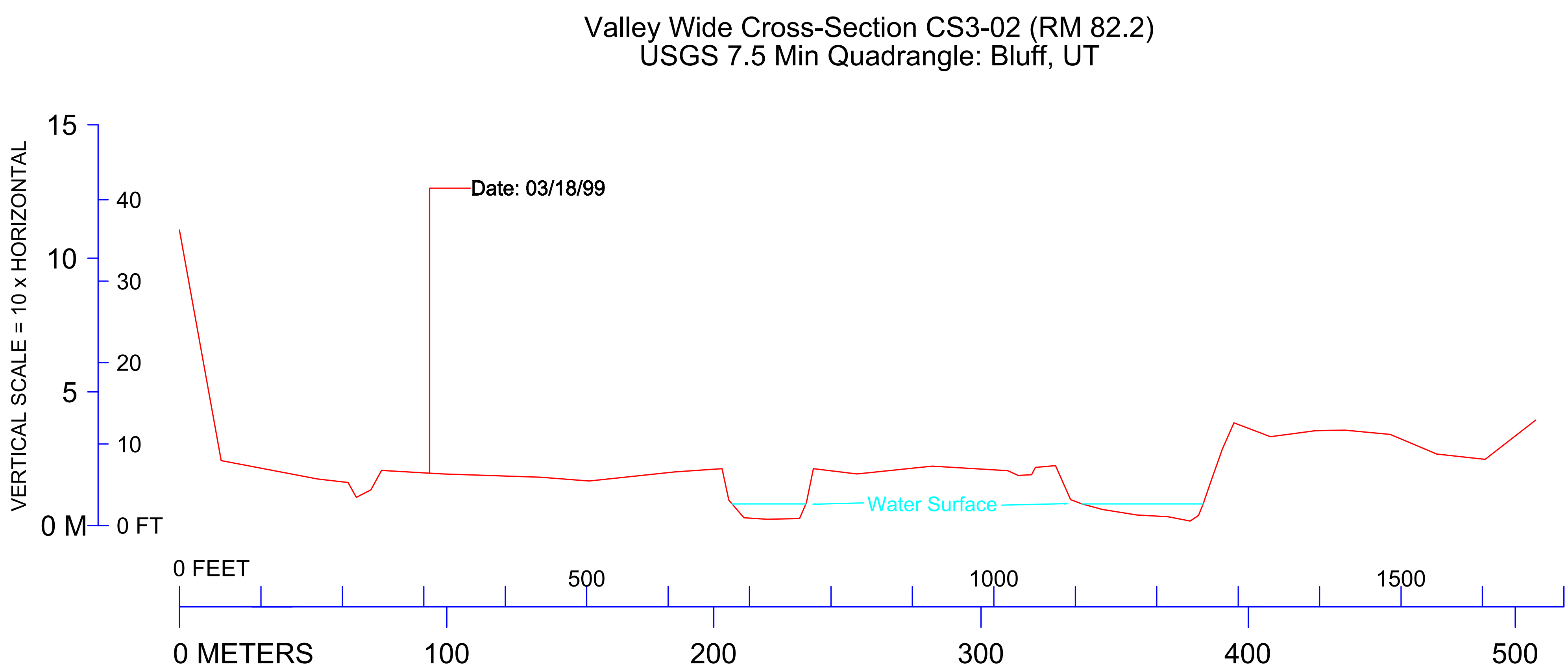
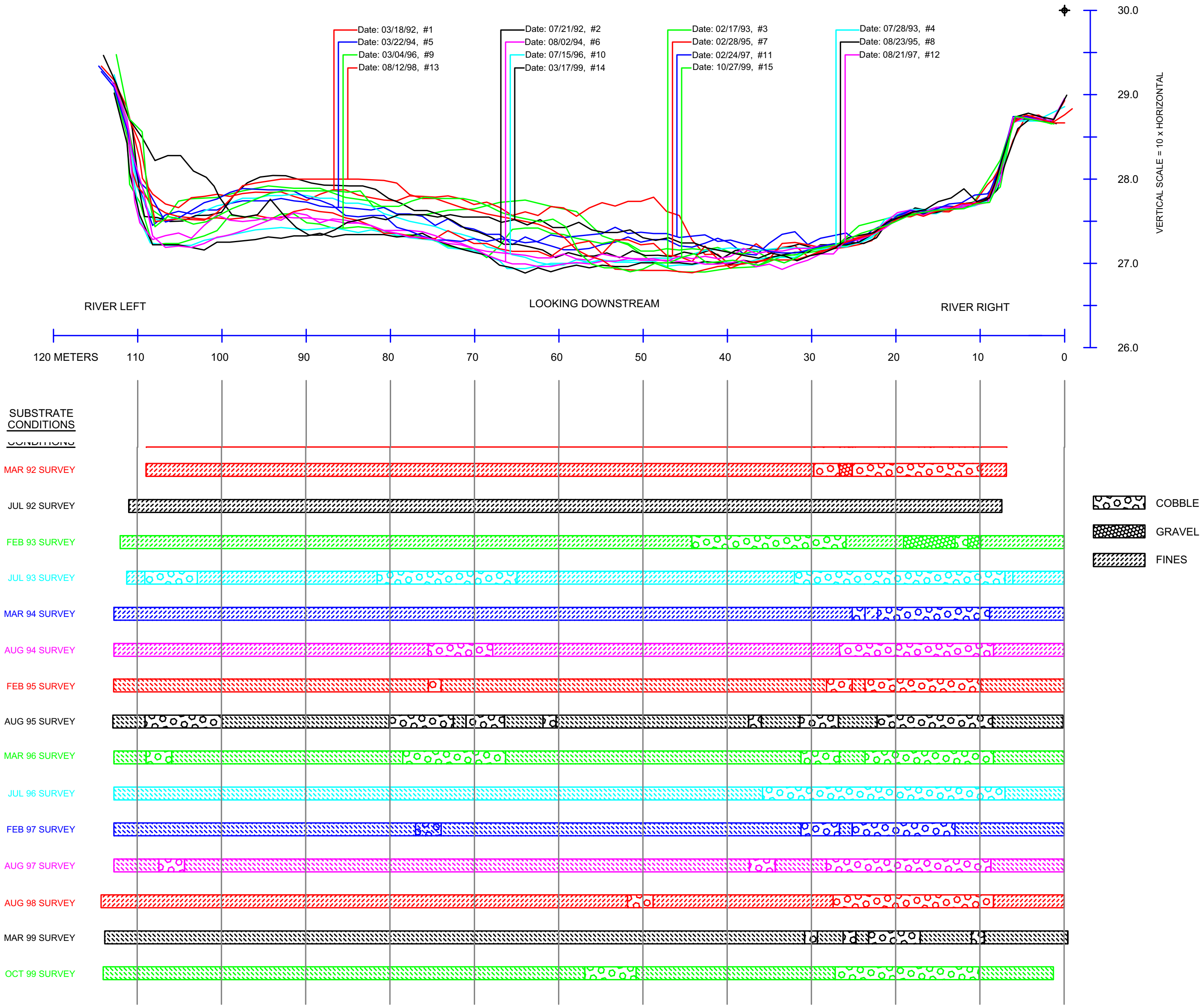
TRANSECT CS5-03 (RT05)
PHOTO 4-1
SALLIES SPRING QUAD.




Valley Wide Cross-Section CS3-02 (RM 82.2)
USGS 7.5 Min Quadrangle: Bluff, UT
VERTICAL SCALE = 10 x HORIZONTAL
15
10
5
0 M
40
30
20
10
0 FT
Date: 03/18/99
Water Surface
0 FEET
500
1000
1500
0 METERS
100
200
300
400
500

TRANSECT CS4-01 (RT06)
PHOTO 4-11
SALLIES SPRING QUAD.



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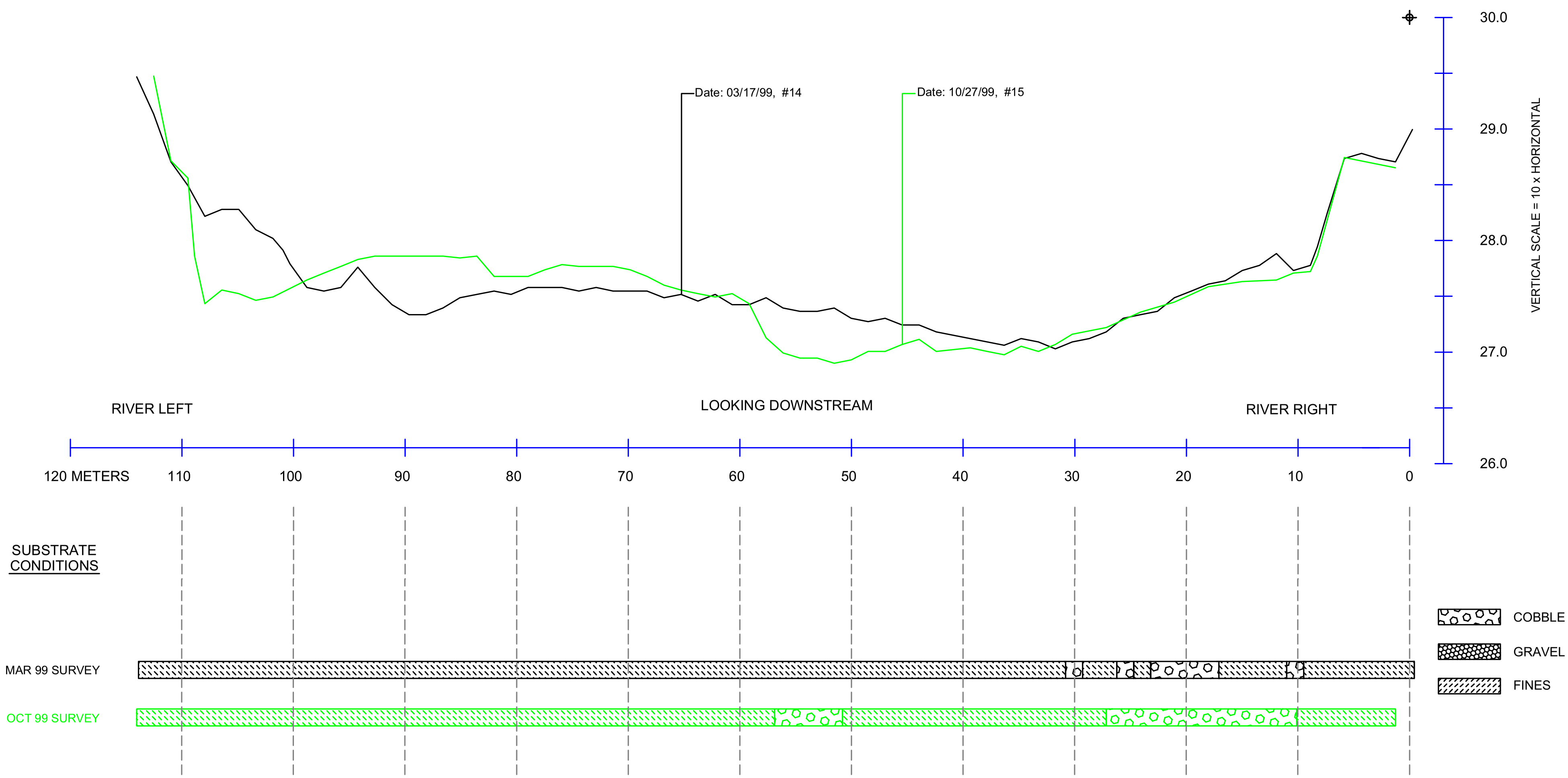
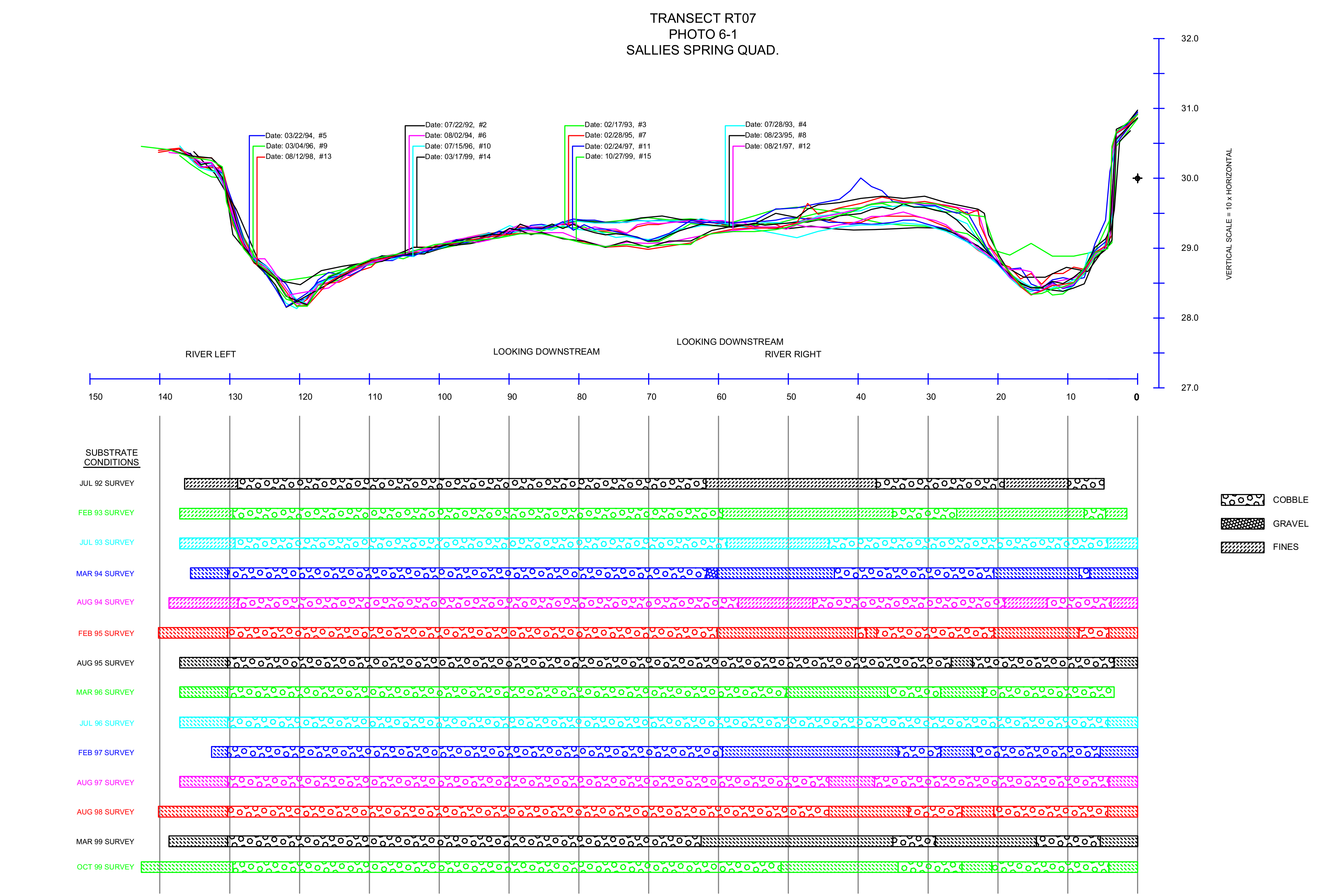
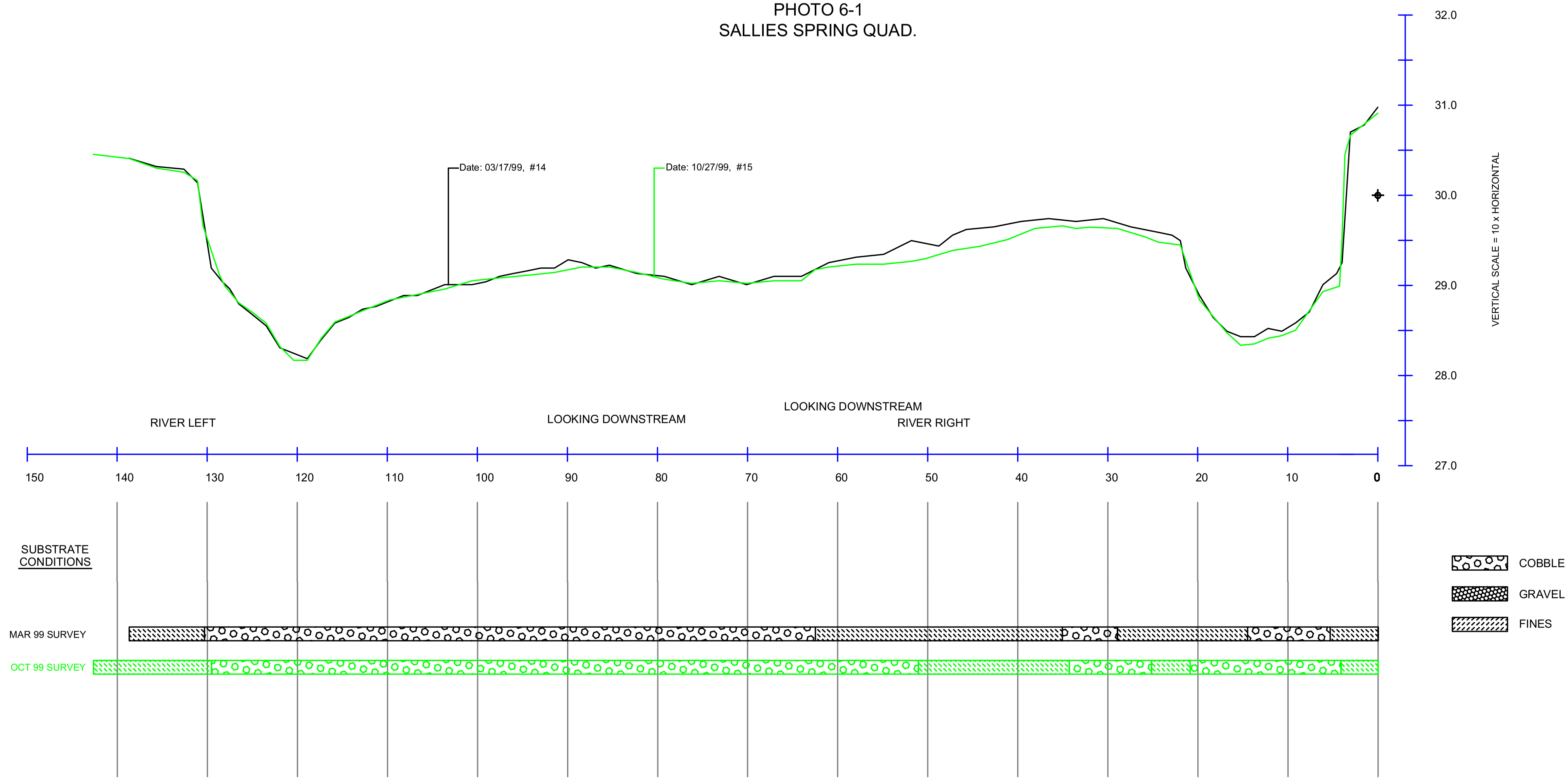
TRANSECT CS4-01 (RT06)
PHOTO 4-11
SALLIES SPRING QUAD.

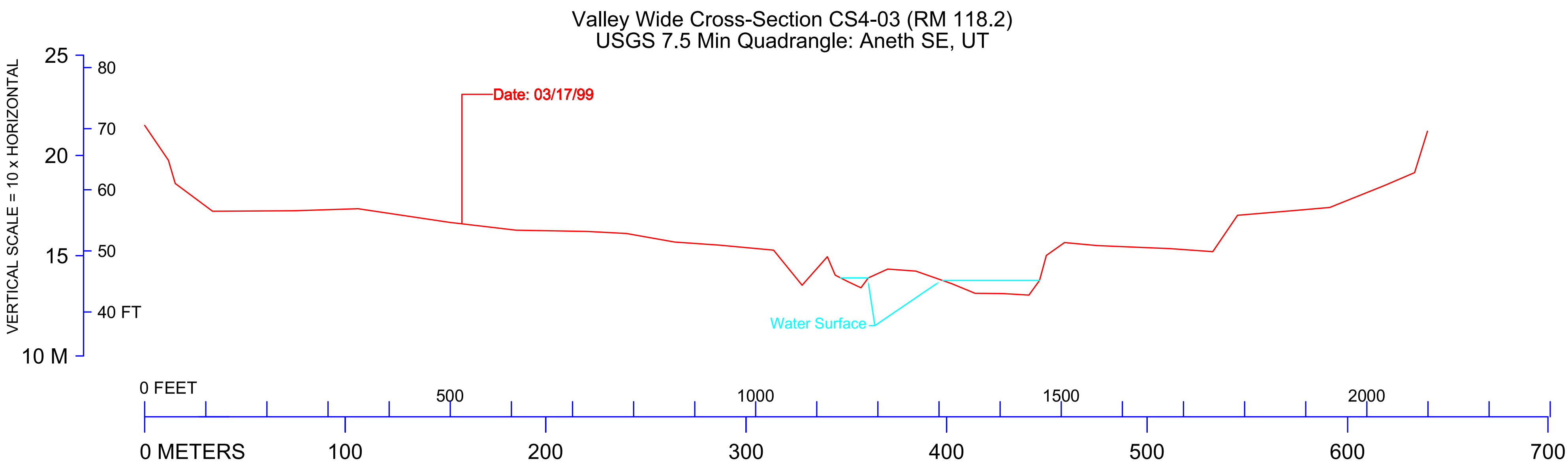




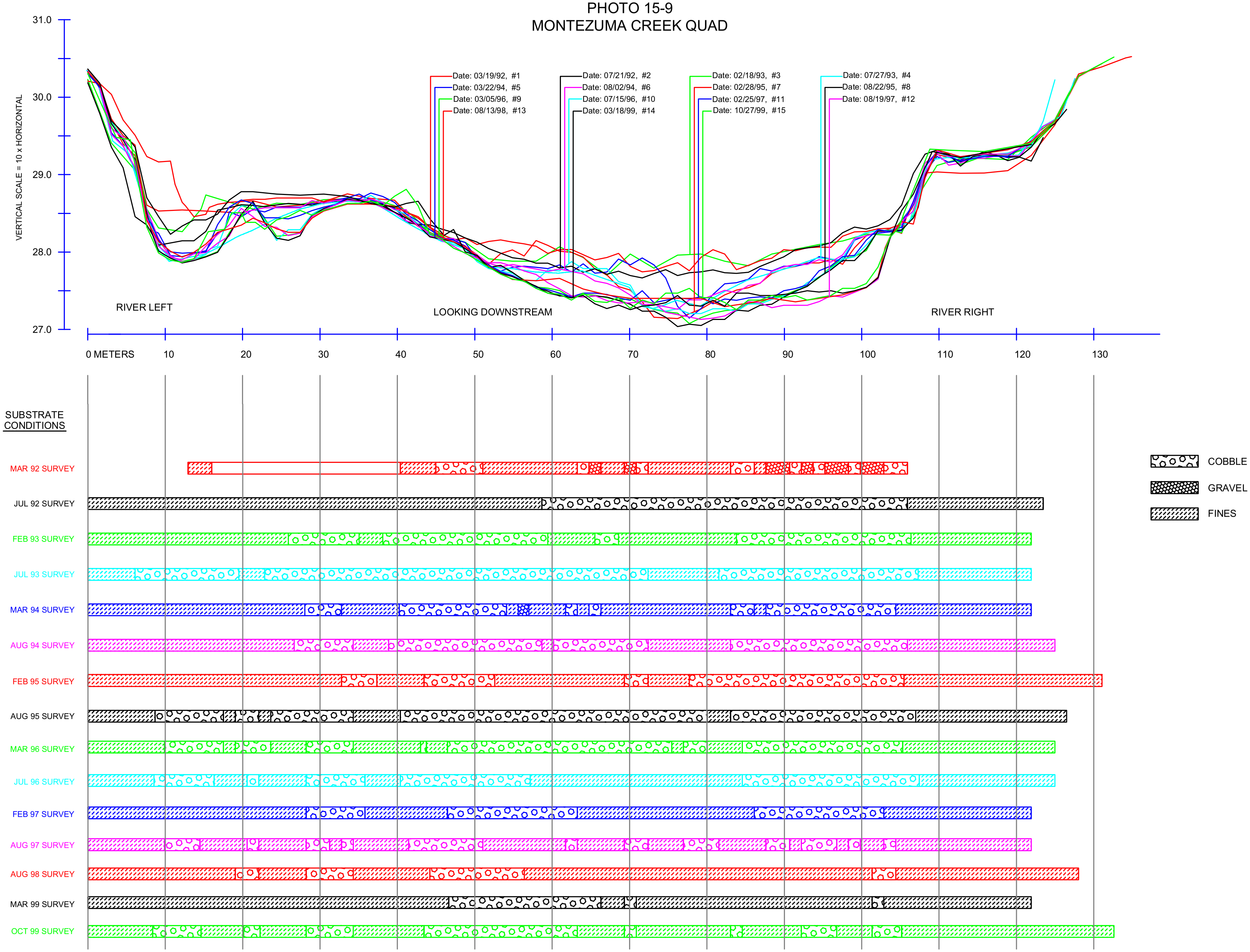
FILE: RT07-GIS.DWG DATE: 09/05/01

TRANSECT RT07
PHOTO 6-1
SALLIES SPRING QUAD.



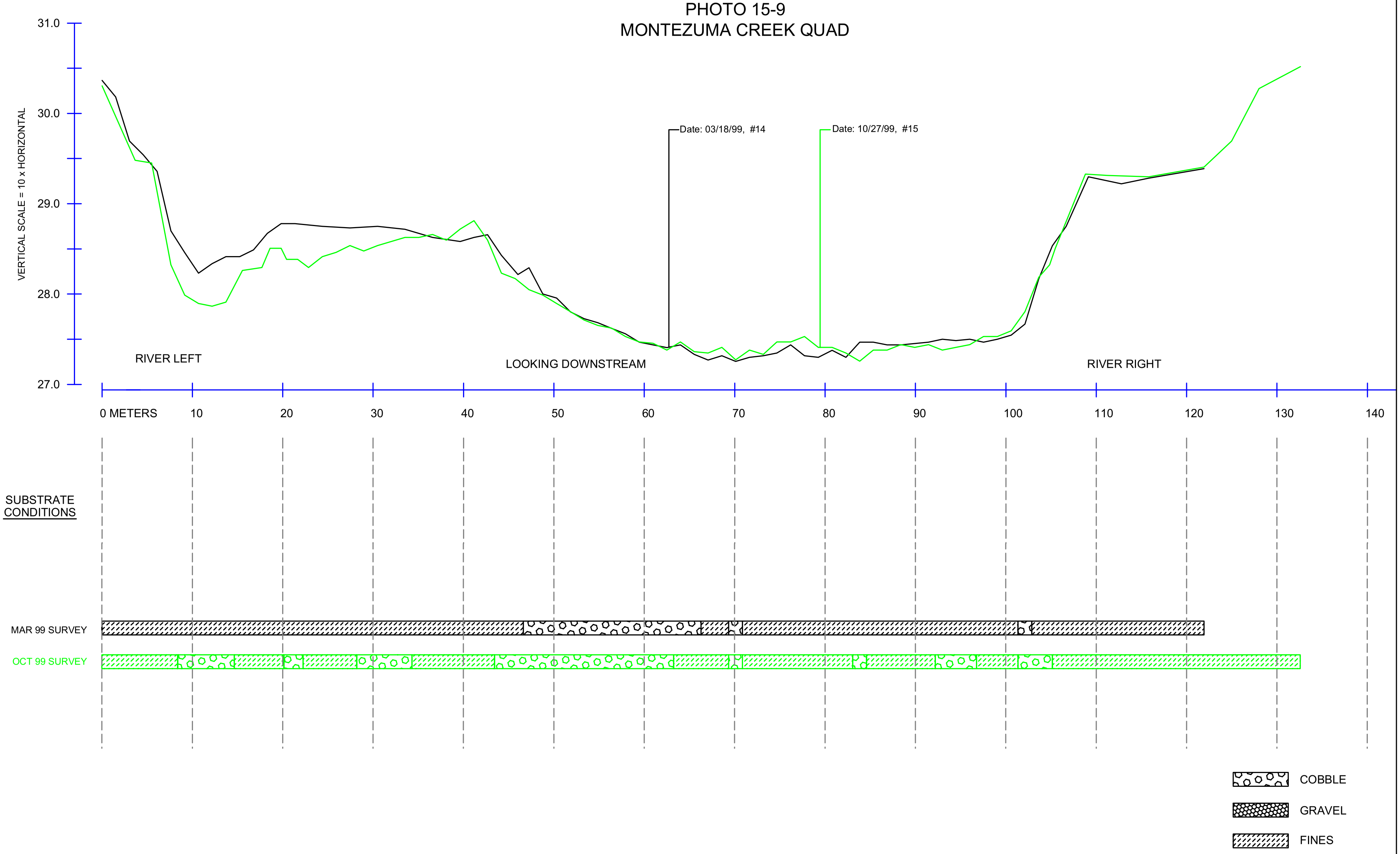

Valley Wide Cross-Section CS4-03 (RM 118.2)
USGS 7.5 Min Quadrangle: Aneth SE, UT
Date: 03/17/99
Water Surface
VERTICAL SCALE = 10 x HORIZONTAL
25
20
15
10 M
80
70
60
50
40 FT
0 FEET
500
1000
1500
2000
0 METERS
100
200
300
400
500
600
700

TRANSECT CS3-01 (RT09)
PHOTO 15-9
MONTEZUMA CREEK QUAD

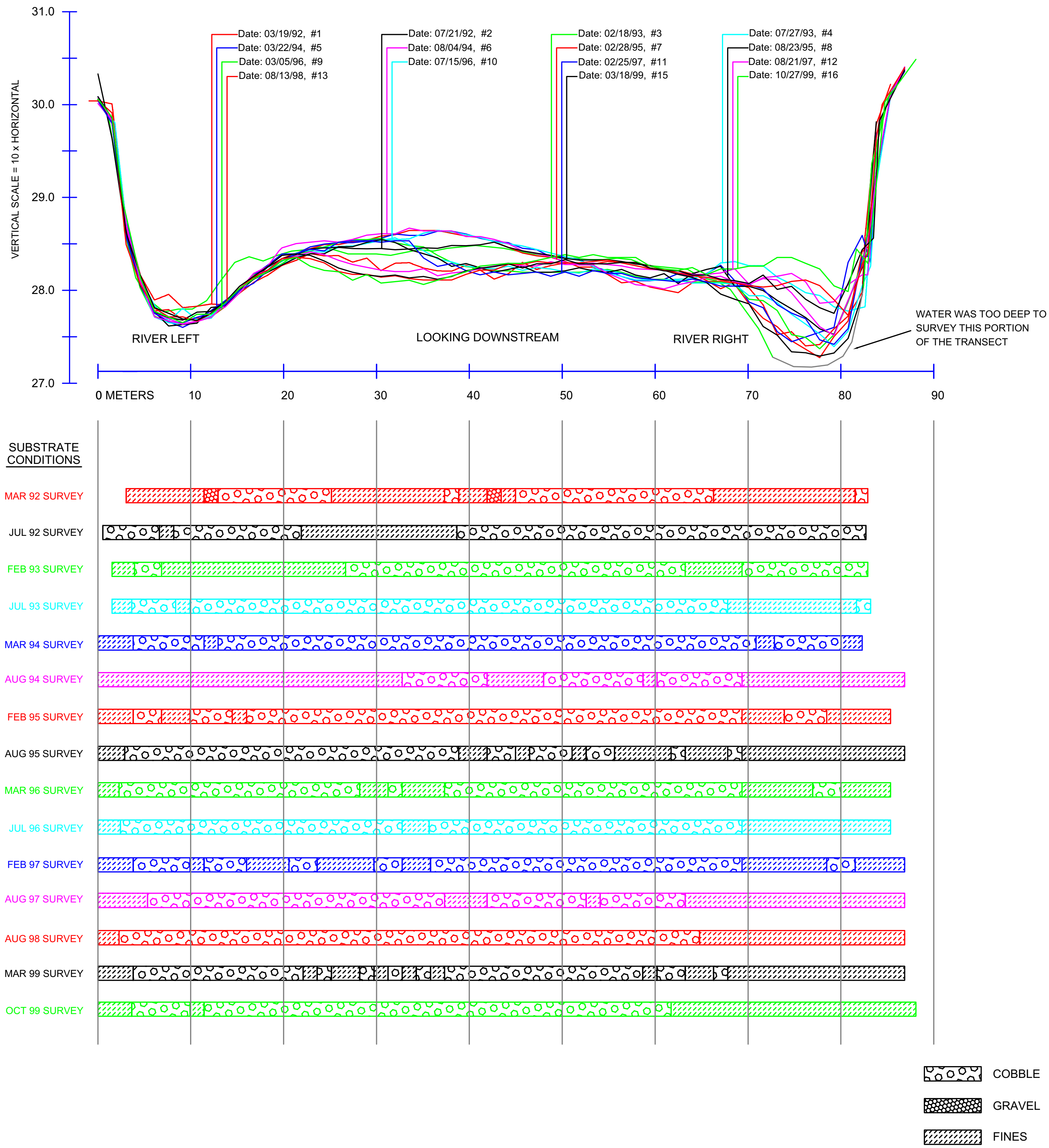


FILE: RT09-GIS.DWG DATE: 09/05/01

TRANSECT CS3-01 (RT09)
PHOTO 15-9
MONTEZUMA CREEK QUAD

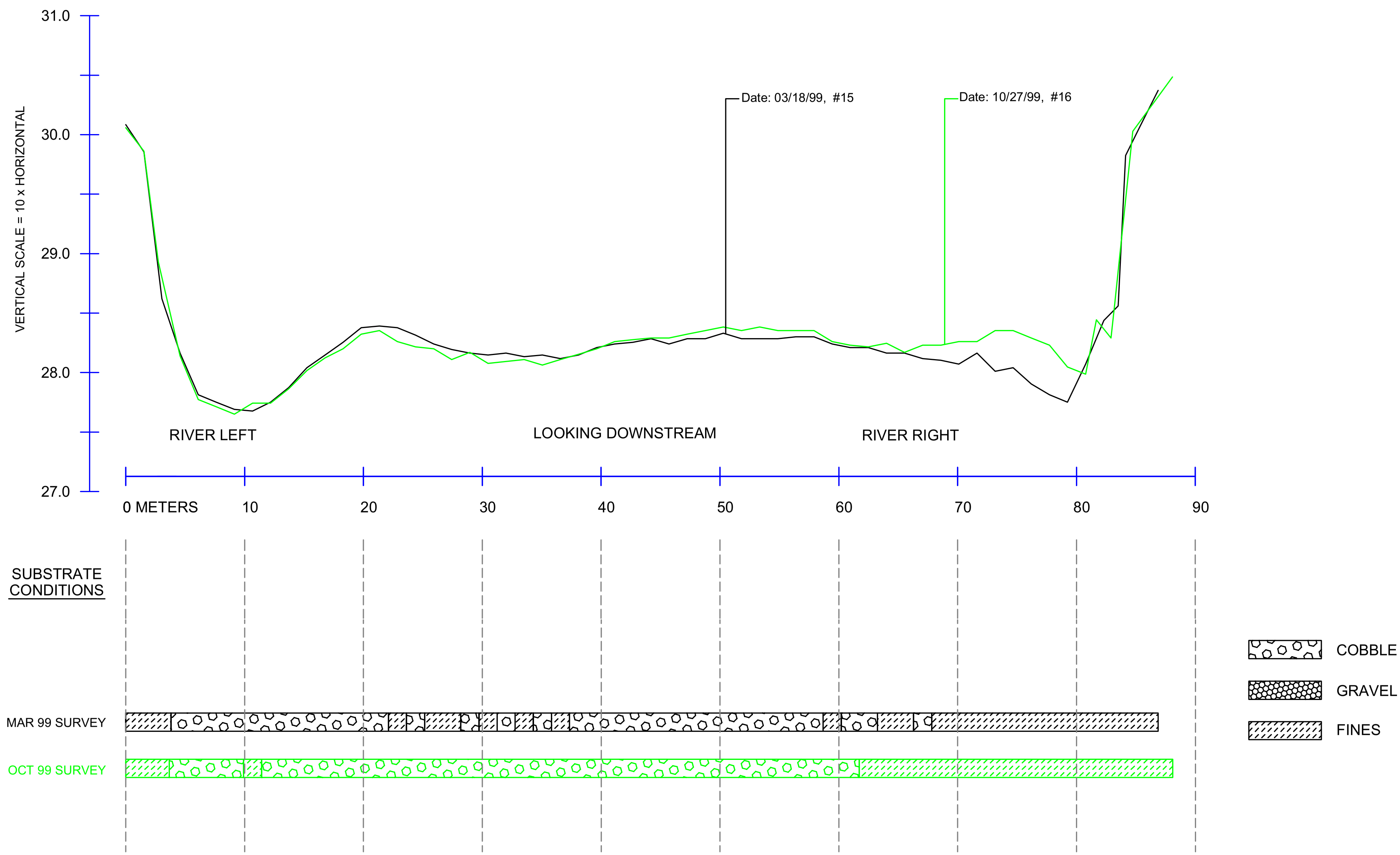


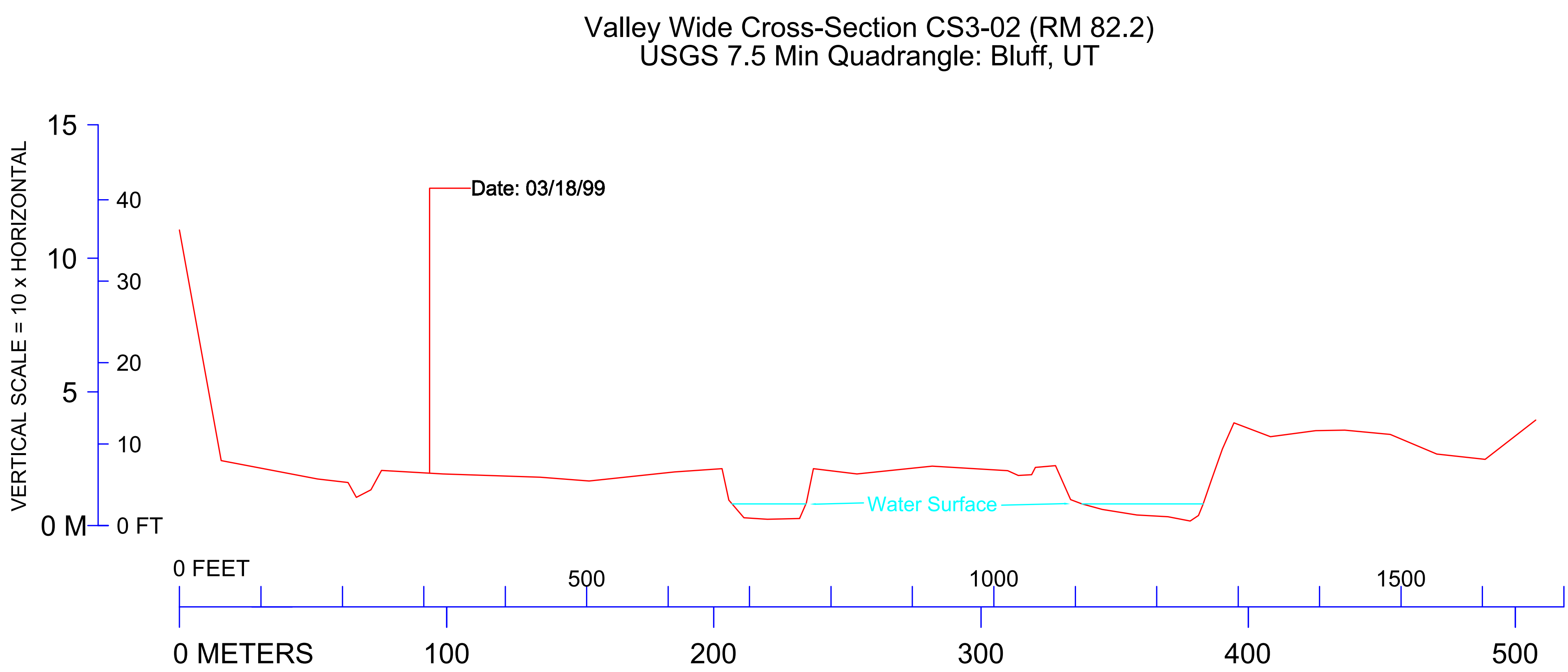
TRANSECT CS3-02 (RT10)
PHOTO 16-5
BLUFF QUAD.



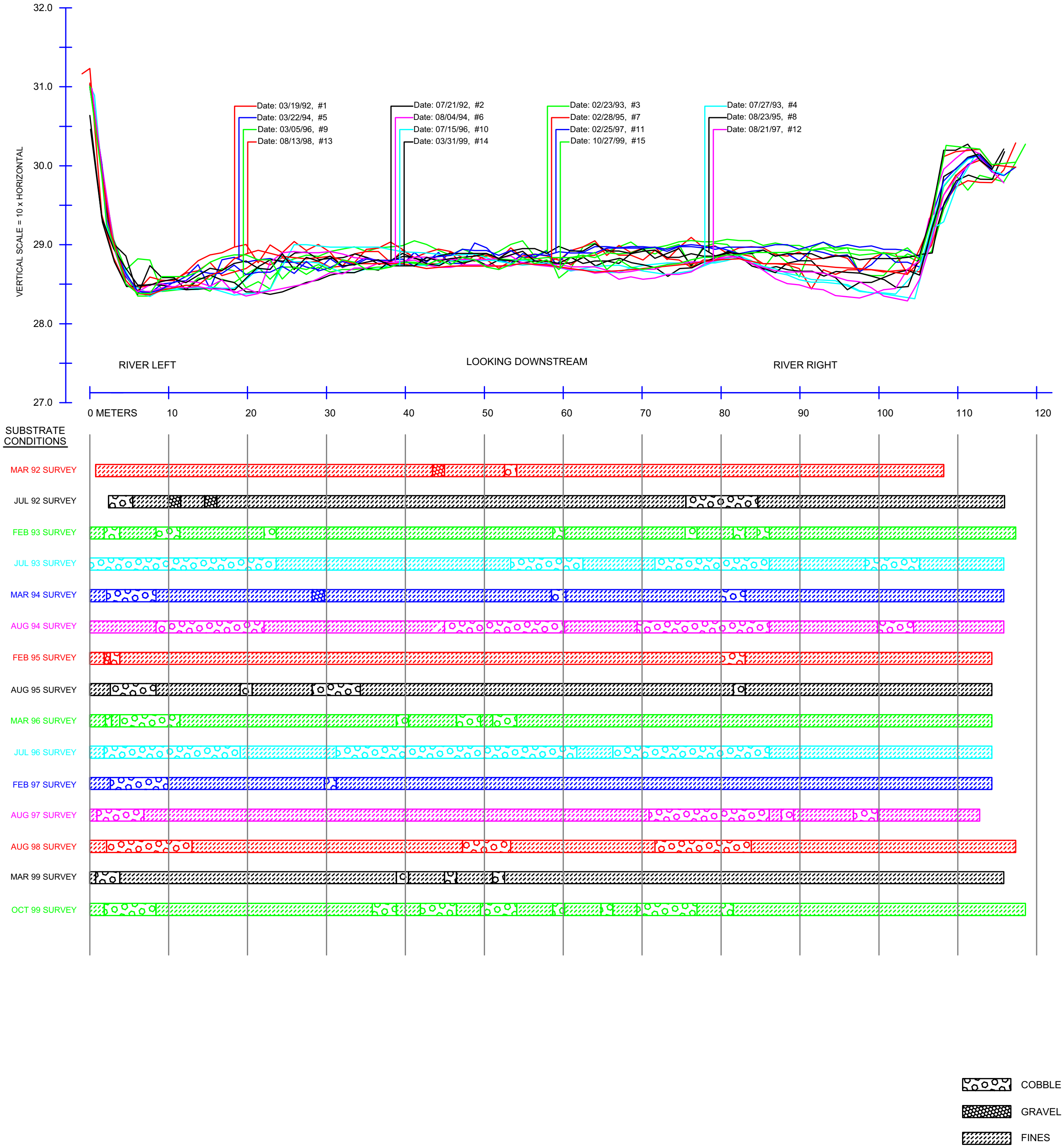
FILE: RT10-GIS.DWG DATE: 09/05/01

TRANSECT CS3-02 (RT10)
PHOTO 16-5
BLUFF QUAD.

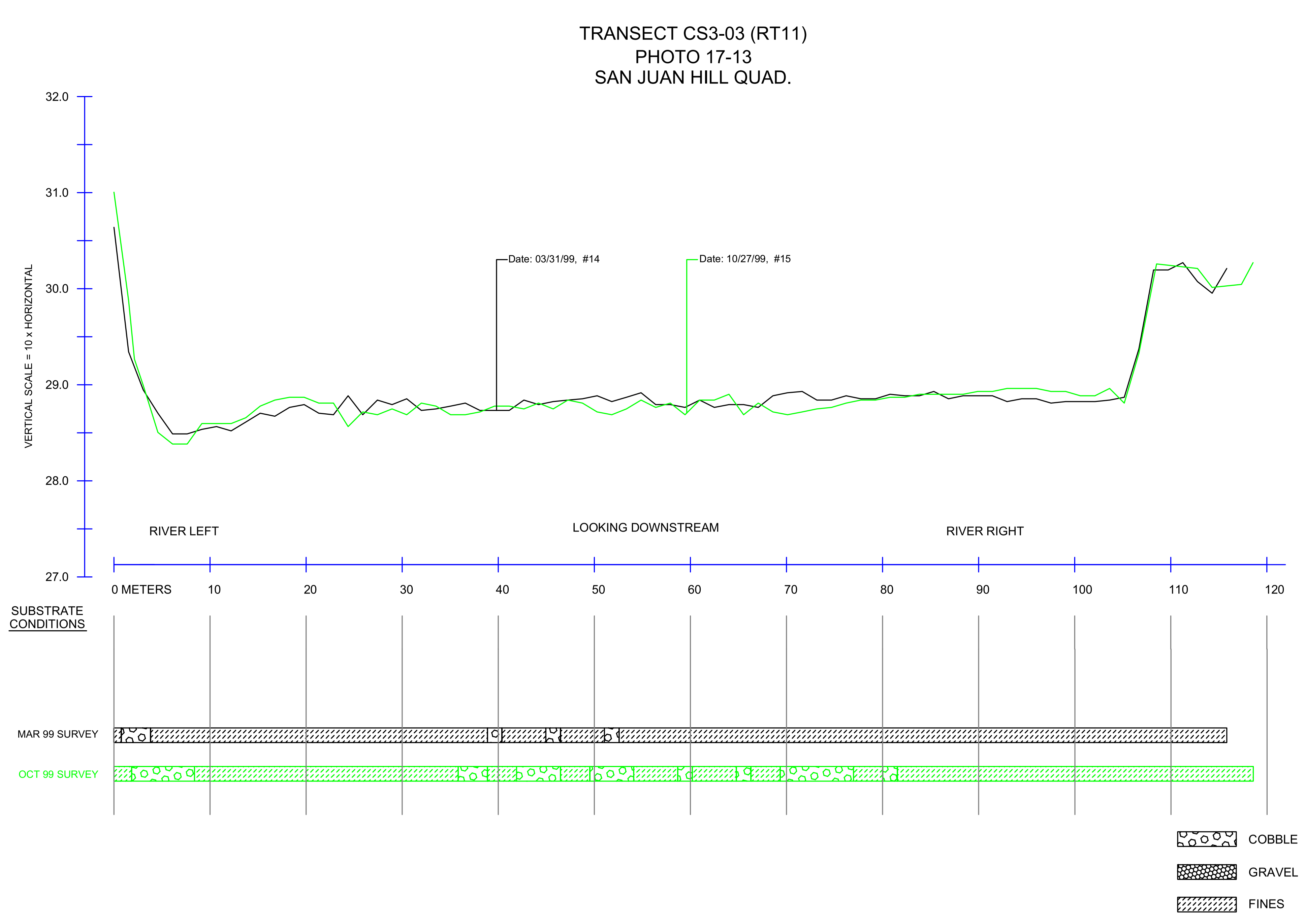



Valley Wide Cross-Section CS3-02 (RM 82.2)
USGS 7.5 Min Quadrangle: Bluff, UT
Date: 03/18/99
Water Surface
VERTICAL SCALE = 10 x HORIZONTAL
15
10
5
0 M
40
30
20
10
0 FT
0 FEET
500
1000
1500
0 METERS
100
200
300
400
500

TRANSECT CS3-03 (RT11)
PHOTO 17-13
SAN JUAN HILL QUAD.

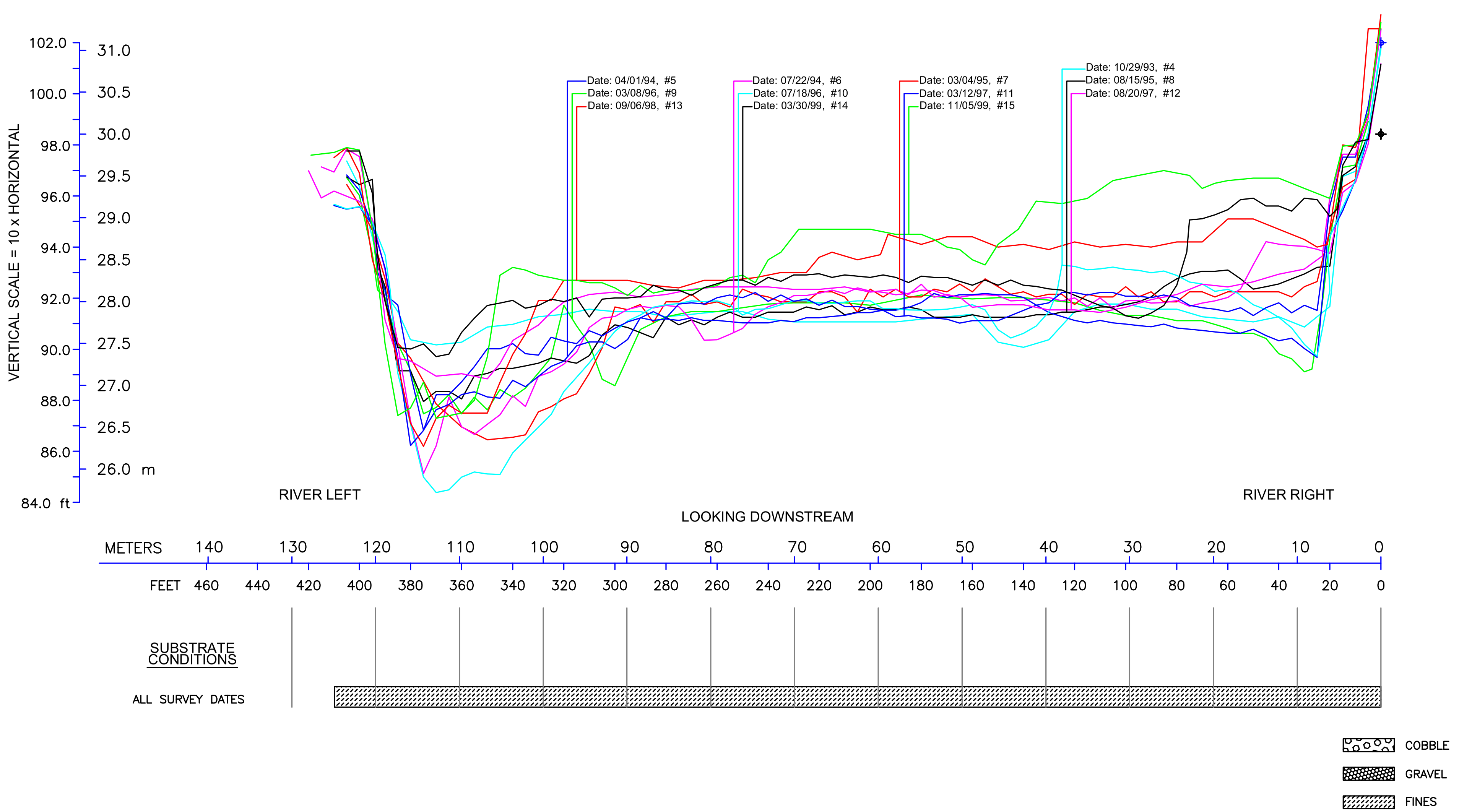


FILE: RT11-GIS.DWG DATE: 09/05/01



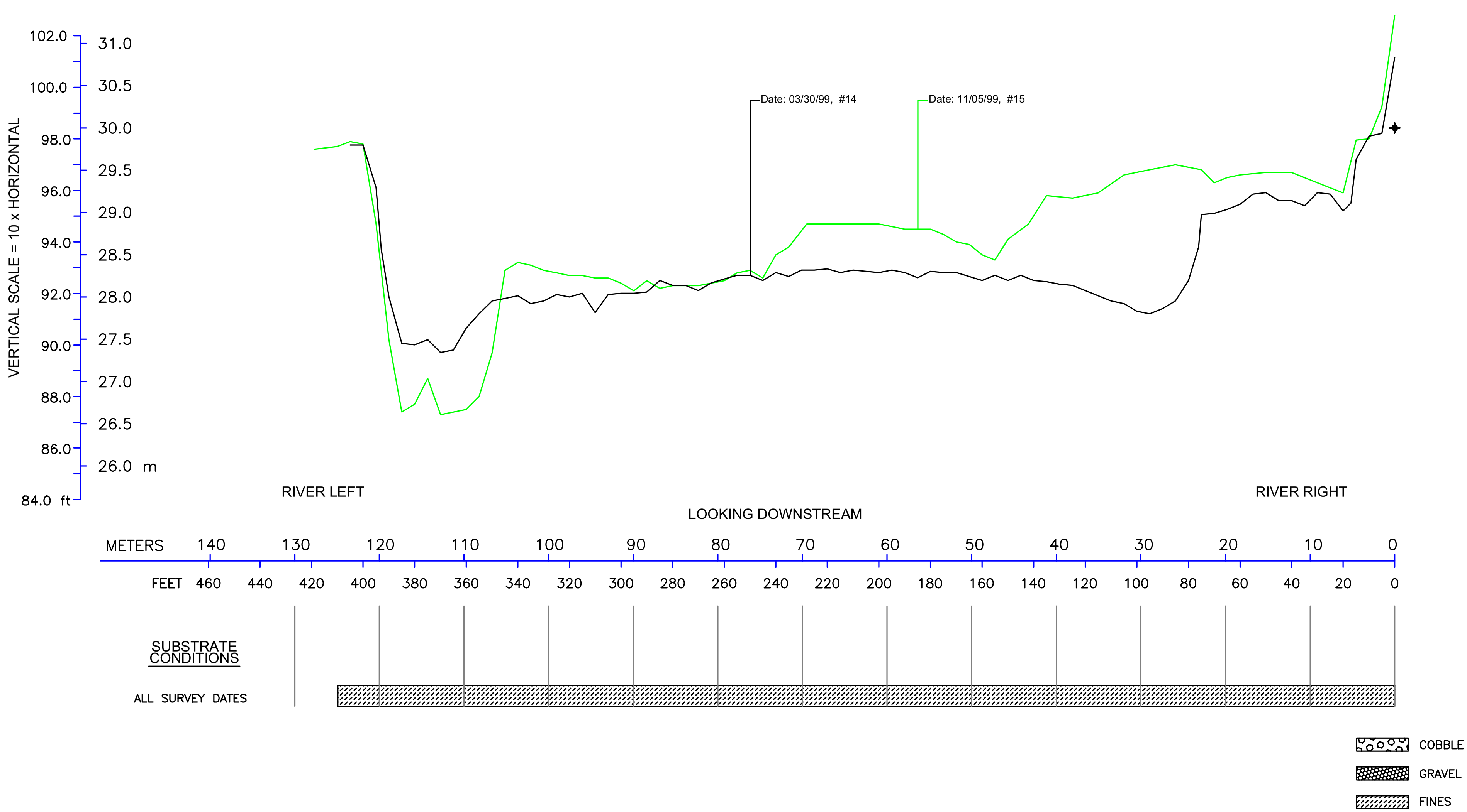
TRANSECT CS3-03 (RT11)
PHOTO 17-13
SAN JUAN HILL QUAD.
32.0
31.0
30.0
29.0
28.0
27.0
VERTICAL SCALE = 10 x HORIZONTAL
Date: 03/31/99, #14
Date: 10/27/99, #15
RIVER LEFT
LOOKING DOWNSTREAM
RIVER RIGHT
0 METERS
10
20
30
40
50
60
70
80
90
100
110
120
SUBSTRATE CONDITIONS
MAR 99 SURVEY
OCT 99 SURVEY
COBBLE
GRAVEL
FINES

TRANSECT CS1–01 (CLAY HILLS 1)



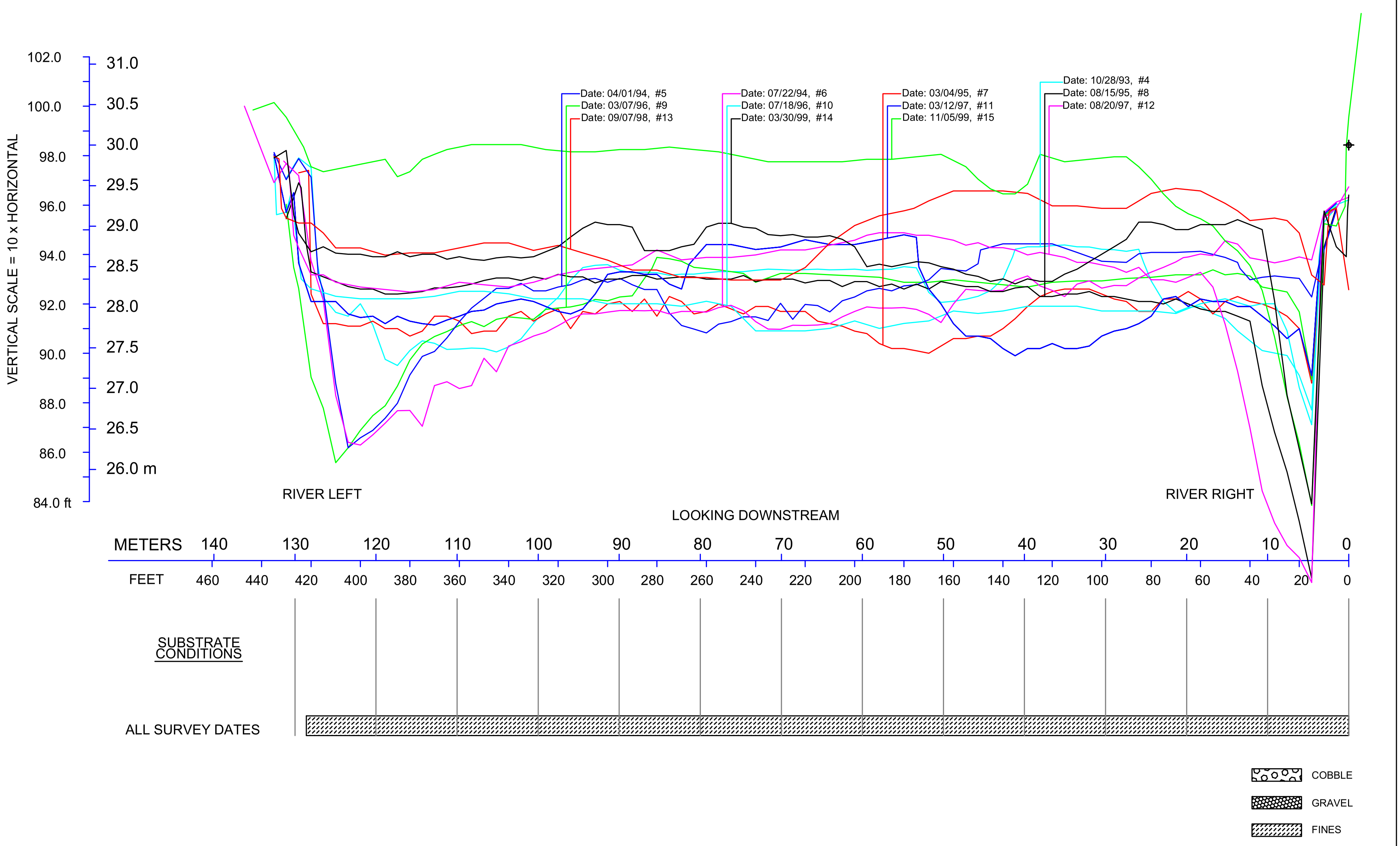
FILE: CH1–GIS.DWG DATE: 10/13/00

TRANSECT CS1−01 (CLAY HILLS 1)



FILE: CH1−GIS.DWG DATE: 10/13/00

TRANSECT CS1-02 (CLAY HILLS 2)



TRANSECT CS1-02 (CLAY HILLS 2)