San Juan River Basin
Recovery Implementation Program

HYDROLOGY/GEOMORPHOLOGY/HABITAT 2001-2002 ANNUAL REPORT

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May 16, 2003

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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 2001 and 2002 as a part of the long-term monitoring program and compares this data to that collected since 1992.

Data collected in the following areas are summarized here:

- Hydrology
- River Cross-Section Measurement
- Cobble Bar Characterization
- 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 2001and 2002 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.

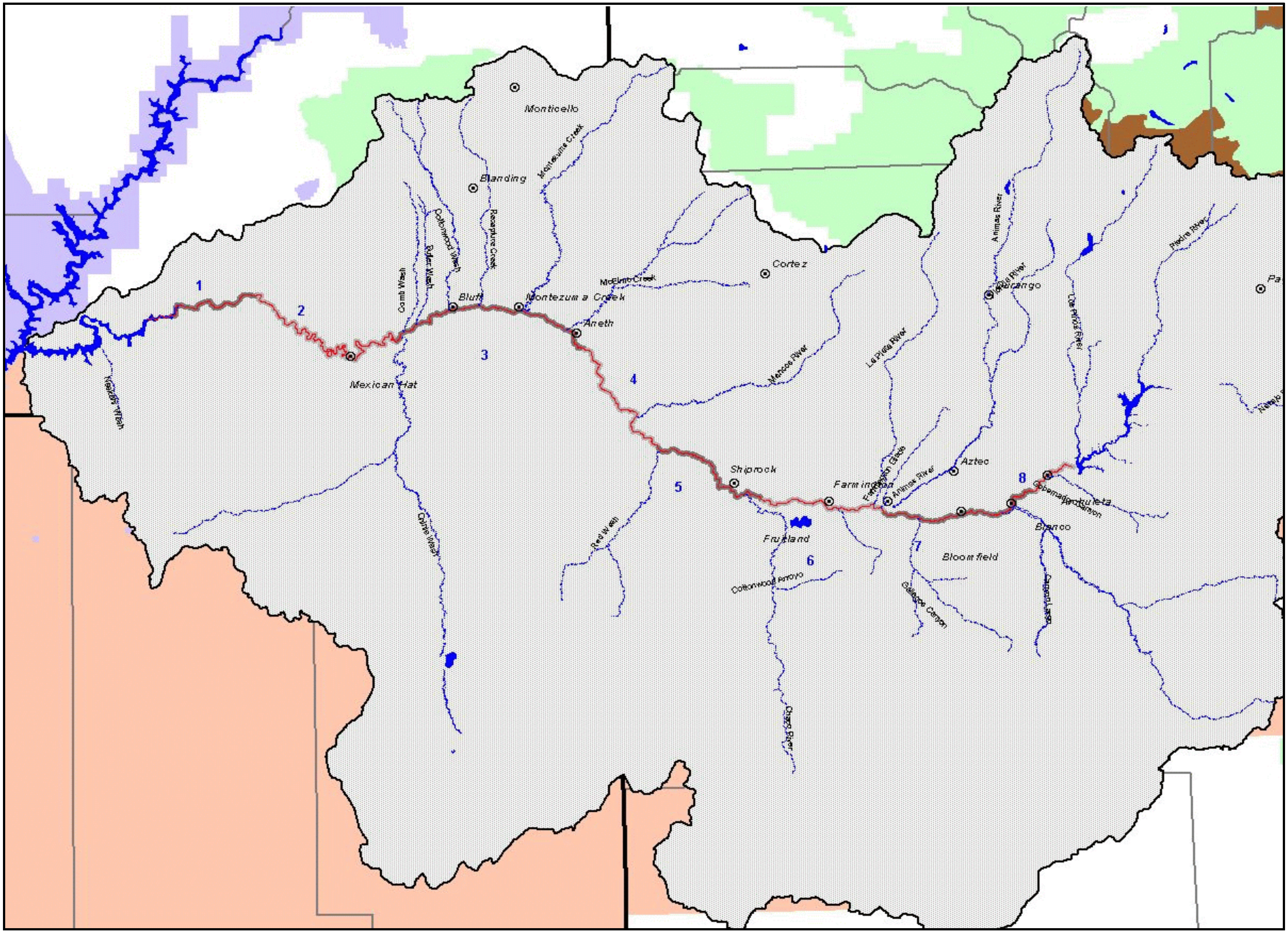

Figure 1.1. San Juan Basin Location Map Showing Geomorphic Reaches

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 from 1929 through the present are available for the key points on the San Juan River. These data have been used to analyze the 2001 and 2002 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. There was no flushing release in 2000. A release of 166,000 acre-feet (based on a 600 cfs base flow) over 27 days was called for in early Spring 2001 per the Navajo Fish Release Decision Tree. Higher forecasted inflows and the need to complete dam maintenance caused Reclamation to bump the planned release up to 300,000 acre-feet to reach a pool elevation 6,074 feet by the end of September.

One of the 72-inch Hollow Jet Valves experienced hydraulic control problems and was shut down on May 30th. At that time flows were reduced to about 4,300 cfs. Not all of the forecasted inflows materialized and hence there was an over release, resulting in the reservoir being about 10 ft lower than planned, even though the release was terminated early in response to the smaller runoff volume. The release was about 130,000 af greater than needed to achieve the desired reservoir elevation.

If water year 2002 had been a normal runoff year the over-release in 2001 would not have been a source for much concern. However, 2002 was a record-breaking dry year. There is a continuous gage record for the San Juan near Bluff starting in 1927. Sporadic records exist back as far as 1915. As measured at the Bluff gage, the 2002 March through July runoff was only 73% of 1977, the driest year on record. Without extra releases from Navajo Reservoir to maintain flows for the endangered fish, the flow at Bluff would have been even lower. The inflow to Navajo Reservoir was only 52% of the dries year, having a 2.5% recurrence frequency over the period of record.

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. In 2002 there was not sufficient water to make a release.

Table 2.2 compares the flow statistics from 2001/2002 to those of the 1992-2000 period for each non-base flow category identified in the Flow Recommendation Report. Also indicated are the desired conditions that were met. Table 2.3 shows a summary of the base flow conditions.

The 2001 and 2002 hydrographs for the San Juan River at Archuleta (release hydrograph) and at Four Corners are presented in Figure 2.1 and 2.2. The hydrographs at Four Corners are shown in Figures 2.3 and 2.4. The large flow spike in the Fall of 2002 is due to a short duration high intensity storm event that passed through the Farmington area, resulting in very high peak flows and high sediment load in the lower San Juan Basin. 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 here.

Table 2.1. Summary of Navajo Dam Release Hydrograph Characteristics since the Beginning of the Research Period, 1992 to 2001

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

Table 2.2. Flow Statistics Met in Each Year

Flow Condition	Std	1994	1995	1996	1997	1998	1999	2000	2001	2002
10,000 cfs or more	5	0	**11**	0	**10**	0	0	0	0	0
8,000 cfs or more	10	**13**	**27**	0	**33**	2	0	0	0	0
5,000 cfs or more	21	**49**	**72**	0	**50**	**34**	**29**	3	**33**	0
2,500 cfs or more	10	**67**	**135**	**36**	**100**	**65**	**70**	**37**	**55**	0
Yrs w/o meeting 10,000cfs	10	8	0	1	0	1	2	3	4	5
Yrs w/o meeting 8,000 cfs	6	0	0	1	0	1	2	3	4	5
Yrs w/o meeting 5,000 cfs	4	0	0	1	0	0	0	1	0	1
Yrs w/o meeting 2,500 cfs	2	0	0	0	0	0	0	0	0	1

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

Table 2.3. 2002 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	569.0	0	0	0
Shiprock	285.1	101	71	5
Four Corners	326.6	63	33	0
Bluff	307.9	80	47	0

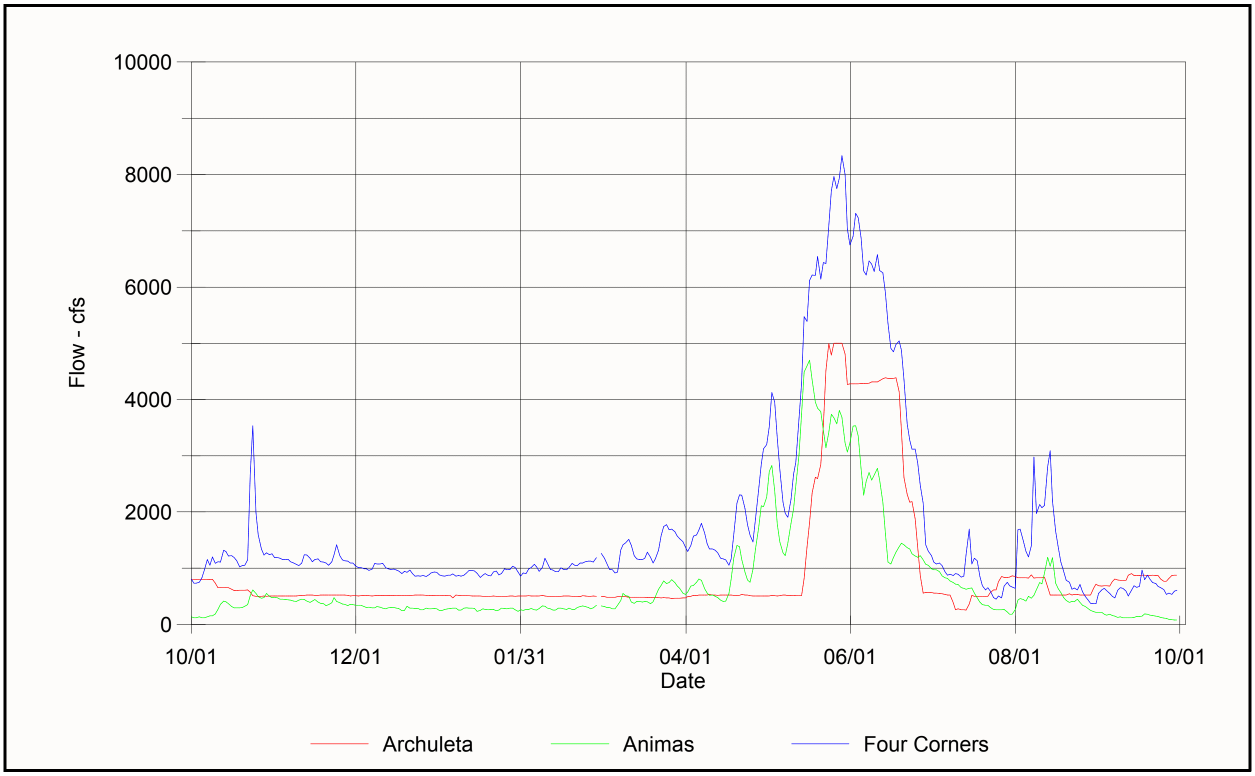

Figure 2.1. **2001 Hydrographs for Animas River at Farmington, San Juan River at Archuleta and Four Corners**

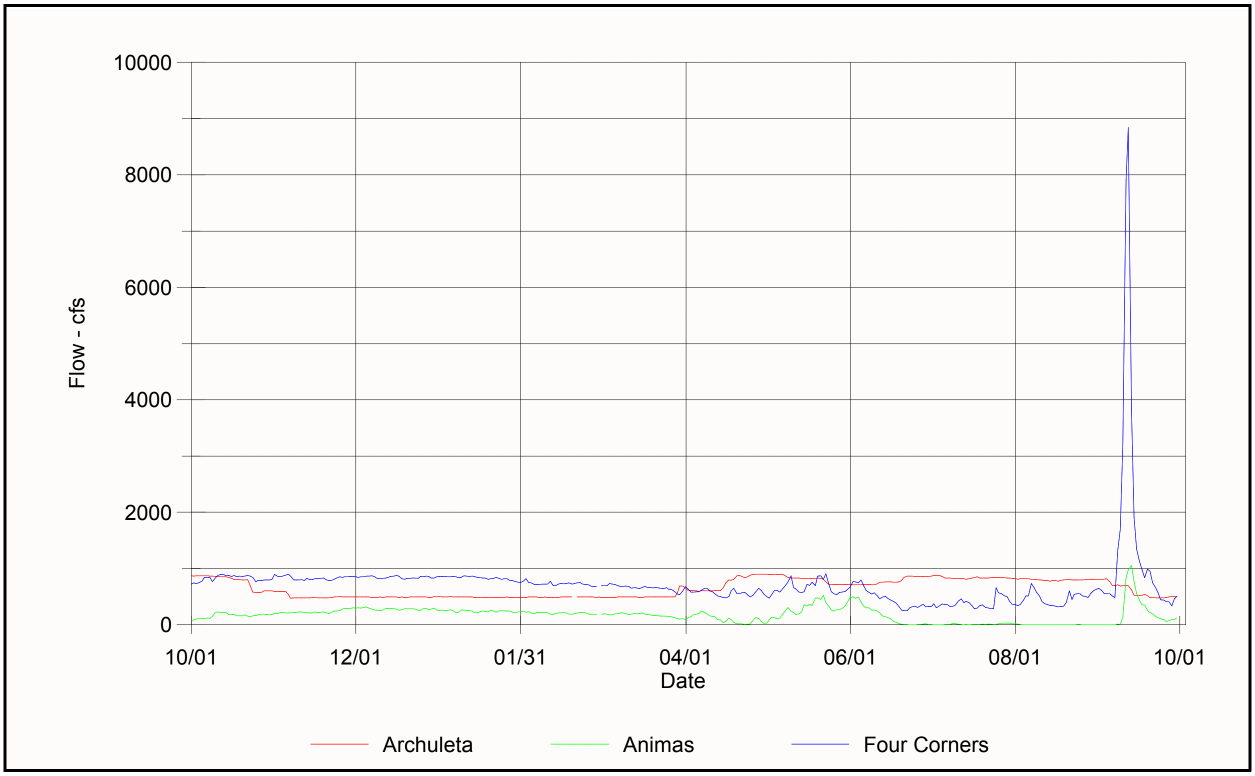

Figure 2.2. **2002 Hydrographs for Animas River at Farmington, San Juan River at Archuleta and Four Corners**

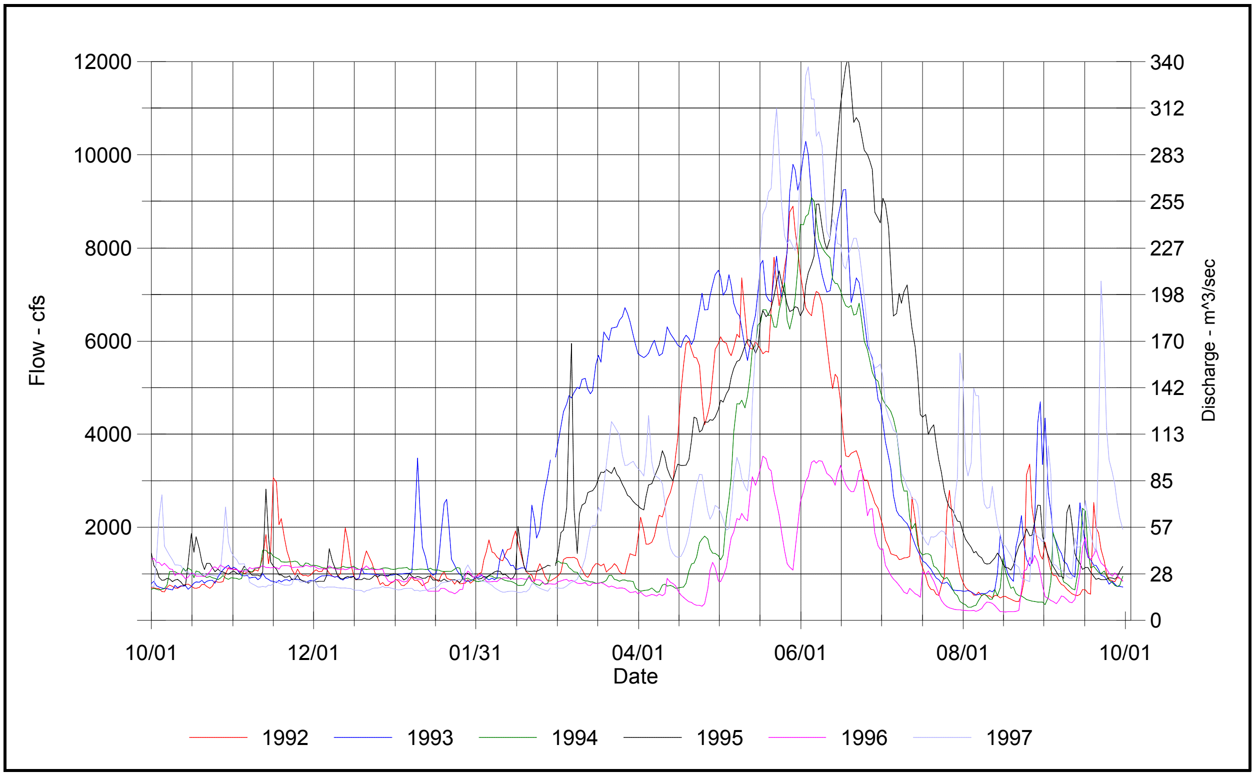

Figure 2.3. Hydrographs for the San Juan River at Four Corners 1992 - 1997

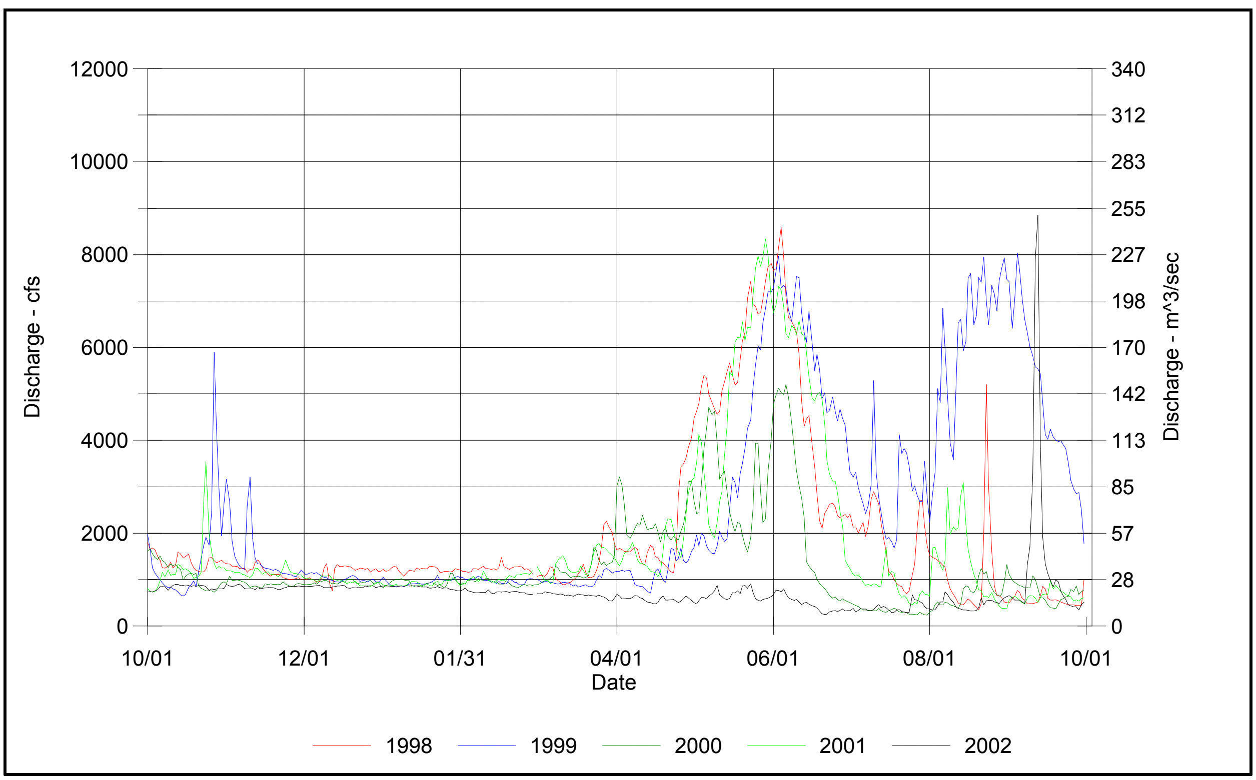

Figure 2.4. Hydrographs for the San Juan River at Four Corners 1998-2002

Table 2.4. Summary of Flows for the Research (1991-1998) and Monitoring (1999-2002) Periods, San Juan River at Four Corners, New Mexico

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Peak Runoff-cfs	8,900	10,300	10,000	12,100	3,540	11,900	8,580	8,030	5210	8340	926
Runoff (Mar-Jul)-af	1,074,795	1,714,328	1,039,601	1,624,927	431,913	1,338,539	931,106	876,846	548,424	848,626	174,282
Runoff (total annual)-af	1,512,795	2,216,819	1,448,893	2,102,228	815,795	1,844,019	1,401,536	1,901,803	928,807	1,288,345	534,642
Peak Date	29-May	03-Jun	05-Jun	19-Jun	18-May	04-Jun	04-Jun	03-Jun	06-Jun	29-May	23-May
Days>10,000	0	1	0	11	0	10	0	0	0	0	0
Days>8,000	3	16	13	27	0	33	2	0	0	0	0
Days>5,000	54	109	49	72	0	50	34	29	3	33	0
Days>2,500	81	128	67	135	36	100	65	70	37	55	0
Ave. Daily Flow for month											
October	769	827	941	1,109	1,091	1,276	1,404	1,533	1,141	1,273	829
November	1,356	911	1,210	1,077	1,139	883	1,175	1,494	910	1,154	836
December	1,088	957	1,105	960	1,088	702	1,154	1,031	940	966	848
January	859	1,358	1,050	918	785	789	1,208	947	935	915	835
February	1,298	1,511	781	1,076	899	690	1,239	976	931	1,039	732
March	1,173	5,463	967	2,782	766	2,255	1,267	969	1,186	1.329	663
April	3,723	6,188	1,028	3,478	607	2,529	1,910	1,174	2,263	1,680	582
May	6,634	7,298	5,251	6,119	2,150	6,000	5,831	3,439	2,995	5,146	713
June	4,844	7,701	7,836	9,367	2,925	8,514	4,542	5,986	2,293	4,984	501
July	1,444	1,776	2,170	5,187	715	2,904	1,802	2,925	330	877	411
August	927	1,348	552	1,564	492	2,310	1,073	6,135	708	1,315	482
September	997		1,142	1,193	891	2,365	574	4,852	733	646	1443
Uniqueness	Control	early ave.	early ascent	late ave.	late peak	dry	narrow runoff	early ave.	dry	average	Record dry
		storm @ spawn					storm @ spawn	storm @ spawn			

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.

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 to monitor sediment producing events. The turbidity monitoring equipment at both Shiprock and Montezuma Creek consists of a D&A OBS-3 turbidity probe connected to a Campbell Scientific CR-510 data logger. The probes are calibrated to read between 0 and 4000 NTU's. Turbidity is measured every hour.

RESULTS

Channel Morphology - River Transects

Cross-section plots referenced in Table 3.1 are contained in Appendix A. The long-term valley wide cross-sections were not surveyed in 2001 or 2002. However, the river portion of these cross-sections are surveyed pre- and post-runoff like the other cross-sections beginning in 2000. The next planned valley wide survey date is 2004. 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. CS6-01 and CS4-03 where mistakenly not surveyed pre-runoff 2002 and are not included in the relevant figures throughout this document. There was also an instrument problem on the July 2002 survey of CS4-03. The data was post-processed to correct the problem but the resulting accuracy is less than that of the typical surveys.

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 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 2002. The net change line shows that on average the cross-sections show a pattern of scour and fill, returning to near 1992 levels in 1997, 1999 and 2001.

The cross-sections accumulated an average of 5.3 cm of material between the post-runoff 2000 and pre-runoff 2001 surveys. An average of 6.3 cm of material was scoured between the pre- and post -runoff 2001 surveys. This occurred with peak flows at Bluff of 7630 cfs. This is the largest change since the 1997 runoff season where peak flows at Bluff were over 11,000 cfs.

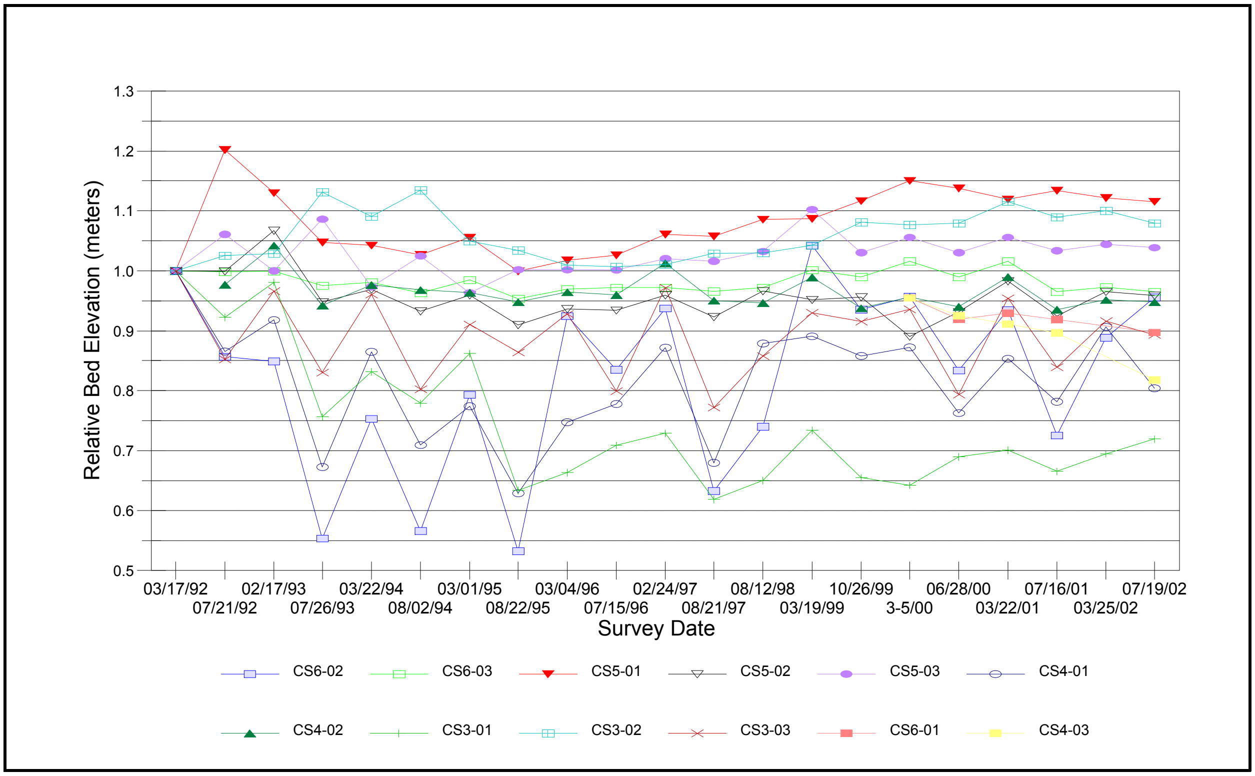

Figure 3.1. Average Relative Bed Elevation for Reach 3-6 Transects, 1992-2002

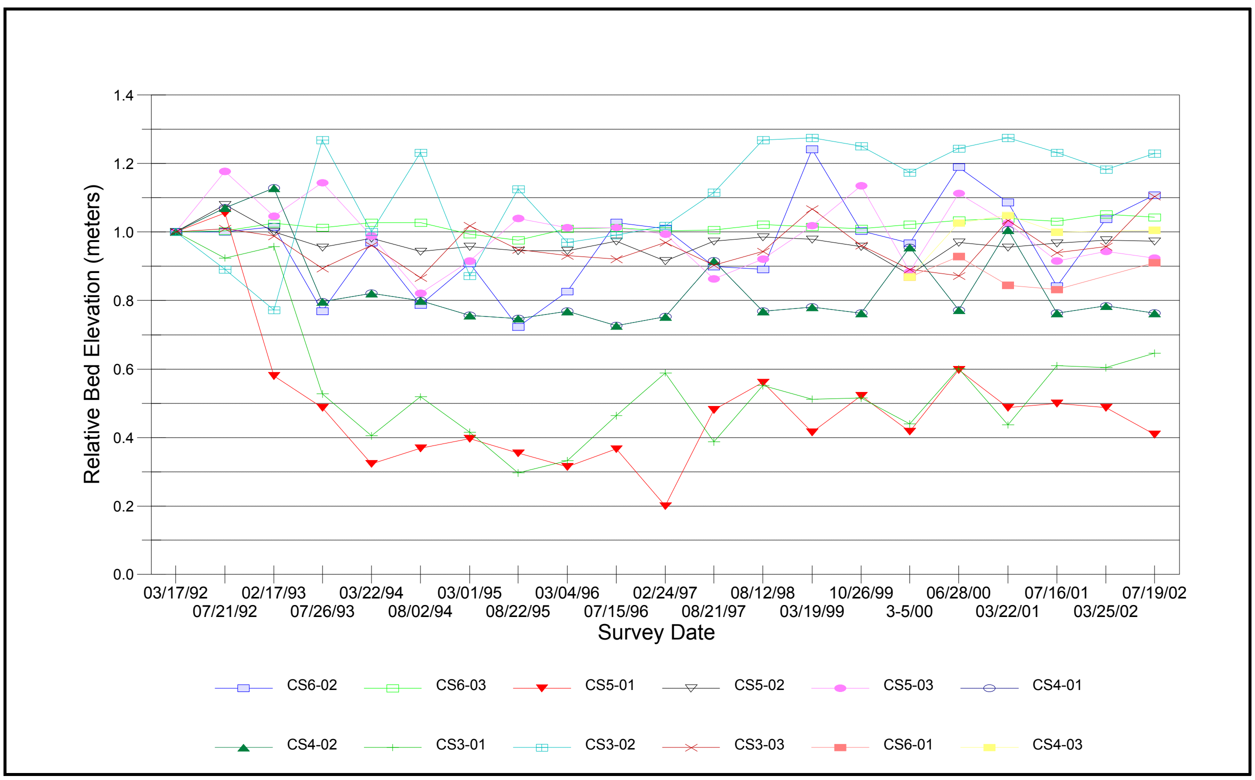

Figure 3.2. Minimum Relative Bed Elevation for Reach 3-6 Transects, 1992-2002

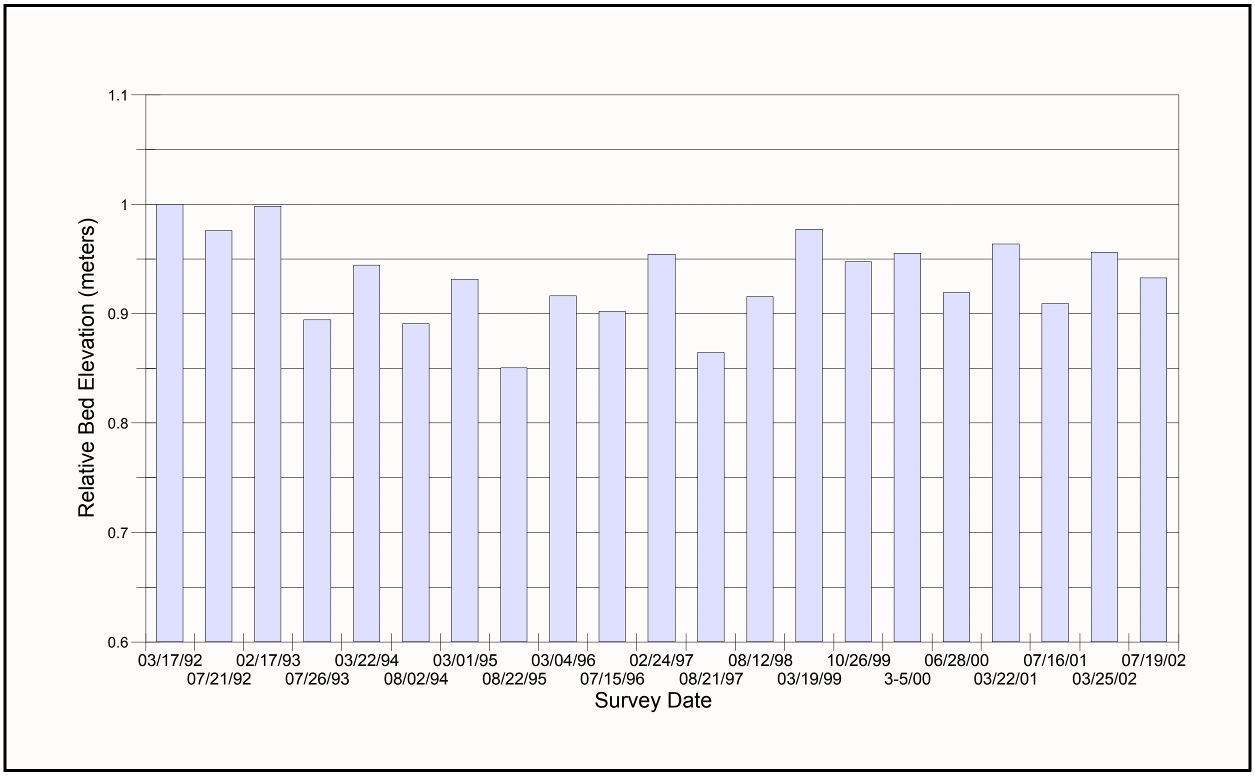

Figure 3.3. Mean Relative Bed Elevation for Reaches 3-6 Transects, 1992-2002

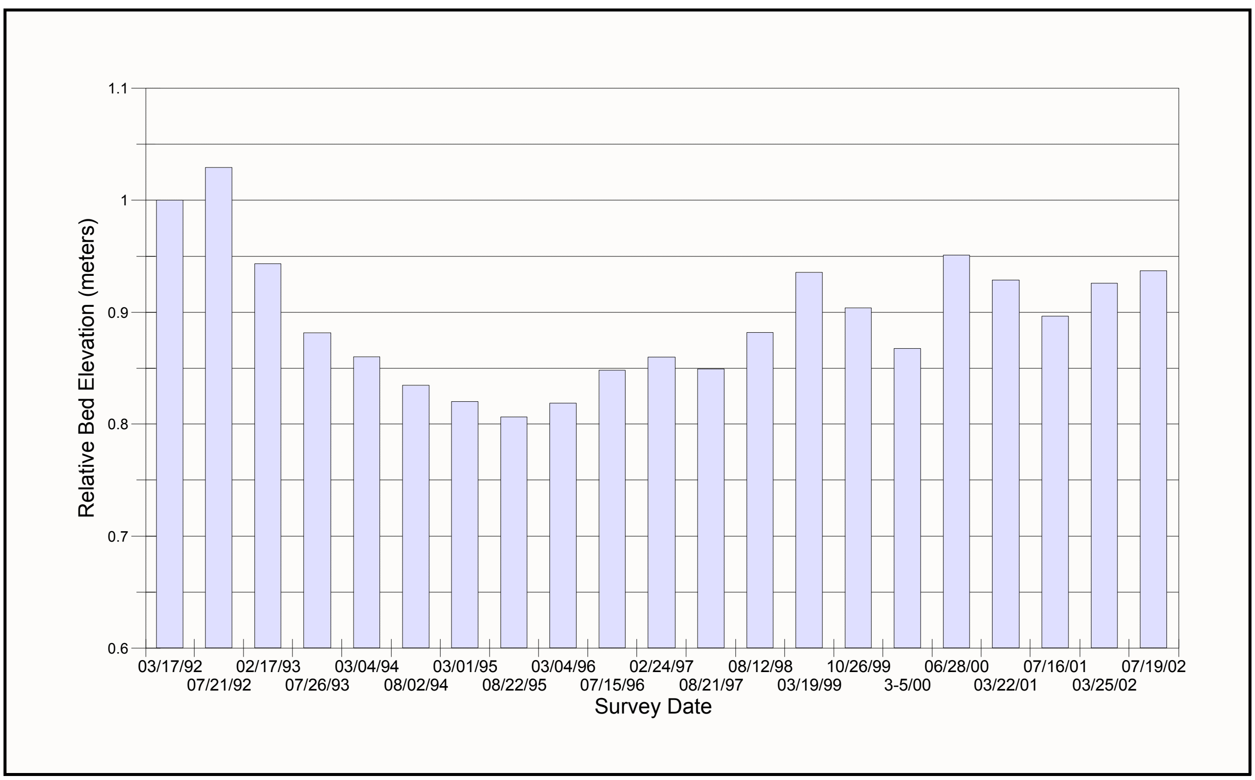

Figure 3.4. Minimum Relative Bed Elevation Averaged for Reach 3-6 Transects 1992-2002

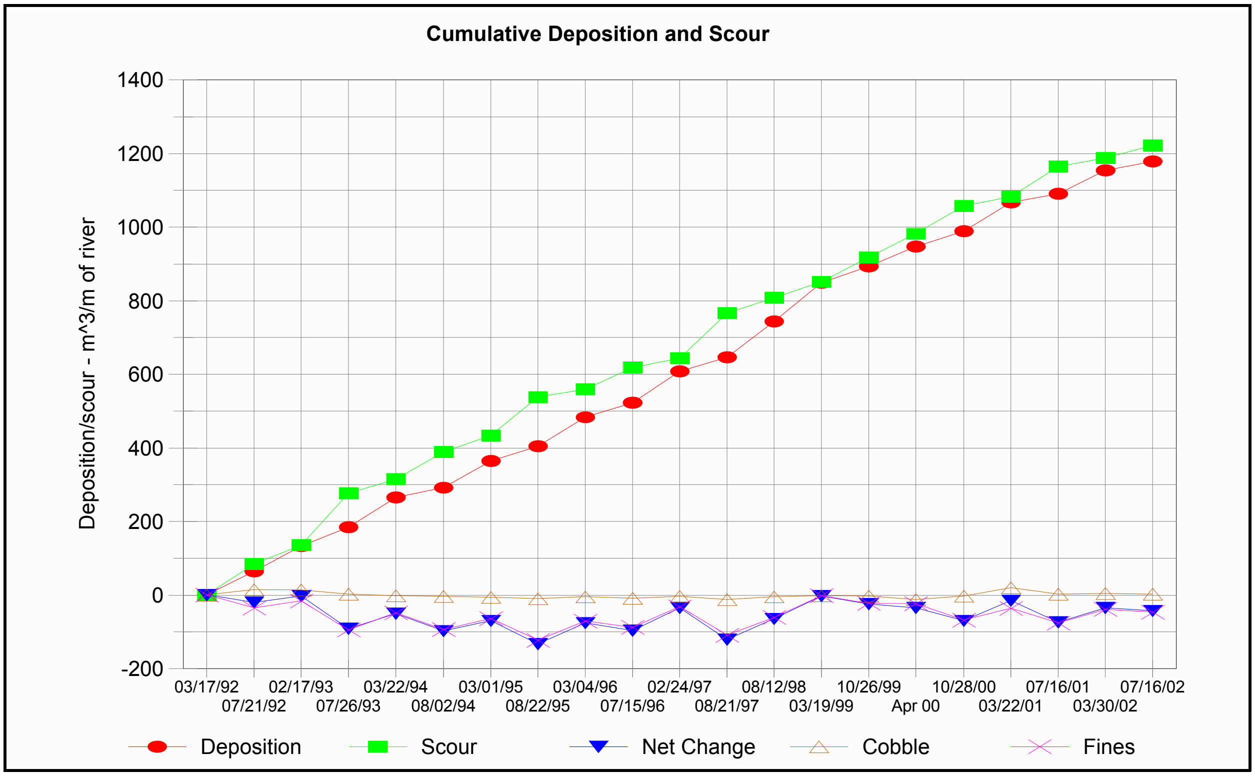

Figure 3.5. Net change in Reach 3-6 Transects, 1992-2002

Between the post-runoff 2001 and pre-runoff 2002 surveys an average of 4.7 cm of material was accumulated at the surveyed transects. However less than 1-cm was scoured between the pre- and post-runoff 2002 surveys. This is likely due to the low flows experienced in 2002 that peaked at only 847 cfs at Bluff. Table 3.2 shows the peak discharge and volume at Bluff for the last 12 years.

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 12-m (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.

Table 3.2. Peak discharge and Volume at Bluff (1991 - 2002)

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
2000	461,000	5,120
2001	752,000	7,630
2002	156,000	847

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.

Lake Powell water surface elevation continued to decrease though the end of 1999 and into spring of 2000. There was a small water surface elevation increase during the runoff season and then a continued fall through the end of 2000. By the end of 2000, the water fall was no longer submerged. The 2001 runoff increased the water surface elevation almost to the waterfall elevation again and then continued to fall through the end of 2001. By the end of 2001 the water surface elevation was at a 6-year low. By the end of 2002 the water surface elevation was at a 10-year low. Lake Powell water surface elevations are shown in Figure 3.8

CS1-01 and CS1-02 started to behave differently during the 2000 runoff season. CS1-01 continued to aggrade through the March 2002 survey with some scour since. CS1-02 continued to degrade through March 2002 and shown some deposition since that time. Both transects are most likely in a recovery phase after being subject to the backwater effects of Lake Powell.

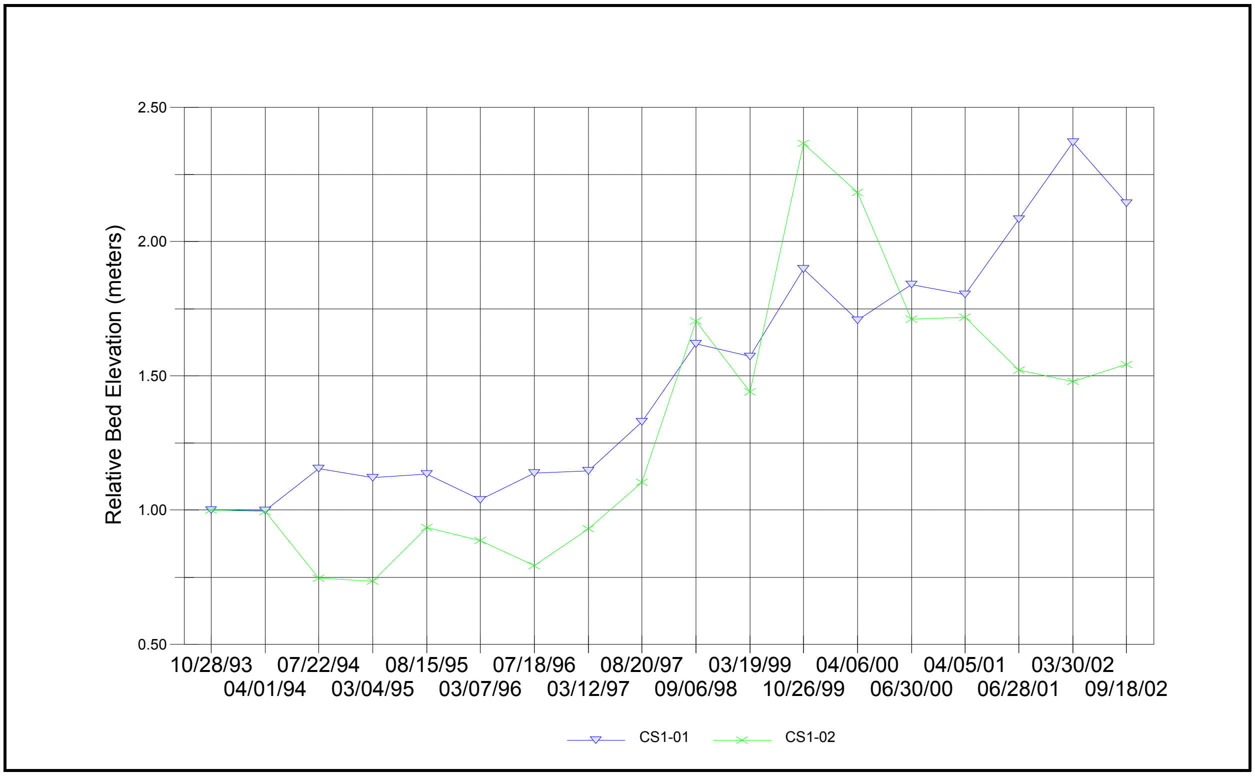

Figure 3.6. Average Relative Bed Elevation for Reach 1 Transects, 1993-2002

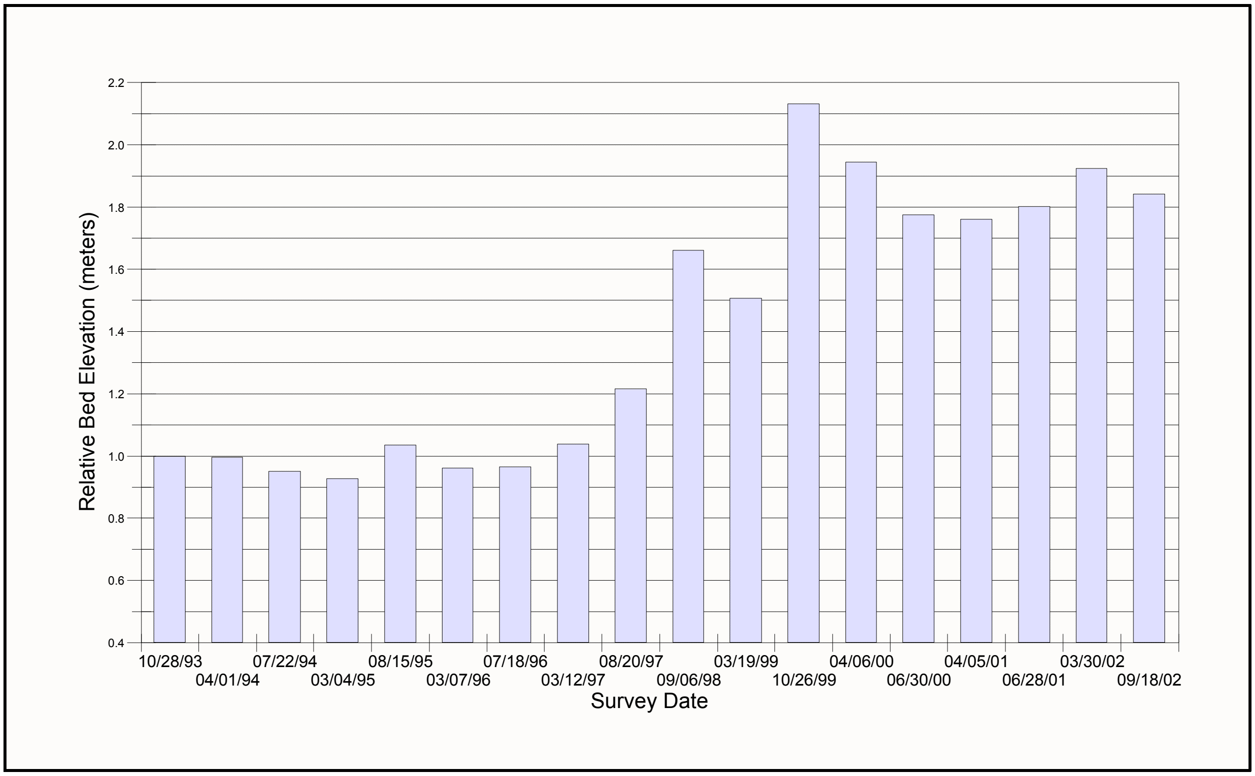

Figure 3.7. Bed Elevation Averaged for both Transects in Reach 1 (1993-2002)

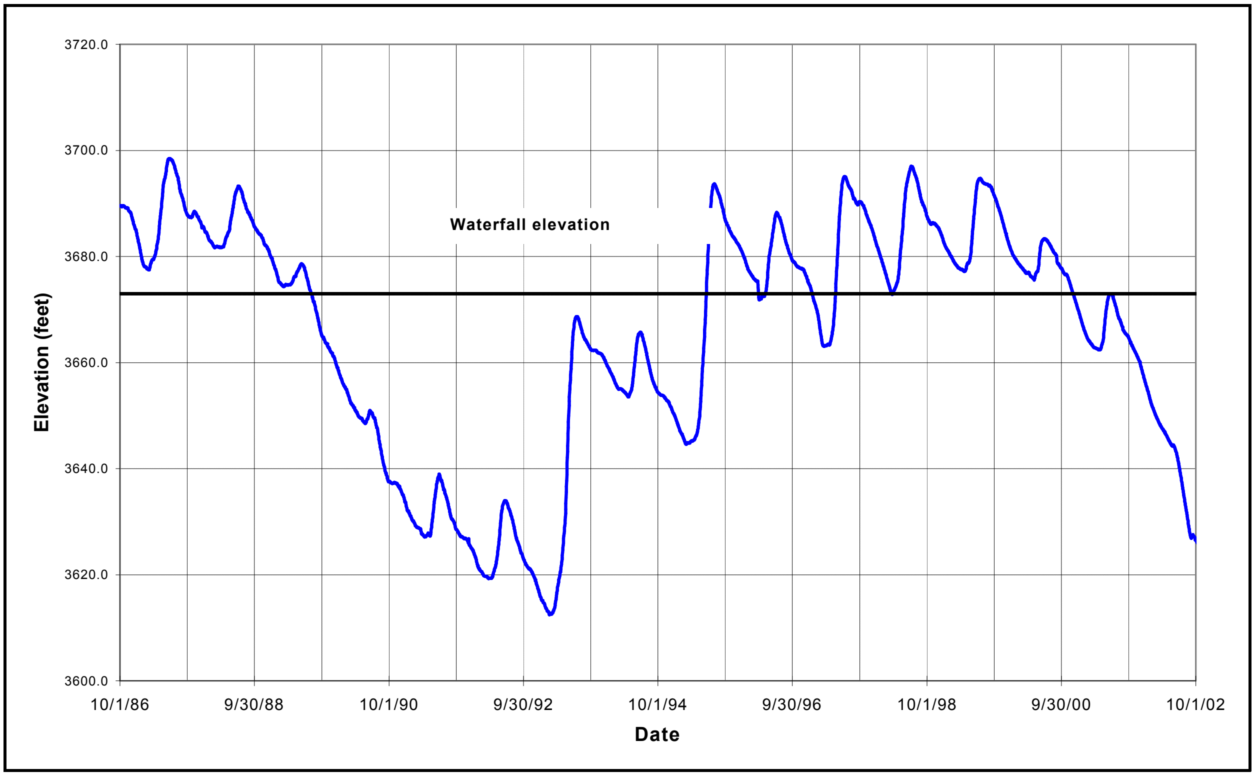

Figure 3.8 Lake Powell Water Surface Elevation 1986 to 2002

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 to 3.16. Each color band represents 15-cm (6-inches) of elevation change. Table 3.3 summarizes the elevation changes for the four bars.

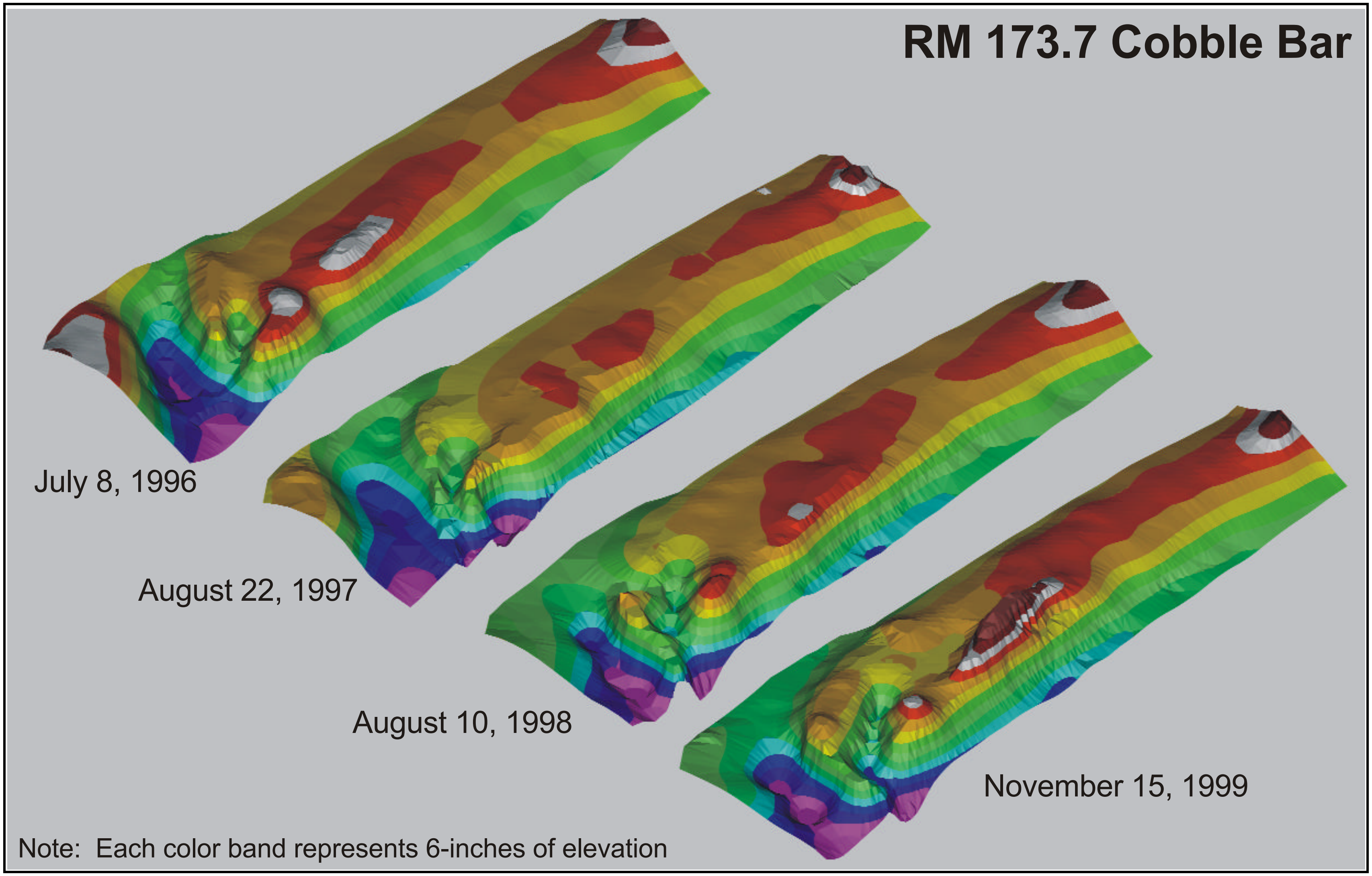

Figure 3.9. Topography of Cobble Bar at RM 173.7, 1993-1999

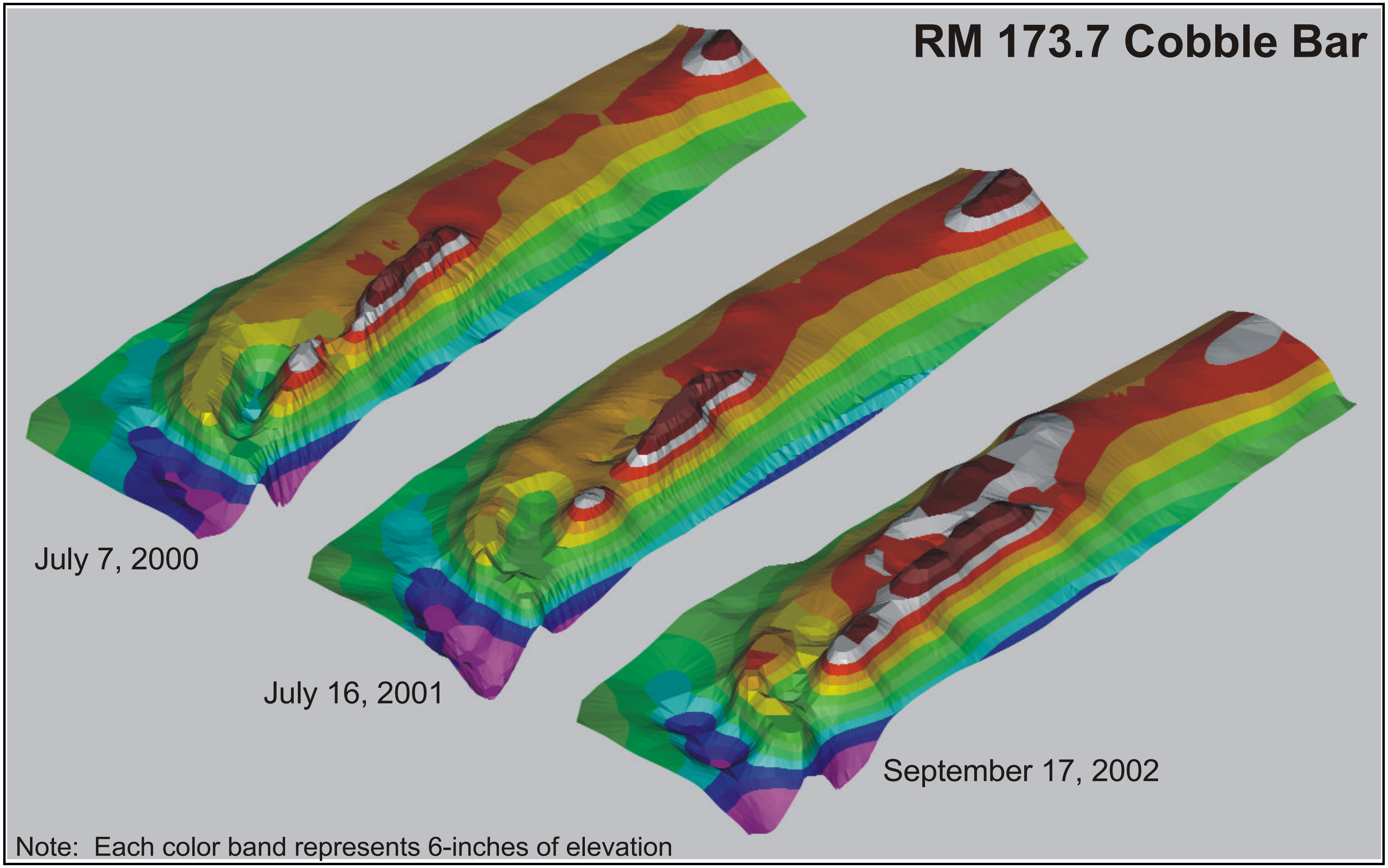

Figure 3.10. Topography of Cobble Bar at RM 173.7, 1999-2002

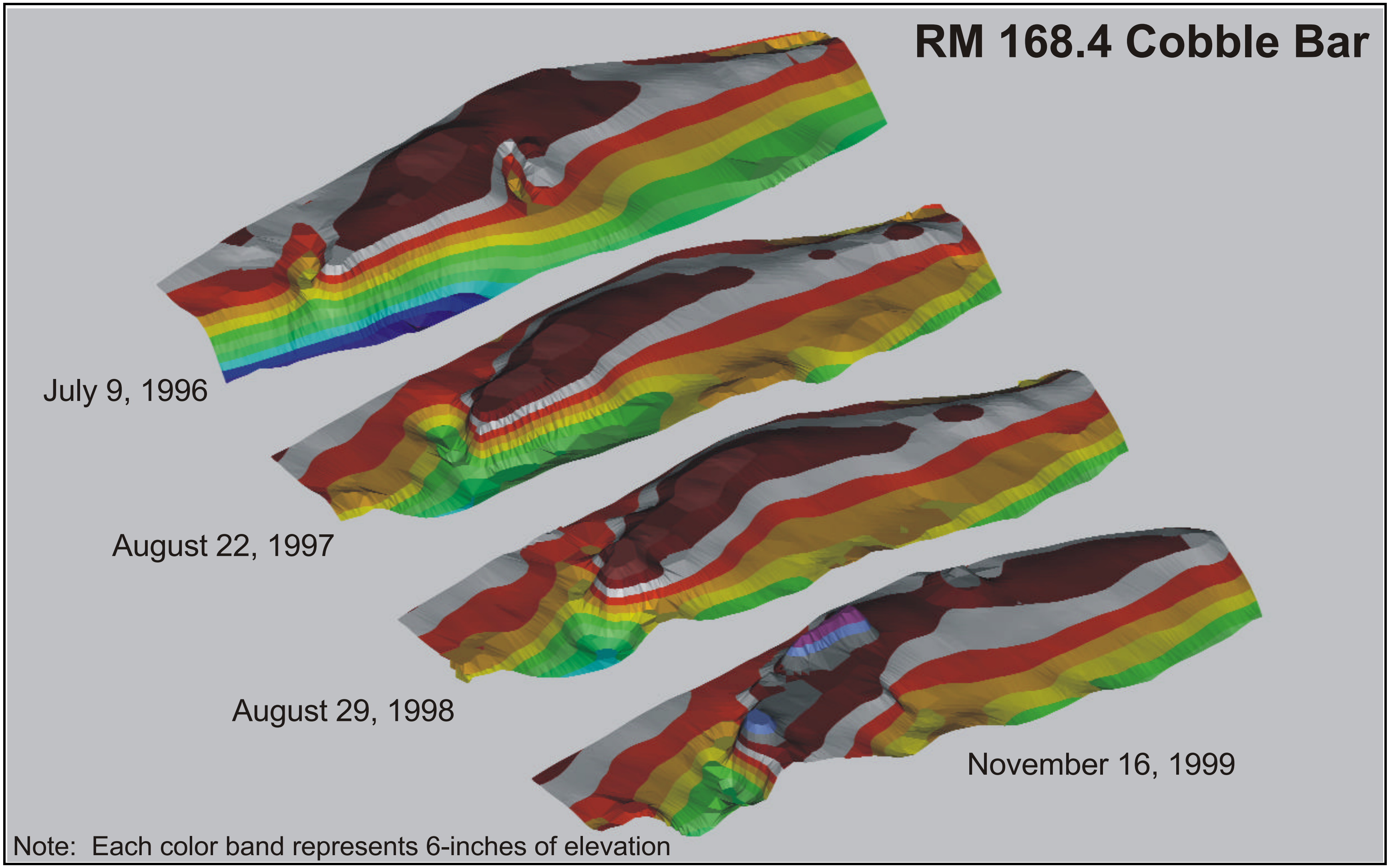

Figure 3.11. Topography of Cobble Bar at RM 168.4, 1993-1999

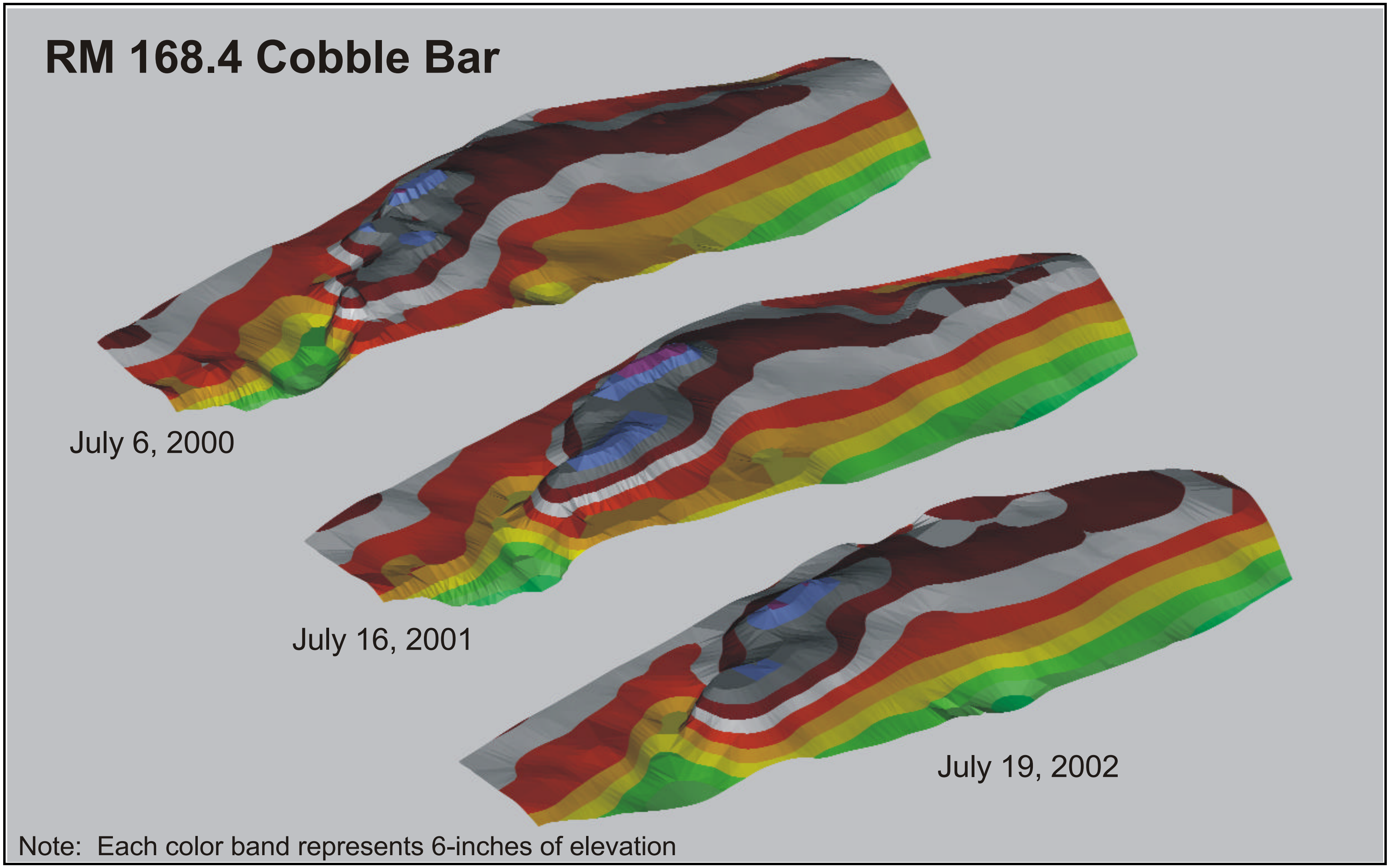

Figure 3.12. Topography of Cobble Bar at RM 168.4, 1999-2002

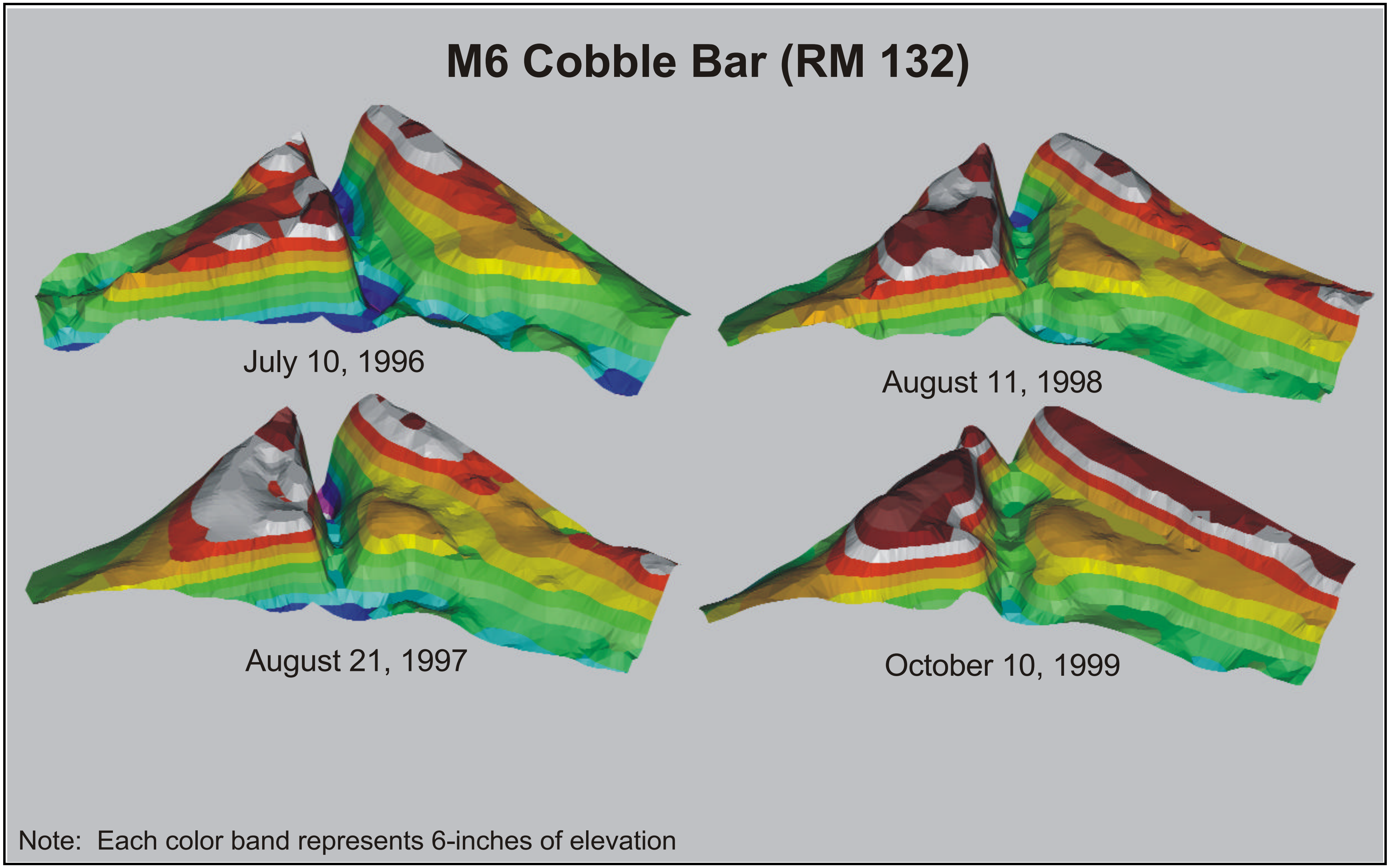

Figure 3.13. Topography of Cobble Bar at RM 132, 1995-1999

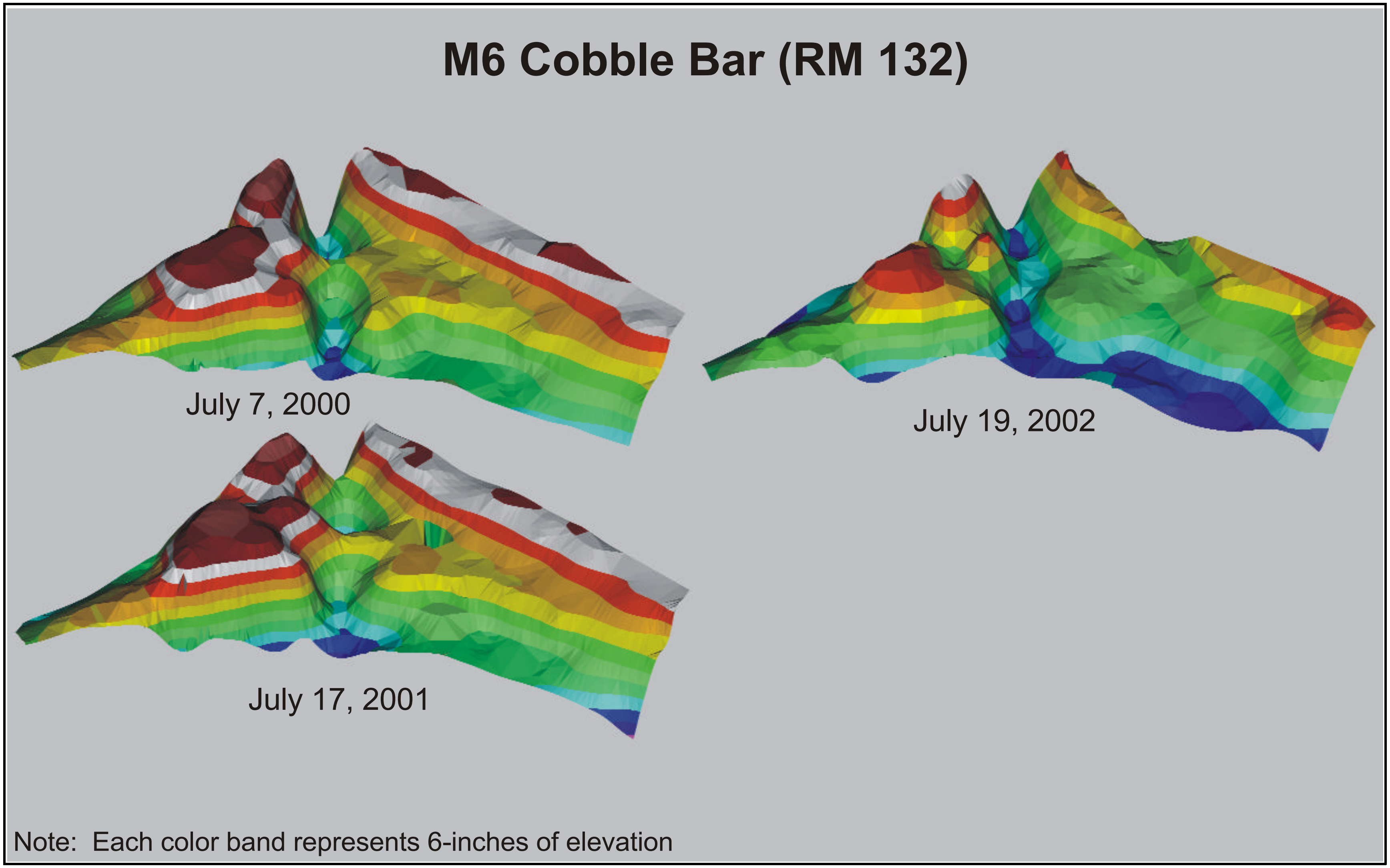

Figure 3.14. Topography of Cobble Bar at RM 132, 1999-2002

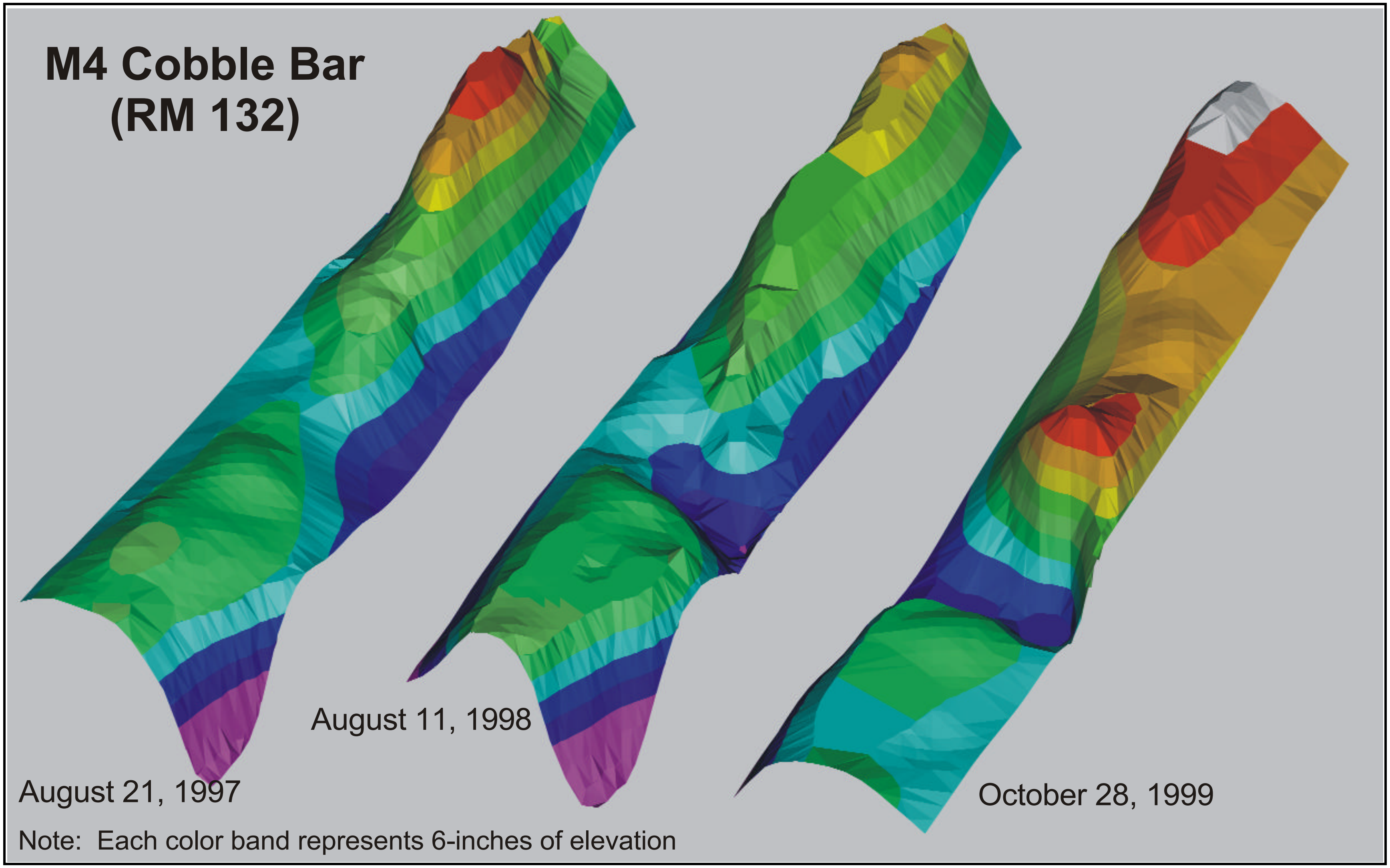

Figure 3.15. Topography of Cobble Bar at RM 131, 1998-1999

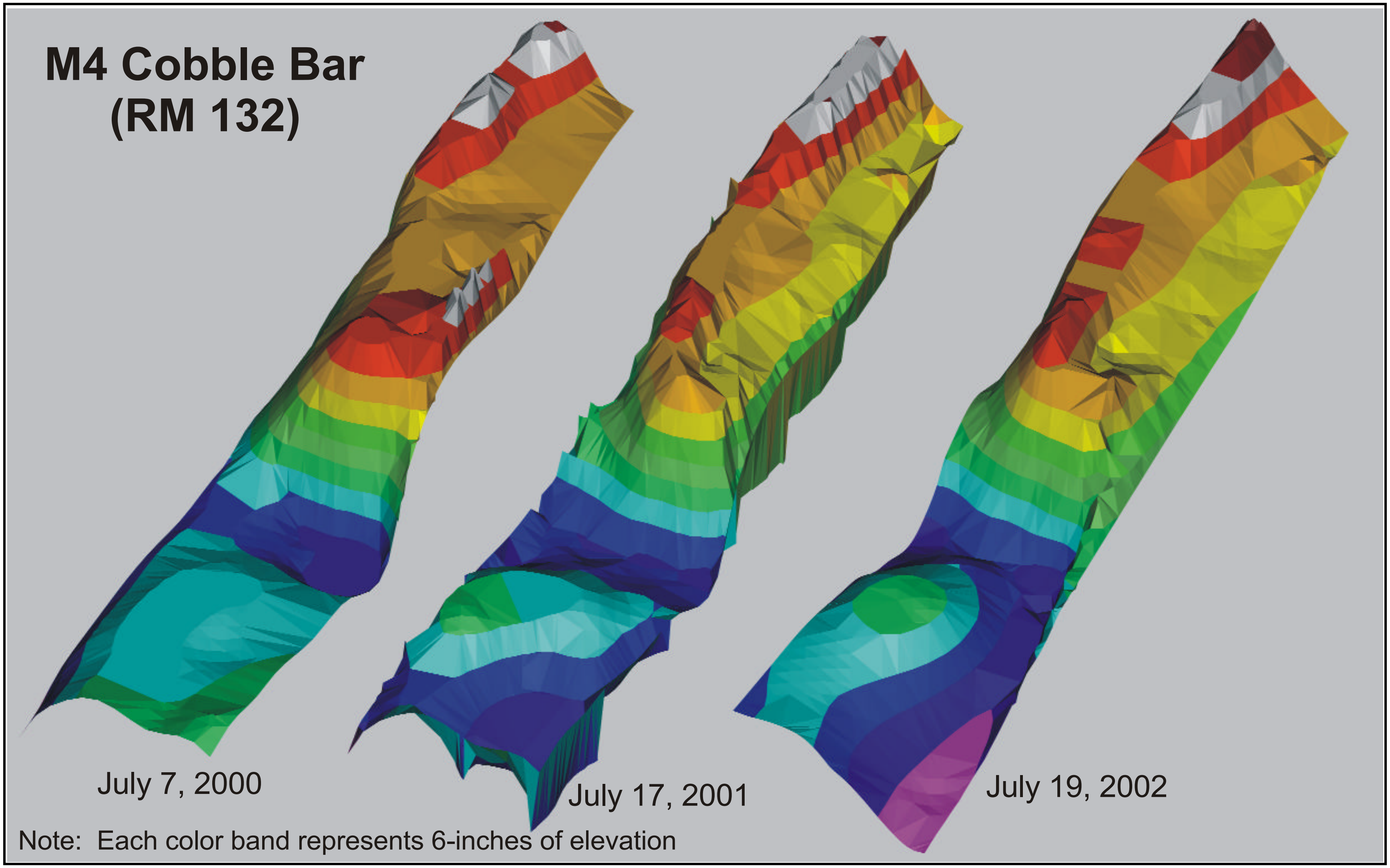

Figure 3.16. Topography of Cobble Bar at RM 131, 1999-2002

Table 3.3. Summary of Cobble Bar Change for Bars at RM 173.7, 168.4, 132 and 131

Survey Date	Average Elev. (m)	Change in Elev. (cm)	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	-10.3	28.96	26.76
08/10/98	30.44	3.1	28.90	26.70
11/15/99	30.43	-1.1	28.93	26.82
07/07/00	30.41	-2.0	29.14	26.82
07/16/01	30.44	2.2	29.20	27.13
09/17/02	30.51	7.3	29.28	26.88
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	4.2	29.11	27.84
11/16/99	30.60	6.7	29.43	28.00
07/06/00	30.58	-2.4	29.34	27.94
07/16/01	30.57	-1.2	29.42	27.93
07/19/02	30.57	0	29.29	27.95
Bar at RM 132 (M-6)				
03/08/95	30.48		28.73	26.91
07/25/95	30.57	8.4	28.80	27.19
03/13/96	30.56	-0.9	28.68	27.04
07/10/96	30.54	-1.6	28.55	27.00
08/21/97	30.64	10.6	28.52	26.76
08/11/98	30.68	3.8	28.67	27.06
10/28/99	30.76	7.9	28.69	27.28
07/07/00	30.69	-7.3	28.65	27.23
07/17/01	30.69	0.4	28.65	27.25
07/18/02	30.64	-5.5	28.56	27.22
Bar at RM 131 (M-4)				
08/11/98	30.48	0.00	29.35	27.80
10/28/99	30.70	21.80	29.63	27.80
07/07/00	30.69	-0.98	29.72	27.80
07/17/01	30.72	3.31	29.69	27.77
07/19/02	30.72	0.13	29.72	28.01

The cobble bar at RM 173.7 showed slight overall deposition of 2.2 cm. The maximum elevation increased by 0.06 meters and the minimum elevation increased by 0.31 meters. Figure 3.17 shows areas of deposition and scour between the 2000 and 2001 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 2000 and 2001 surveys. Similar figures have been created for each of the cobble bars.

The cobble bar at RM 173.7 showed continued deposition between the 2002 pre- and post-runoff. However most of the deposition occurred during a storm event that occurred on September 11-12, 2002. This cobble bar was surveyed on July 19, 2002 but due to an error had to be re-surveyed. The storm hit prior to the second survey being complete. The second survey was done on September 17, 2002. The storm event produced a peak average daily flow of 2120 cfs at Farmington and 8090 cfs at Shiprock. Since this cobble bar is between the two station the flow at the bar is unknown. Areas of deposition and scour are shown in Figure 3.18.

The cobble bars at 168.4 showed an overall loss of 1.2 cm in 2001 and no net change in 2002. Figures 3.19 and 3.20 show areas of deposition and scour for both the 2001 and 2002 surveys. Although there was no net change in 2002 there was sediment movement on the bar as shown in Figure 3.20.

The cobble bar at 132 showed a gain of 0.4 cm in 2001. This is within our survey error so there was little net change at 132 but there was considerable sediment movement on the bar as shown in Figure 3.21. It showed a 5.5 cm loss in 2002 and the areas of scour are clearly shown in Figure 3.22.

The cobble bar at 131 showed a 3.3 cm gain in 2001 and essentially no change in 2002. Like the other bars, even with little or no net change there is considerable sediment movement on the bar itself as shown in Figures 3.23 and 3.24.

Characterization of Bed Material

Table 3.4 shows the surface substrate composition for the 2001 and 2002 pre- and post-runoff surveys of the Reach 3-6 transects. The pre-runoff 2001 survey averaged 54% sand and 46% cobble The pre-runoff 2002 survey averaged 52 % sand and 48% cobble. The post-runoff 2001 survey averaged 44% sand and 56% cobble while the 2002 survey averaged 51% sand and 49% cobble. The increase in the cobble percentage in the post-runoff 2001 survey shows that some fines were flushed from the system during runoff. The low flows during 2002 produced little change.

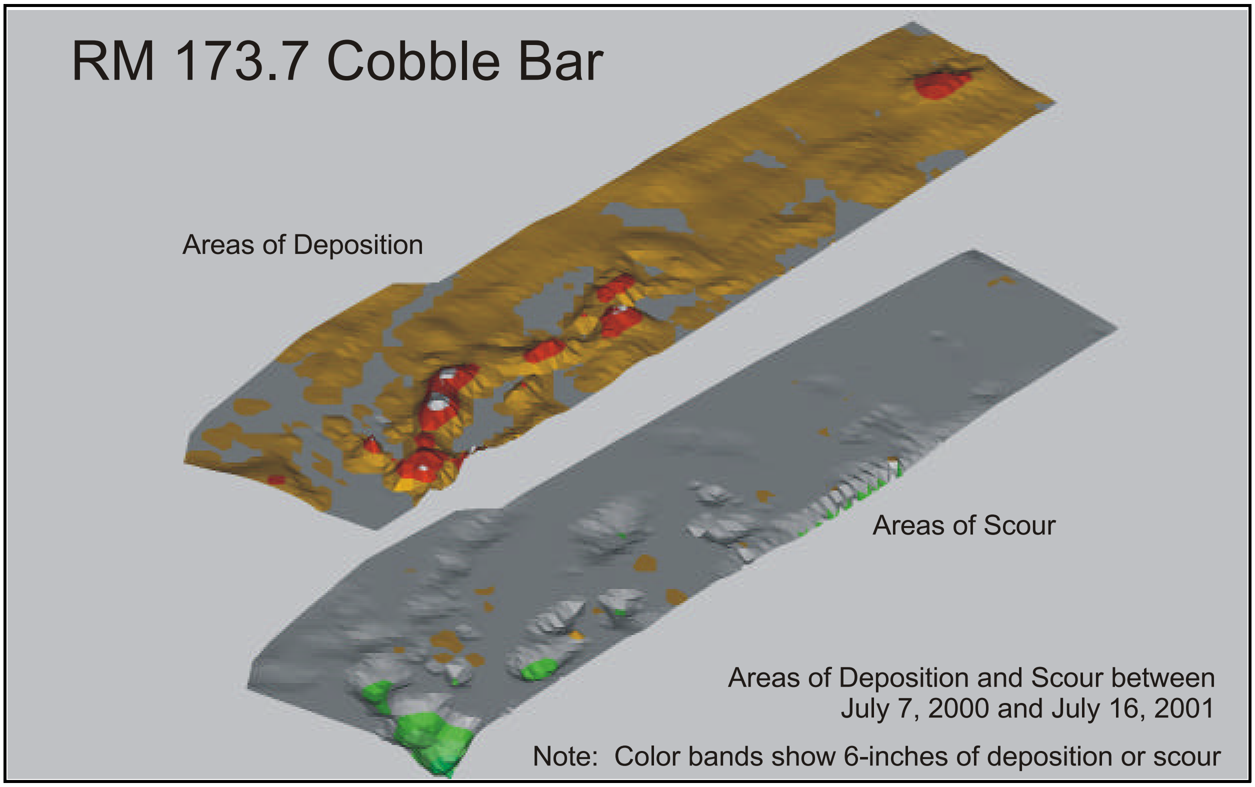

Figure 3.17. Areas of Scour and Deposition Pre- to Post-runoff 2001 for the RM 173.7 Cobble Bar

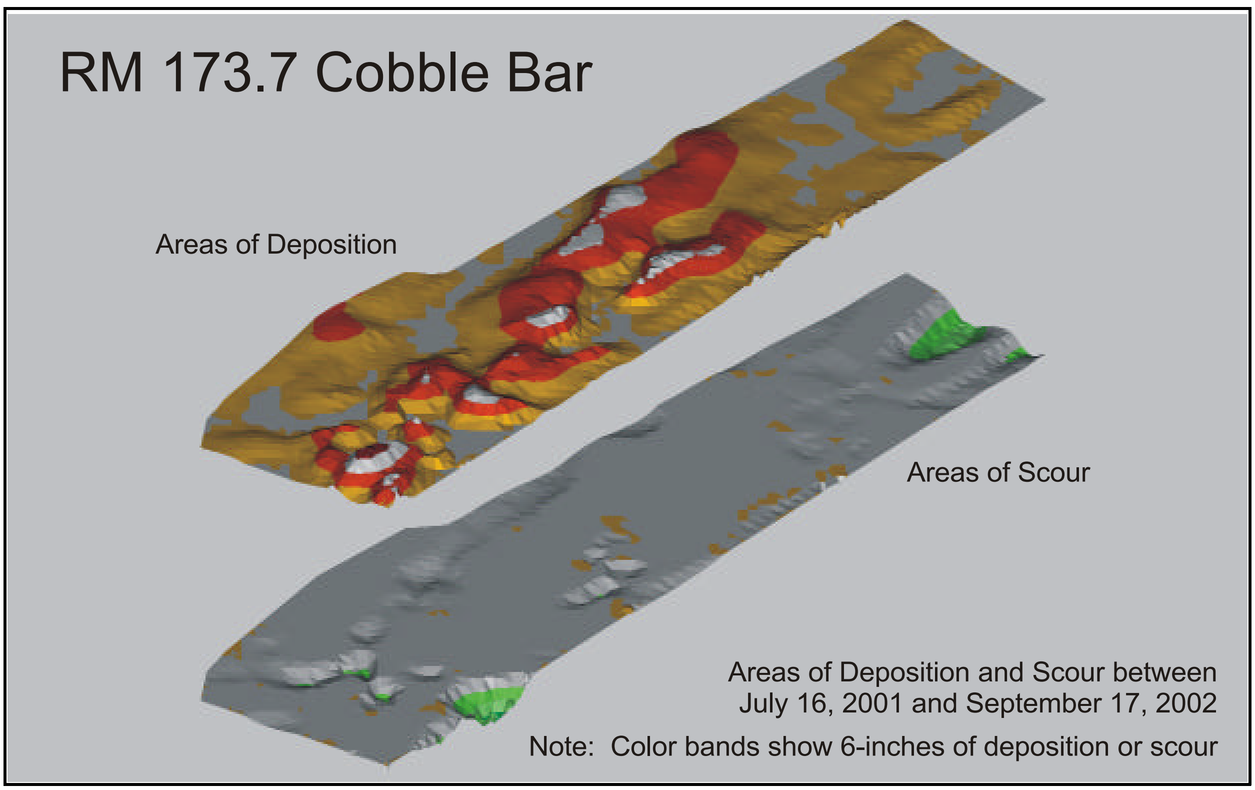

Figure 3.18. Areas of Scour and Deposition Pre- to Post-runoff 2002 for the RM 173.7 Cobble Bar

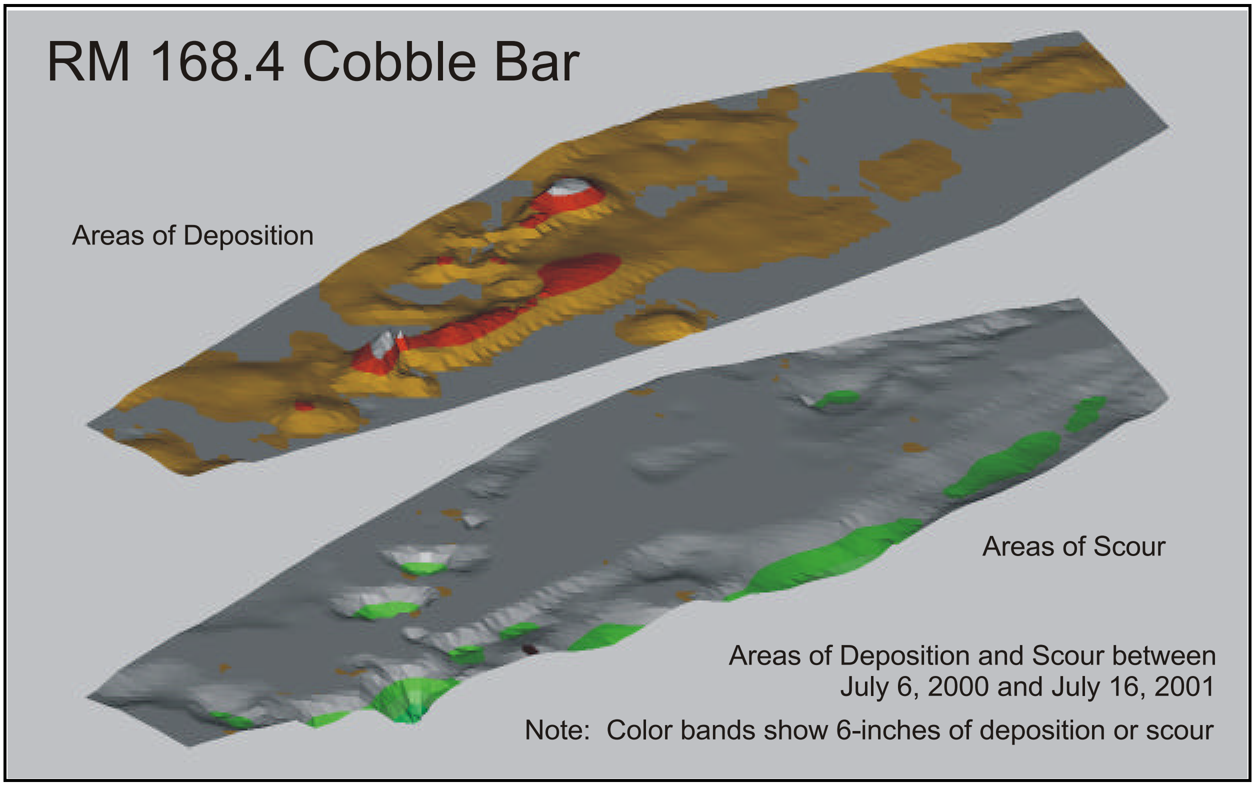

Figure 3.19. Areas of Scour and Deposition Pre- to Post-runoff 2001 for the RM 168.4 Cobble Bar

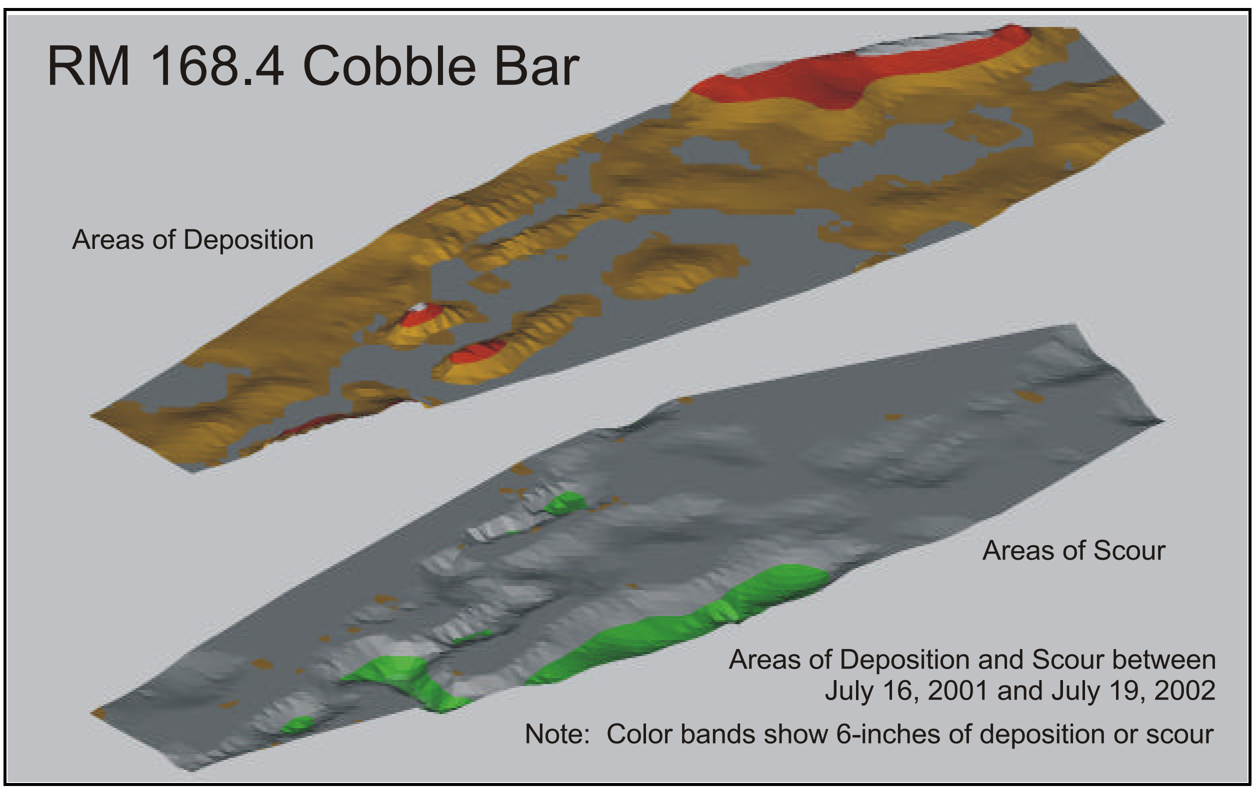

Figure 3.20. Areas of Scour and Deposition Pre- to Post-runoff 2002 for the RM 168.4 Cobble Bar

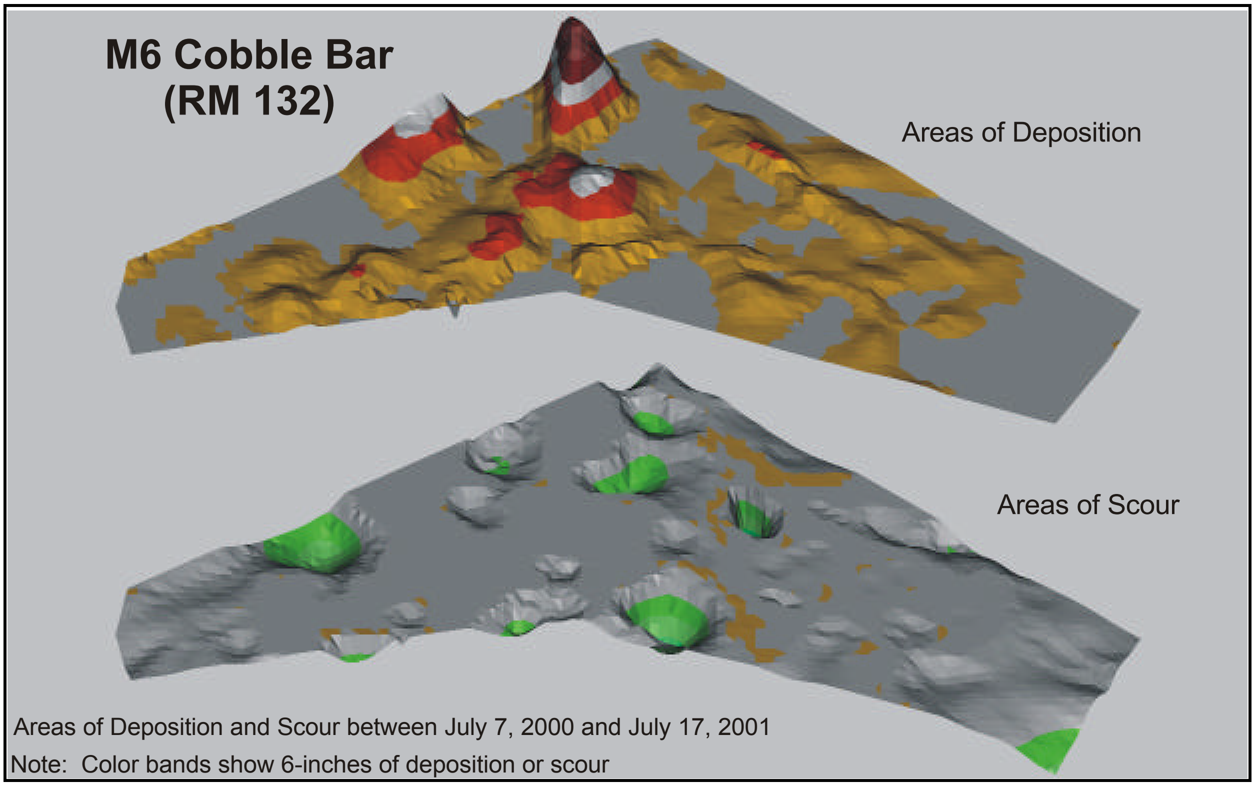

Figure 3.21. Areas of Scour and Deposition Pre- to Post-runoff 2001 for the RM 132 Cobble Bar

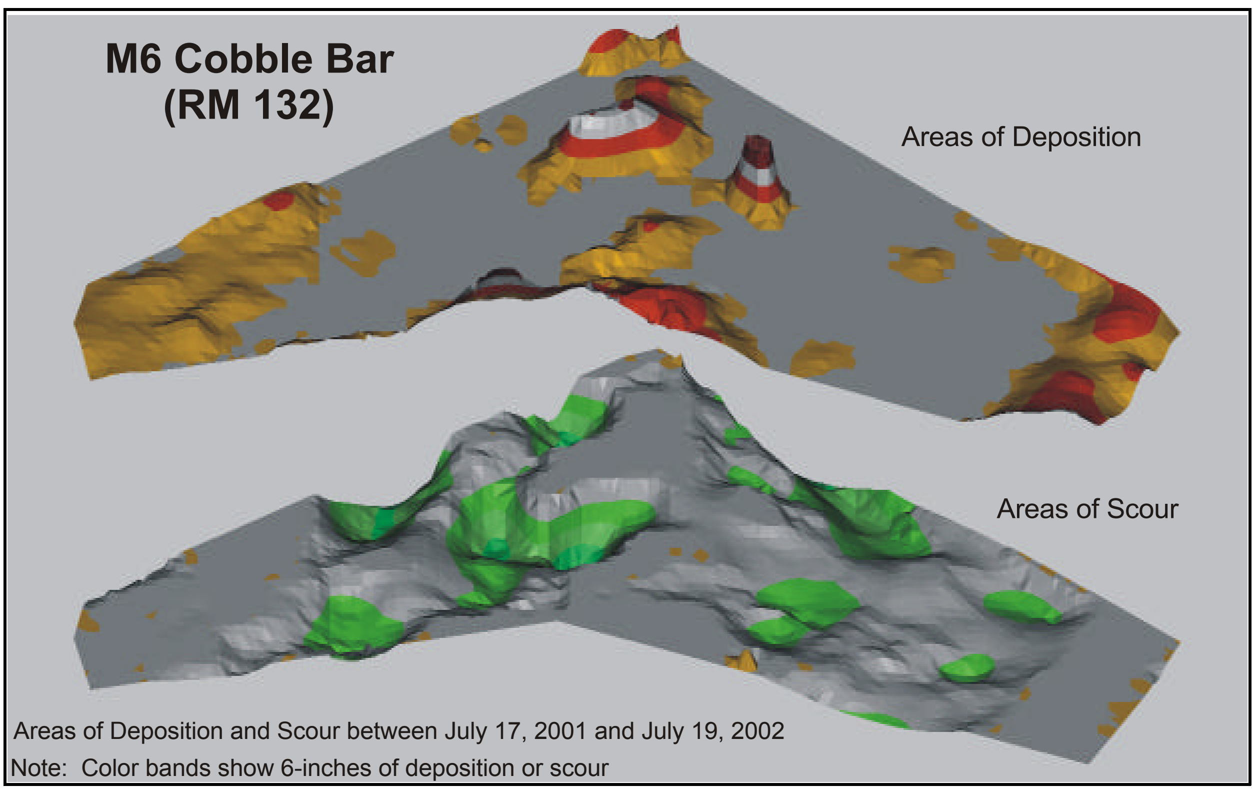

Figure 3.22. Areas of Scour and Deposition Pre-to Post-runoff 2002 for the RM 132 Cobble Bar

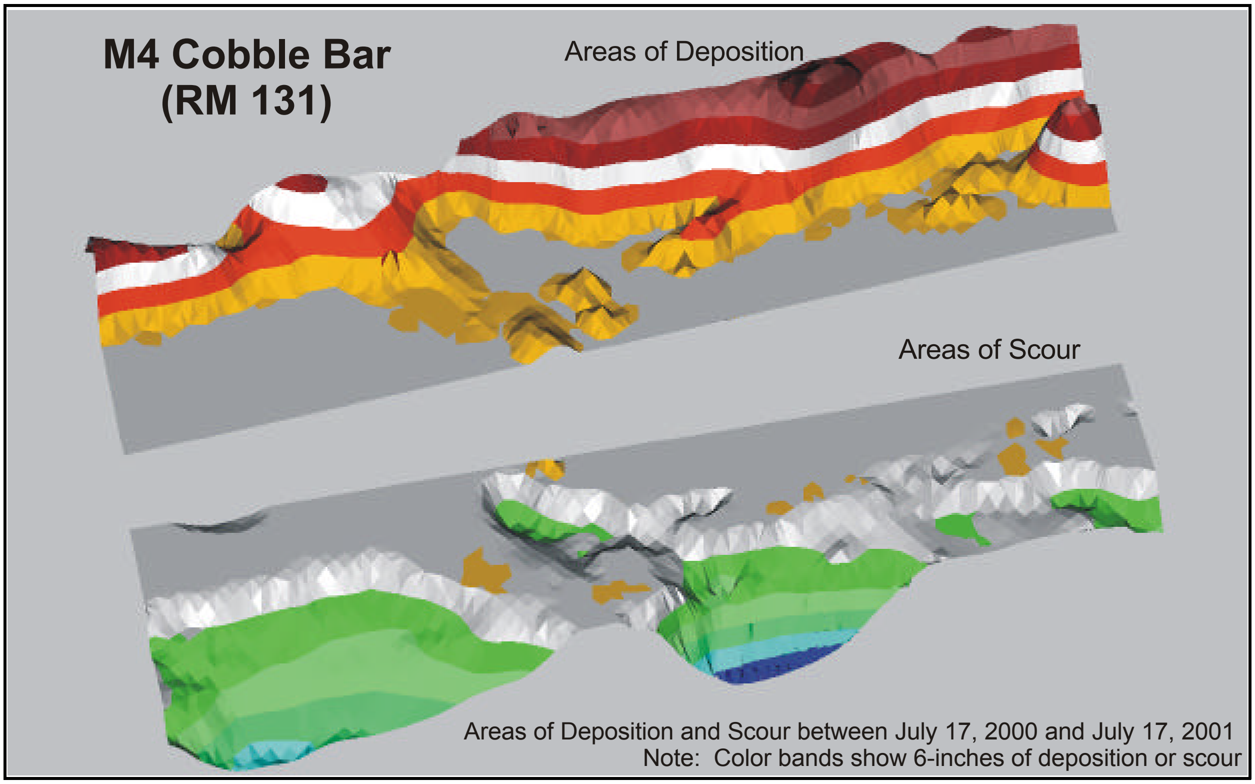

Figure 3.23. Areas of Scour and Deposition Pre- to Post-runoff 2001 for the RM 131 Cobble Bar

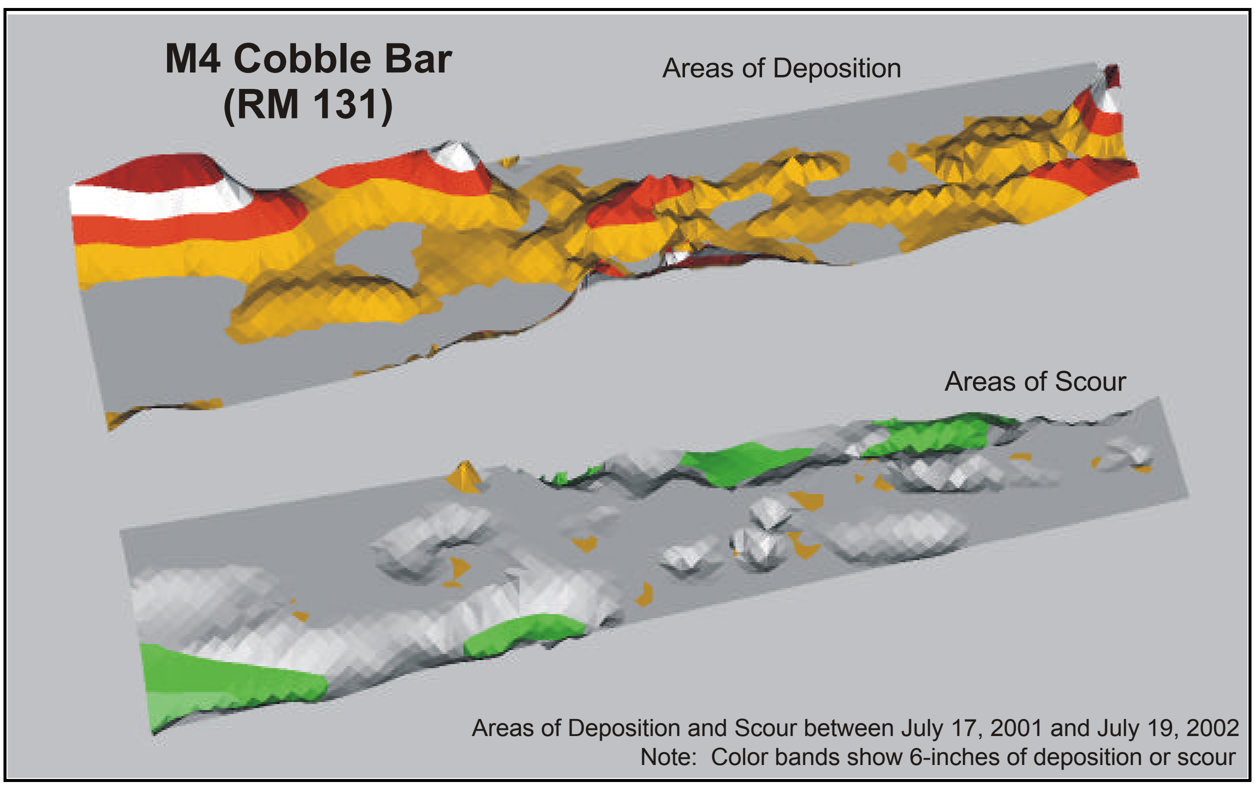

Figure 3.24. Areas of Scour and Deposition Pre- to Post-runoff 2002 for the RM 131 Cobble Bar

Figure 3.25 and Figure 3.26 shows the composition of the scour and deposition that occurred at each of the Reach 3-6 transects pre- and post runoff during 2001 and 2002 respectively. Most of the material moved during both 2001 and 2002 was fines. However, there was some cobble movement at most of the transects during 2001, particularly at CS4-01 and CS3-03. This occurred with an 8,340 cfs peak at Four Corners. There was virtually no cobble moved in 2002 with peak flows below 1000 cfs as Four Corners. Figure 3.27 and 3.28 show 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 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. The change in cobble size shown from one year to the next is as likely due to sampling bias as to flow. This is probably particularly true in low flow years. such as 2002.

Table 3.4. Summary of Percent Cobble Substrate, Pre- and Post-runoff, 2001 for Reach 3-6 Transects

Survey date	03/22/01	07/16/01	03/25/02	07/19/02
Transect	Percent Cobble			
CS6-01	81%	91%	-	80%
CS6-02	20%	31%	23%	11%
CS6-03	37%	83%	80%	67%
CS5-01	48%	64%	57%	66%
CS5-02	50%	82%	65%	67%
CS5-03	50%	53%	61%	60%
CS4-01	61%	8%	11%	23%
CS4-02	56%	74%	67%	72%
CS4-03	75%	65%	-	67%
CS3-01	30%	46%	25%	18%
CS3-02	59%	66%	67%	67%
CS3-03	46%	51%	27%	40%
Average	46%	56%	48%	49%

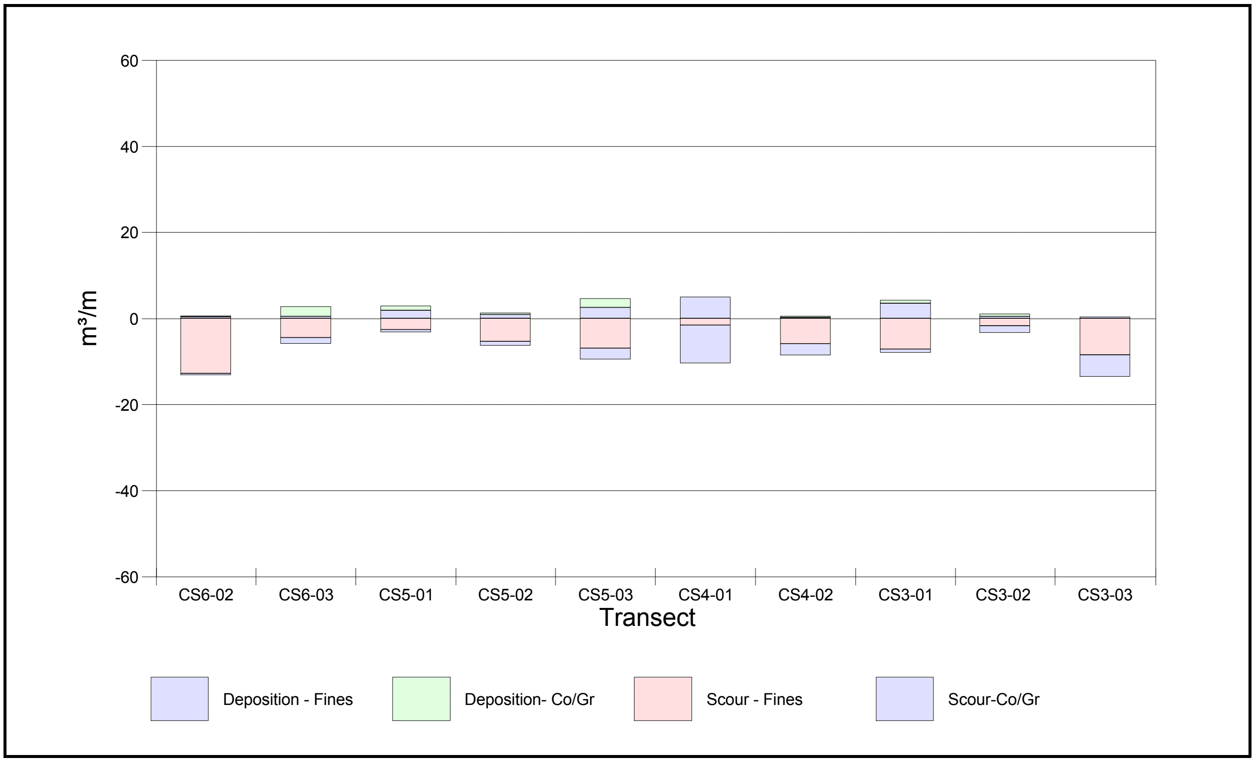

Figure 3.25. Scour and Deposition Composition at Reach 3-6 Transects Between Pre- and Post-runoff, 2001

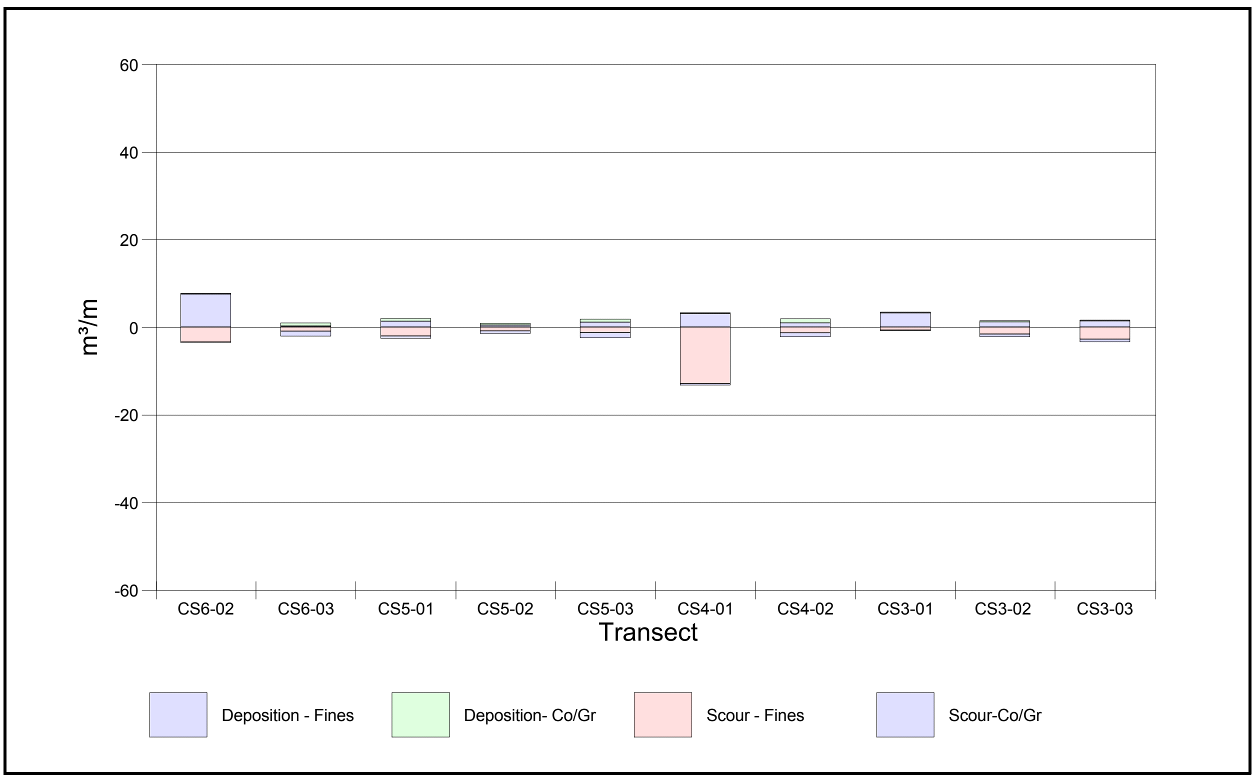

Figure 3.26. Scour and Deposition Composition at Reach 3-6 Transects Between Pre- and Post-runoff, 2002

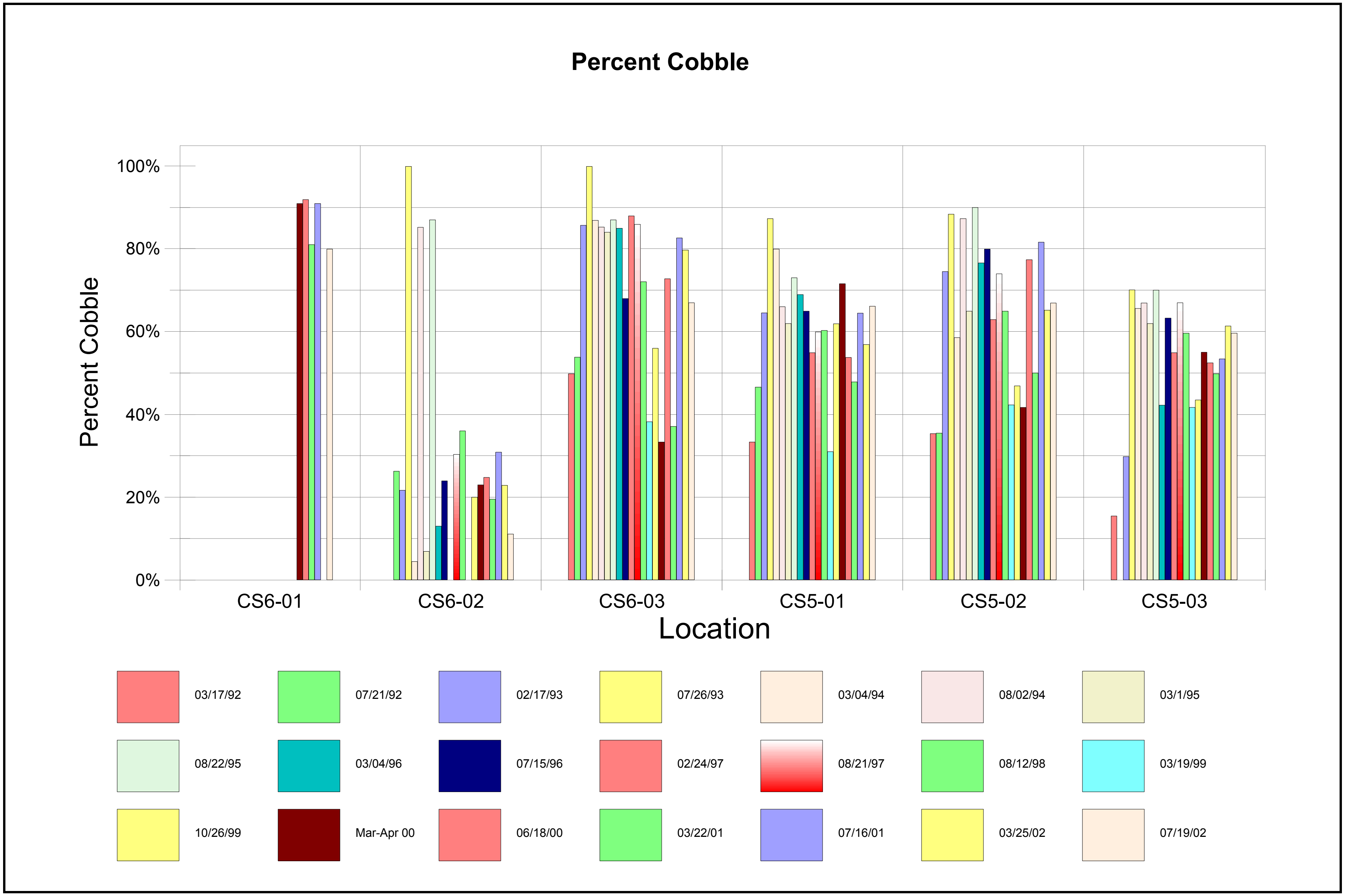

Figure 3.27. Cobble Percentage at CS6-01 to CS5-03, 1992-2002

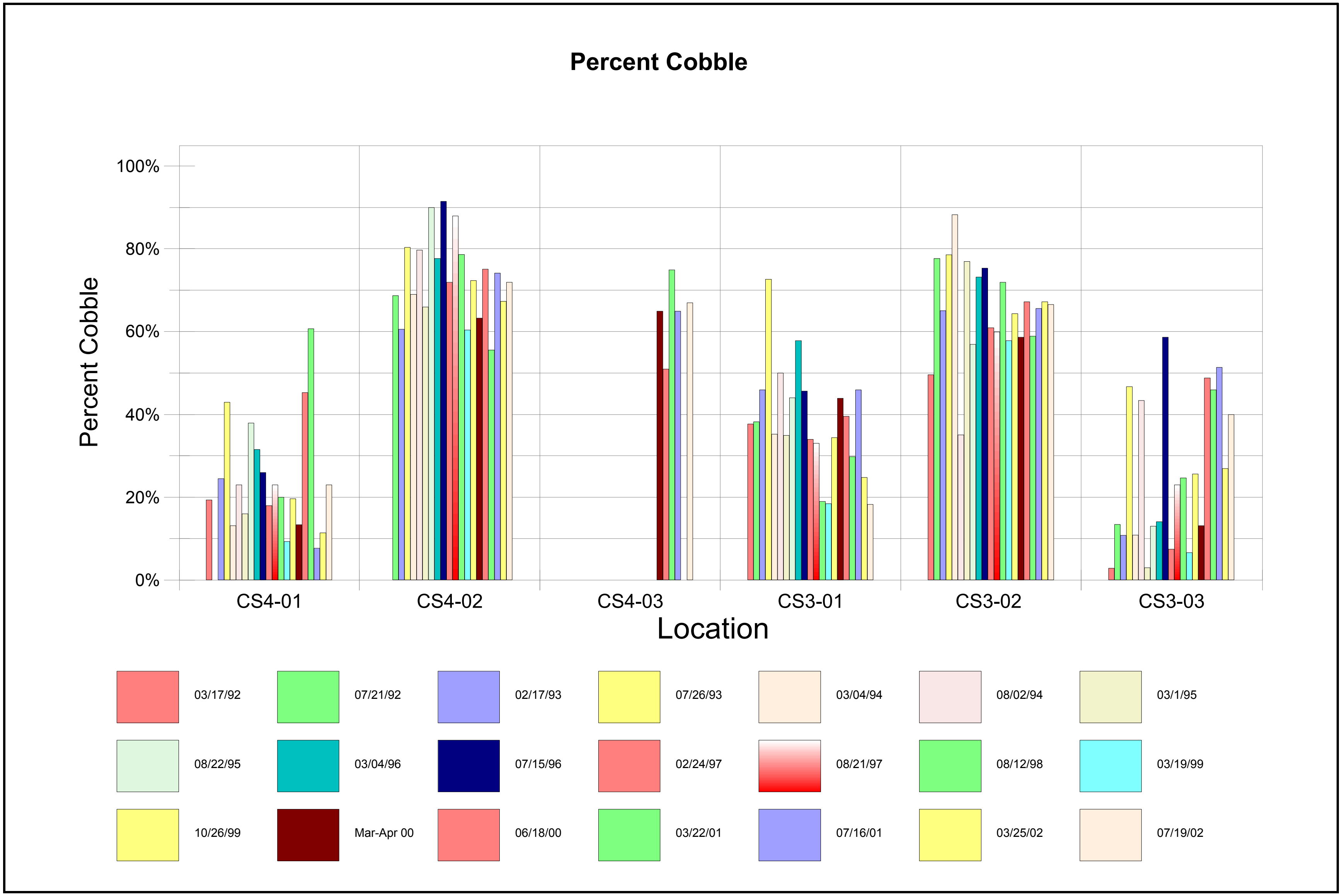

Figure 3.28. Cobble Percentage at CS4-01 to CS3-03, 1992-2002

Table 3.5. Cobble Size Distribution for the Four Surveyed Cobble Bars

Year	1995	1996	1997	1998	1999	2000	2001	2002
Size Fraction				Cobble Size - cm				
				RM 173.7				
D84	n/a	9.93	12.57	12.02	16.68	13.59	11.94	14.59
D75	n/a	7.95	8.00	10.33	13.17	11.21	9.31	11.92
D50	n/a	4.83	3.79	6.96	8.03	6.22	6.15	7.50
D25	n/a	3.03	2.19	4.72	4.41	3.93	4.29	4.96
D16	n/a	2.59	1.69	3.89	3.33	3.16	3.56	4.10
				RM 168.8				
D84	10.97	14.65	10.45	11.24	11.91	11.54	10.30	9.64
D75	10.17	12.62	10.00	9.94	11.00	9.88	8.79	9.02
D50	7.21	8.38	6.25	6.79	7.45	7.29	6.79	6.59
D25	4.94	4.99	4.33	4.65	5.41	5.05	4.74	4.98
D16	4.57	4.58	3.65	3.64	4.64	4.35	4.26	4.36
				RM 132 (M6)				
D84	8.64	11.64	9.90	9.49	9.98	9.92	9.49	10.25
D75	7.28	10.64	8.38	8.18	8.52	8.47	8.33	9.30
D50	5.10	7.79	6.58	5.91	6.04	6.40	6.09	5.97
D25	3.35	5.54	4.88	3.70	4.08	4.66	4.51	4.44
D16	2.75	4.60	4.40	3.03	3.44	4.08	3.66	3.61
				RM 131 (M4)				
D84	6.48	10.82	7.88	8.49	9.98	9.18	9.89	10.71
D75	5.43	9.81	7.06	6.95	8.50	8.27	9.08	9.42
D50	4.17	7.96	5.20	4.64	6.64	5.05	6.21	6.79
D25	2.80	6.58	3.56	2.54	4.68	2.94	4.42	5.08
D16	2.09	5.60	2.76	1.92	4.15	2.48	3.64	4.30

Depth of Open Interstitial Space

Depth of open interstitial space was also measured at each cobble bar. Figures 3.29 through 3.36 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 2001 and 2002 surveys. 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.

The cobble bar at river mile 173.7 was re-surveyed on September 17, 2002 due to an error during the July 17, 2002 survey. The September 11-12, 2002 storm peak deposited a blanket of sediment over the entire cobble bar. Small channels were then eroded in the sediment as the flows dropped. This resulted in little open interstitial space and was not representative of the post-runoff condition. Therefore, the depth of open interstitial space markers shown in Figure 3.30 are from the July 17, 2002 survey.

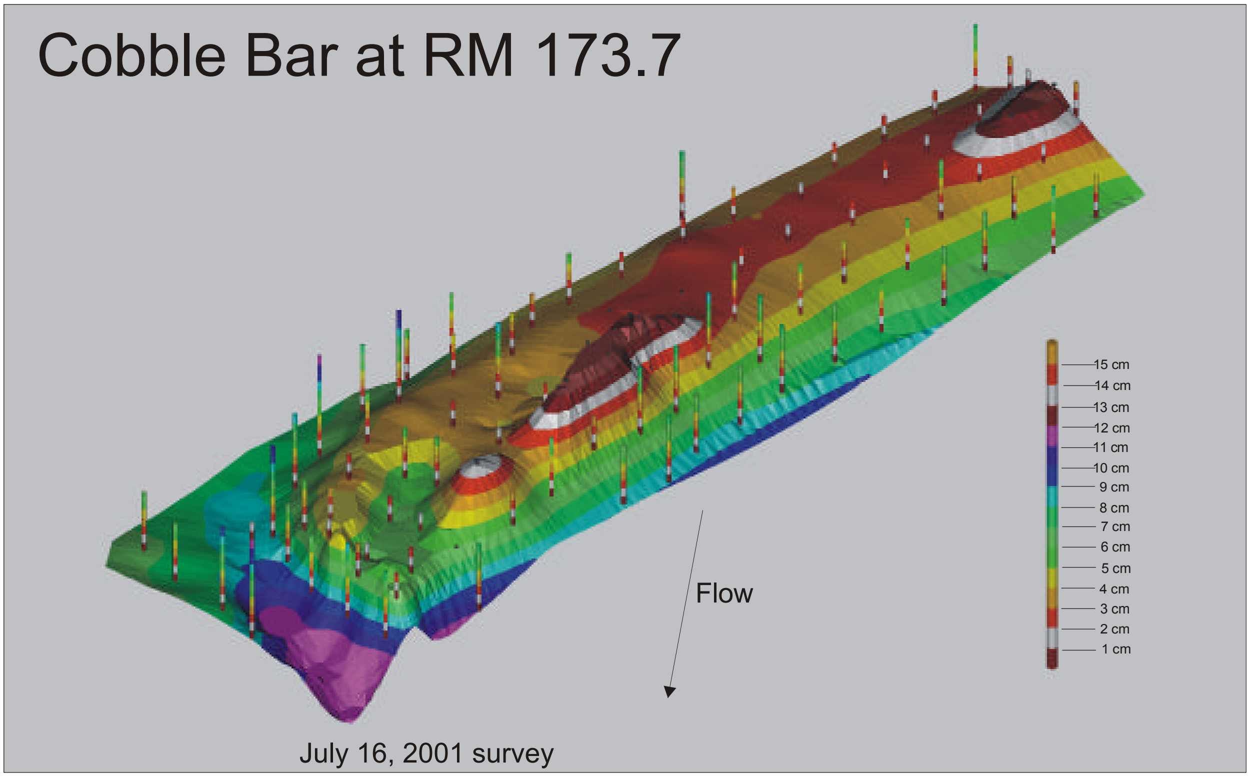

Figure 3.29. July 16, 2001 Survey with Embeddeness Markers

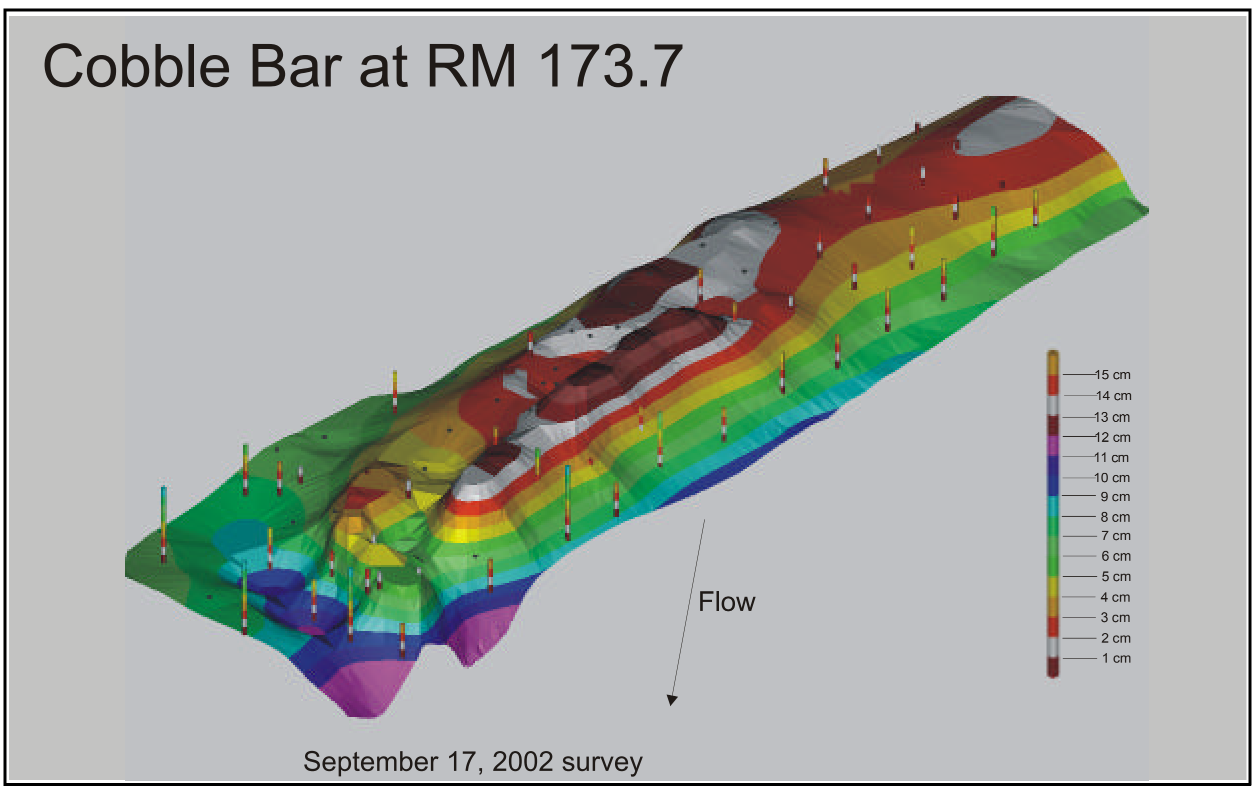

Figure 3.30. September 17, 2002 survey with July 17, 2002 Embeddedness Markers

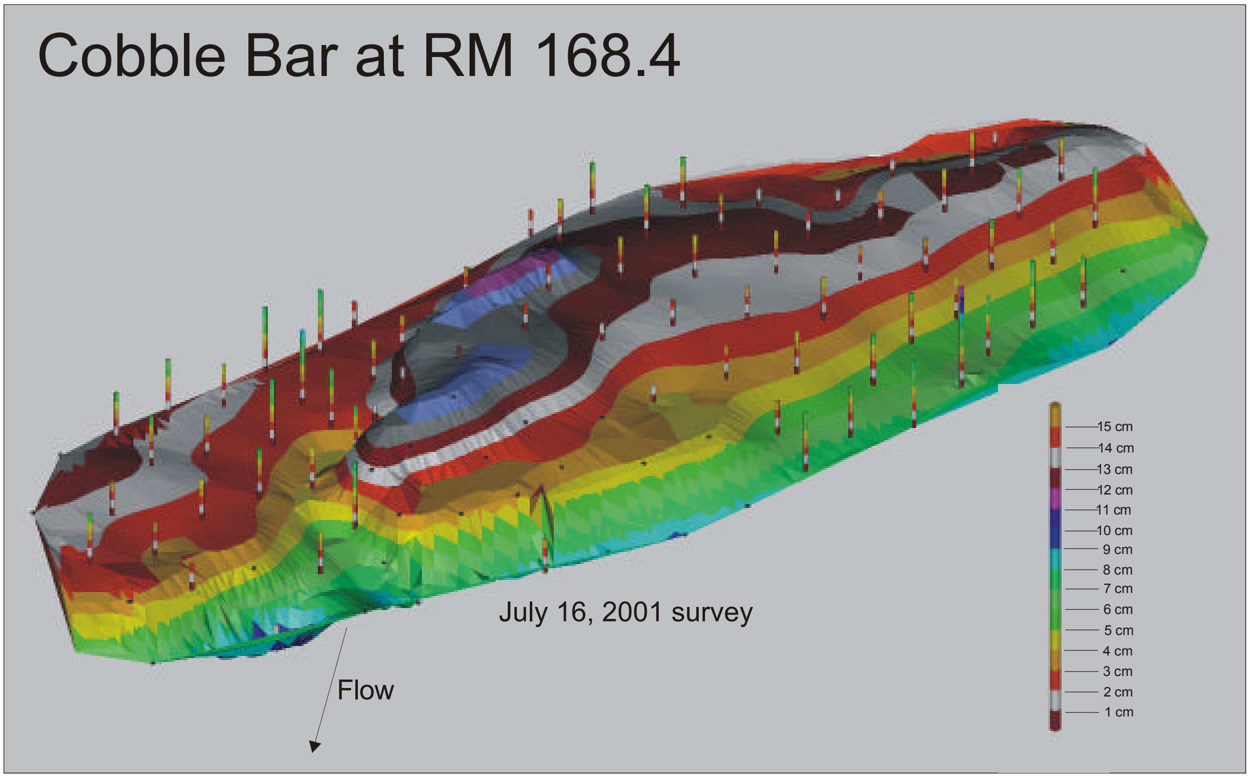

Figure 3.31. July 16, 2001 Survey with Embeddedness Markers

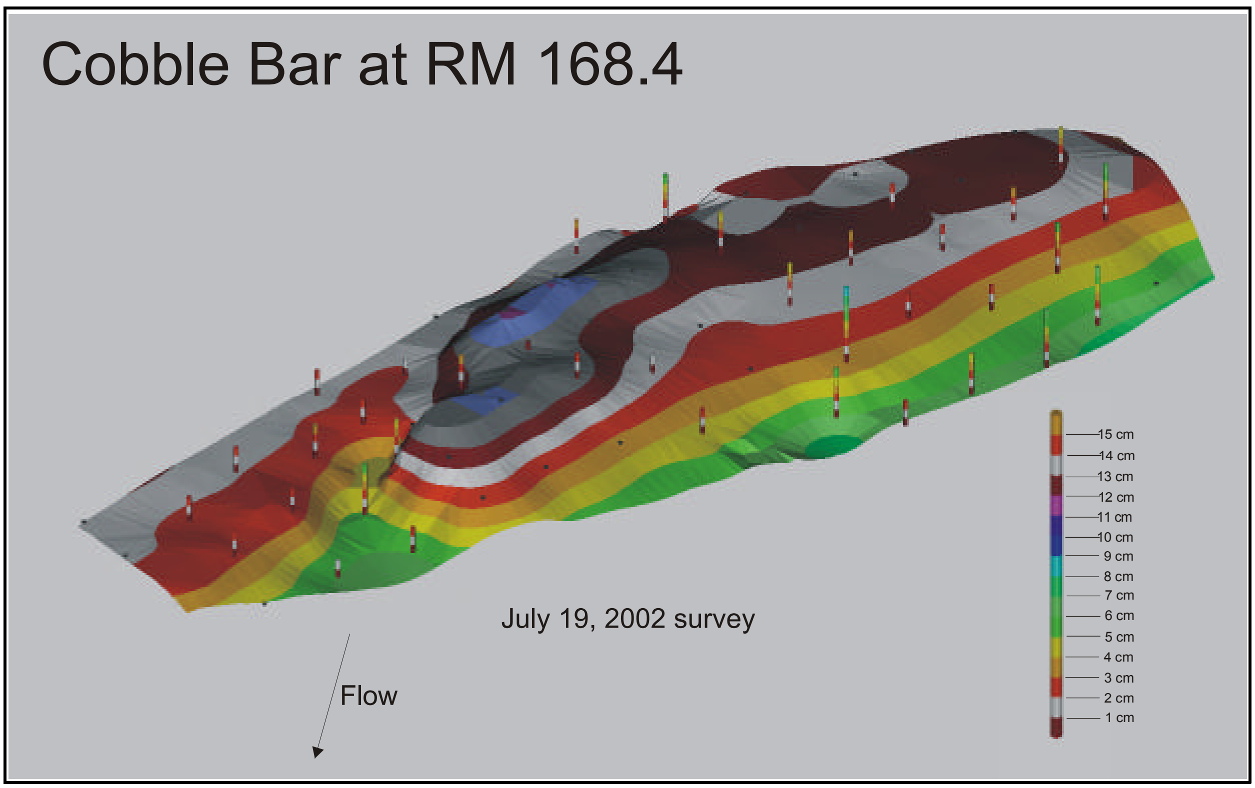

Figure 3.32. July 19, 2002 Survey with Embeddedness Markers

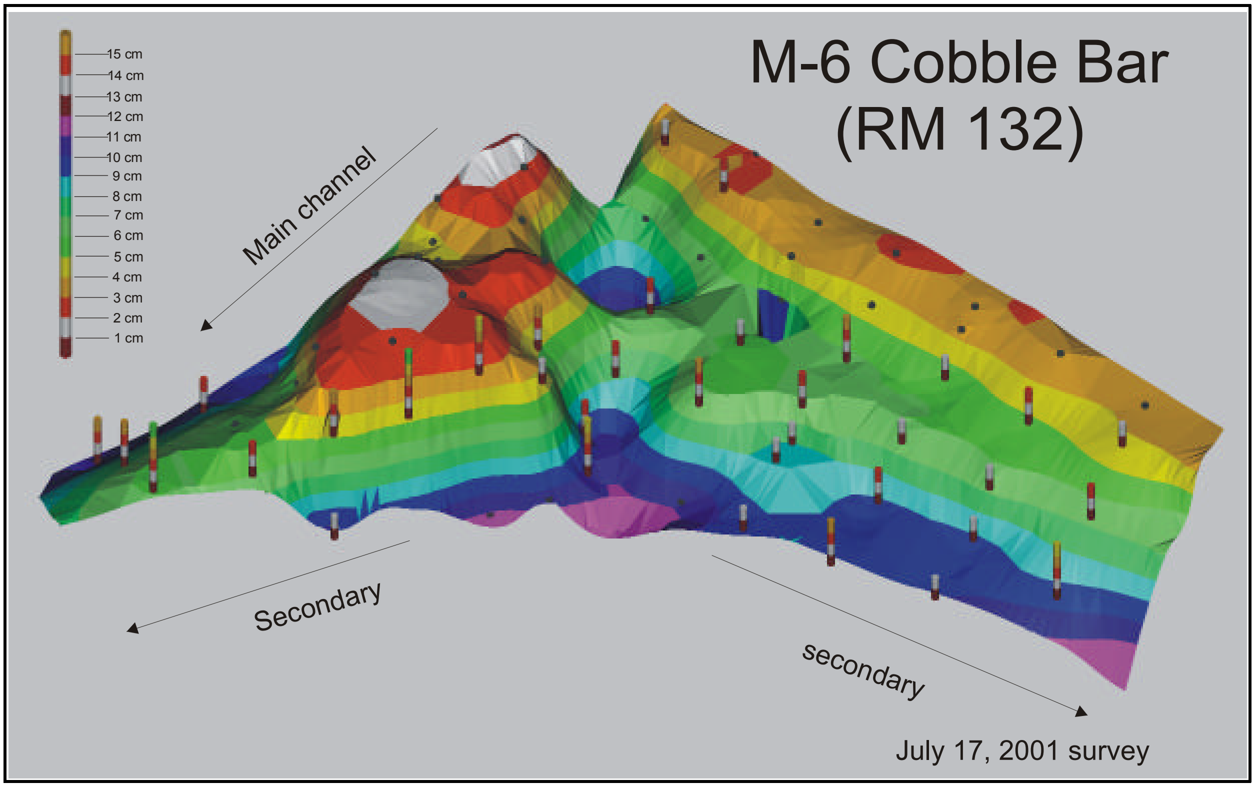

Figure 3.33. July 17, 2001 Survey with Embeddedness Markers

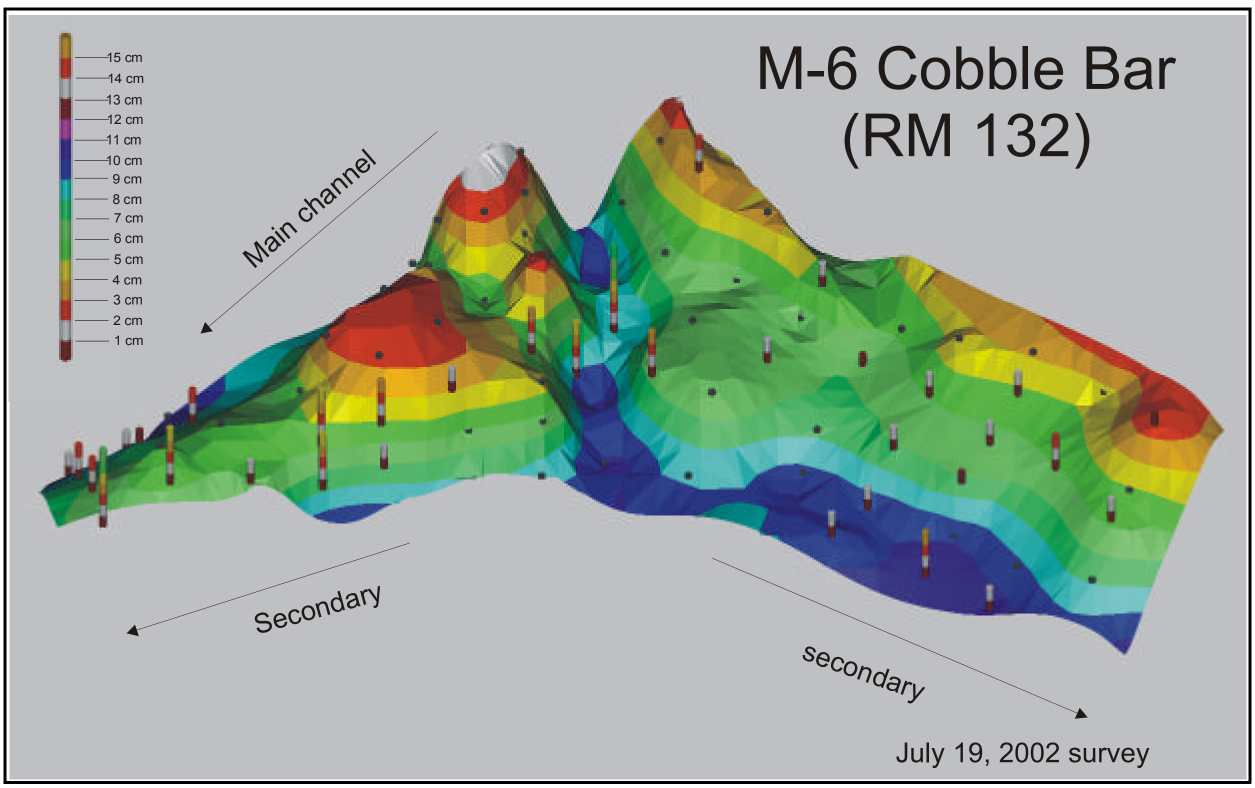

Figure 3.34. July 19, 2002 Survey with Embeddedness Markers

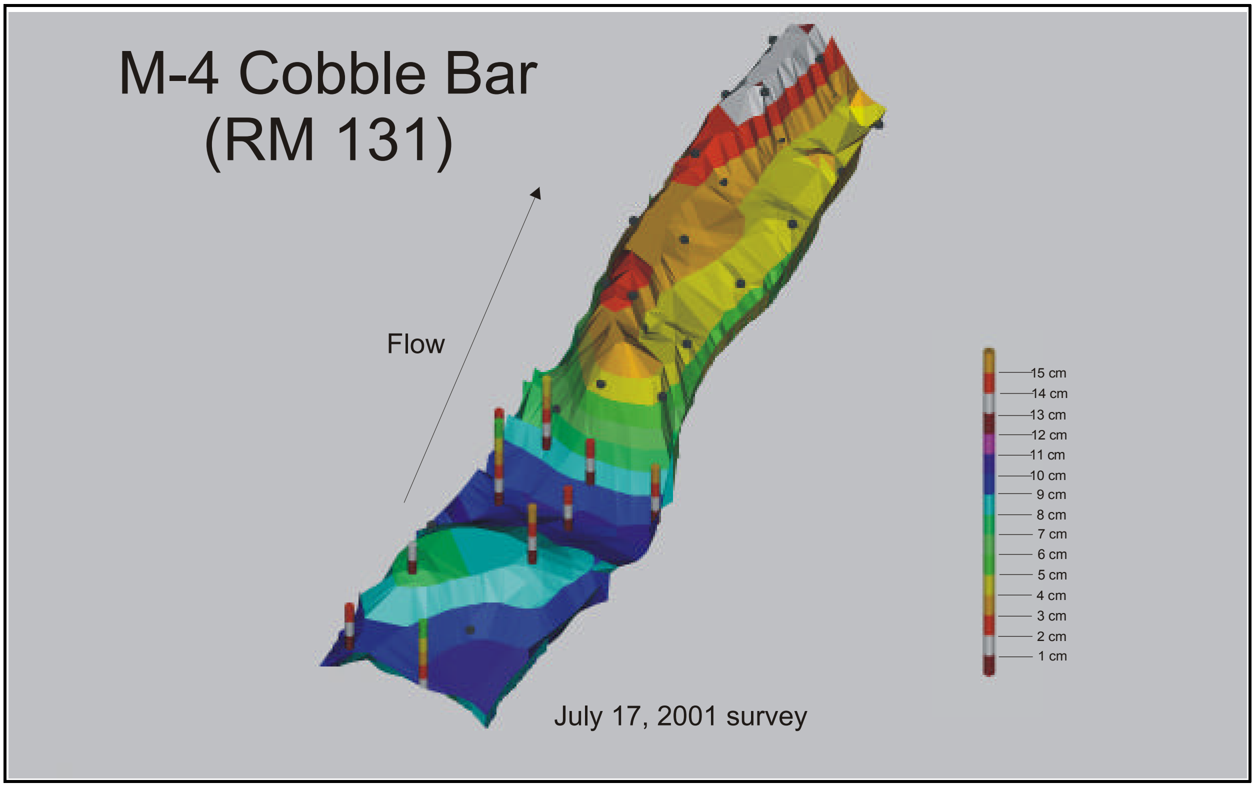

Figure 3.35. July 17, 2001 Survey with Embeddedness Markers

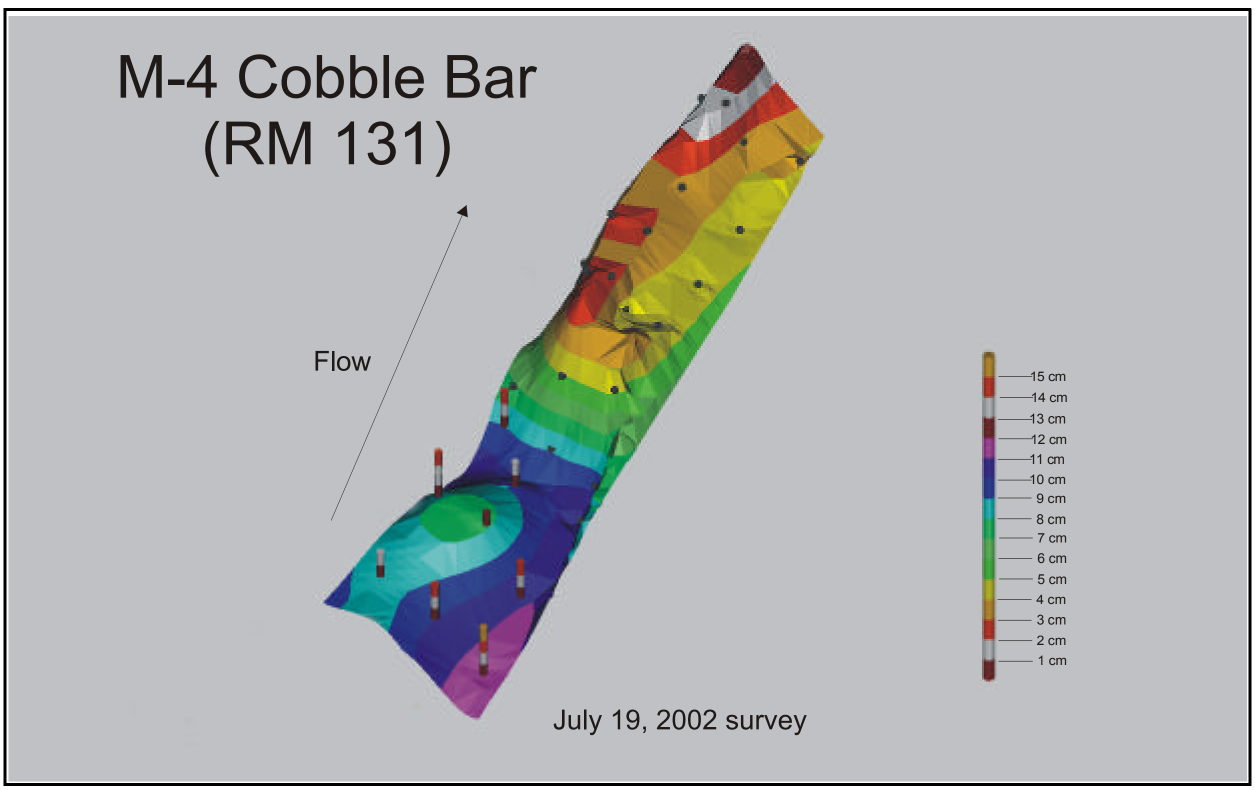

Figure 3.36. July 19, 2002 Survey with Embeddedness Markers

Figures 3.37 and 3.38 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 3.39 to 3.44 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 3.45 to 3.48. 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.

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 0-4000 NTU's (Nephelometric Turbidity Unit). The turbidity data collected 2000, 2001 and 2002 are shown plotted with USGS gage flow in Figures 3.48. The missing record at the Montezuma site is due to a data logger malfunction. The logger was replaced in early 2001. Skips in the data plot as a straight line.
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).

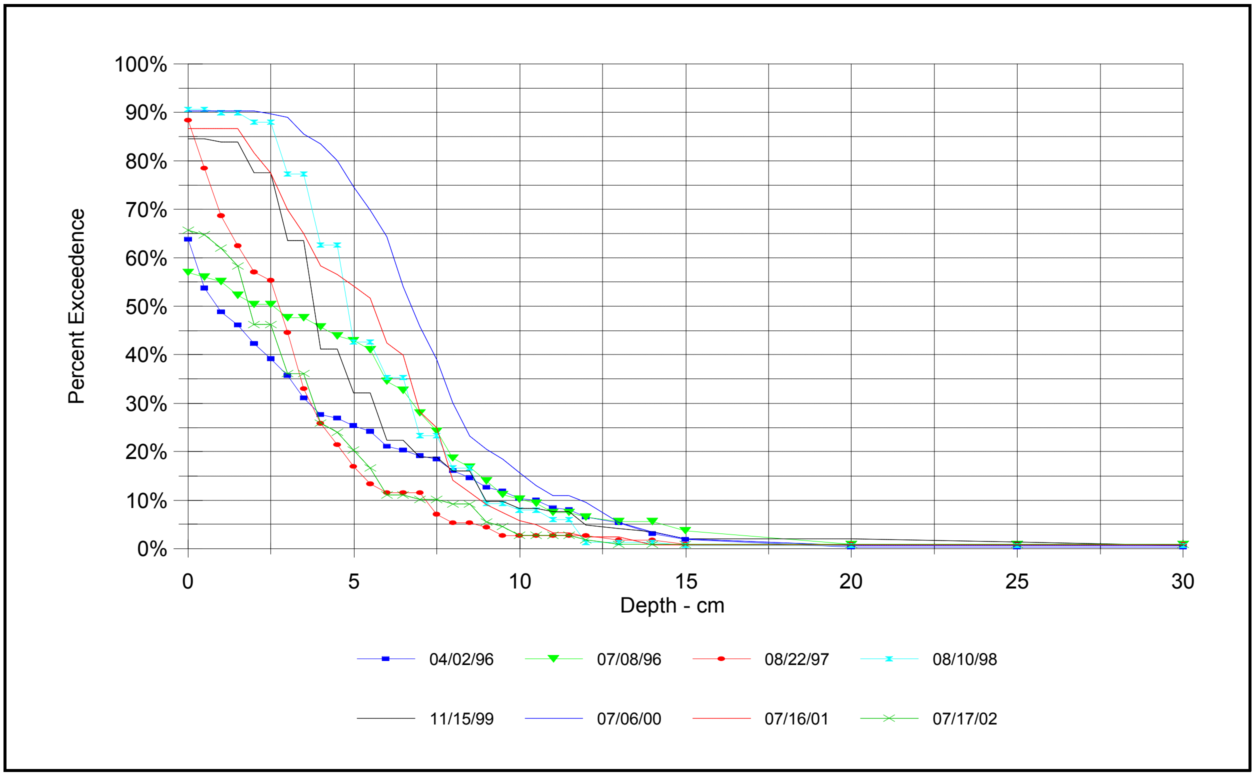

Figure 3.37. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 173.7 Expressed in cm

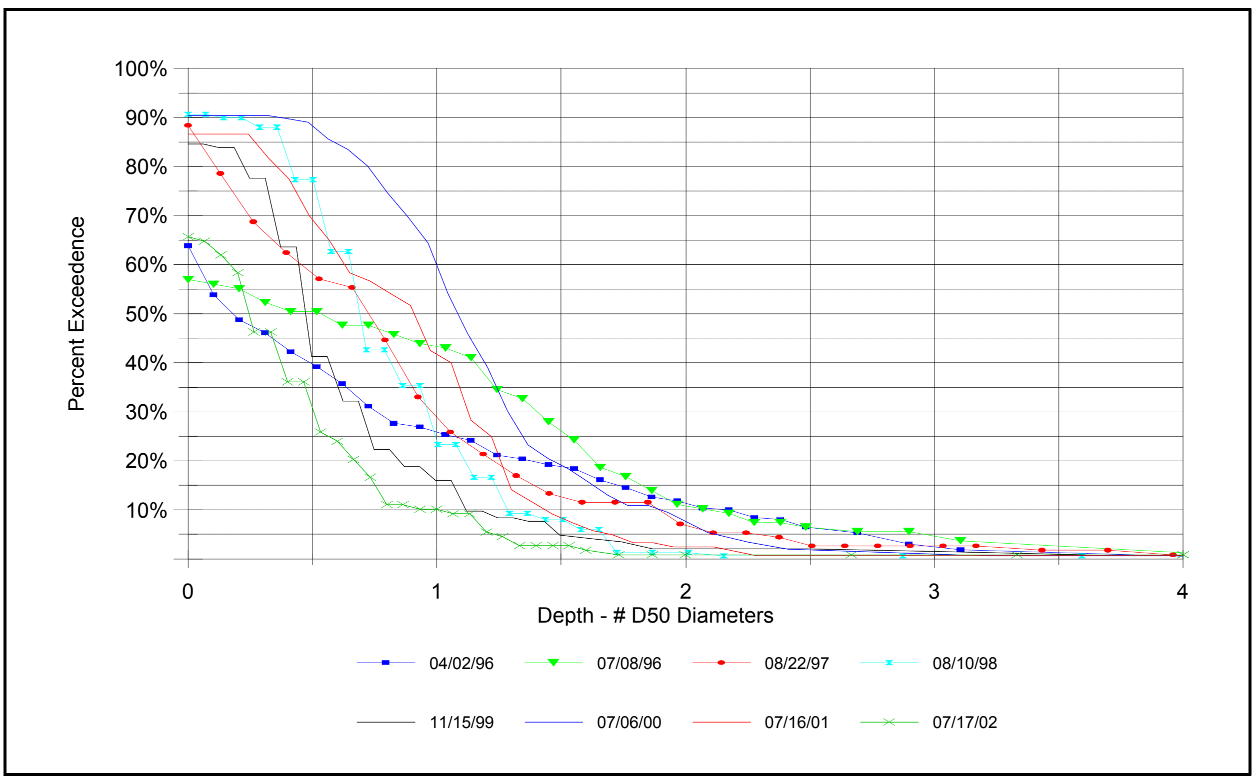

Figure 3.38. Frequency Distribution of Open Interstitial Space for Cobble Bar 173.7 Expressed in d50 Cobble Size.

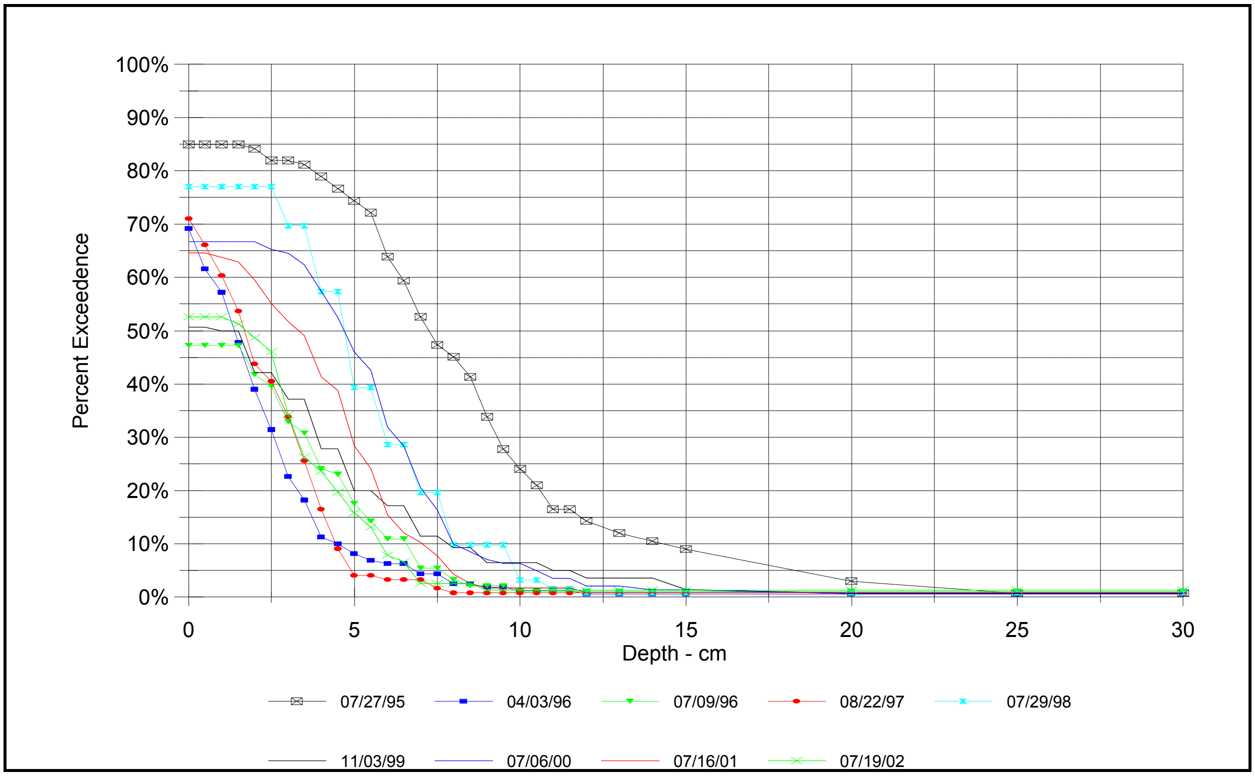

Figure 3.39. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 168.4 Expressed in cm

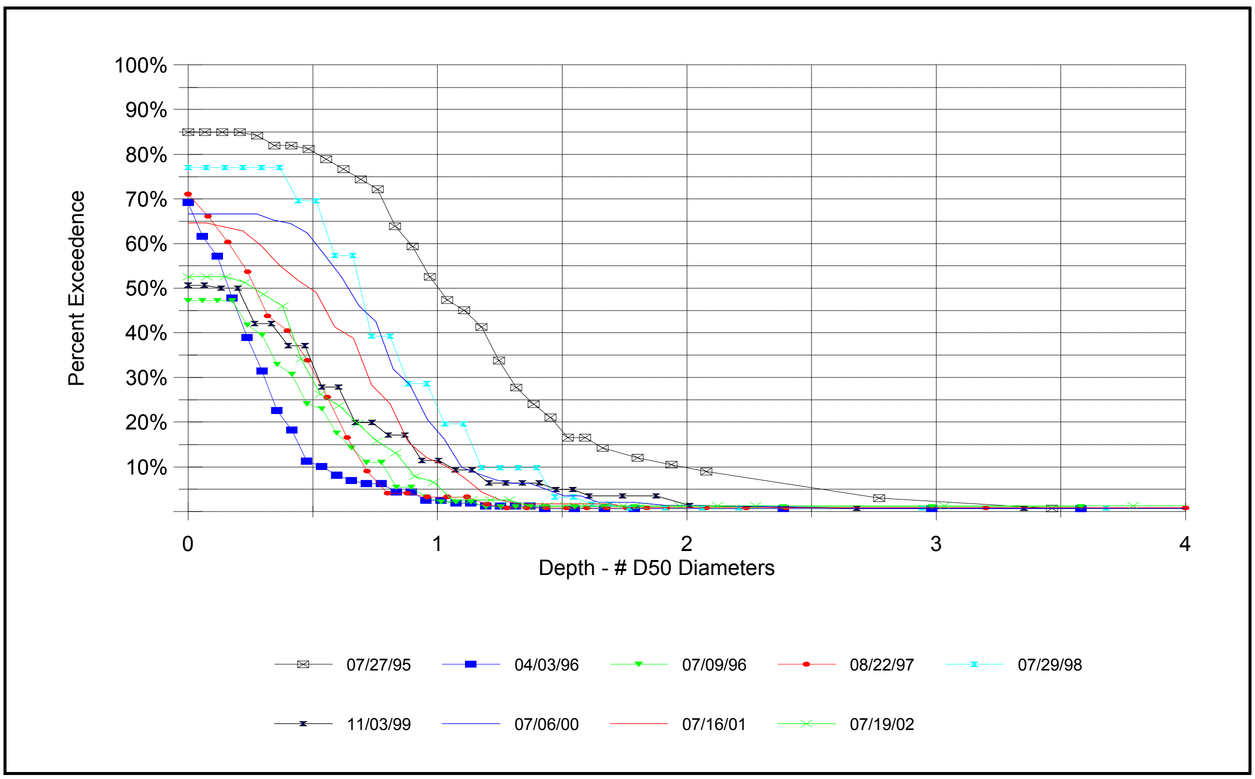

Figure 3.40. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 168.4 Expressed in d50 Cobble Size

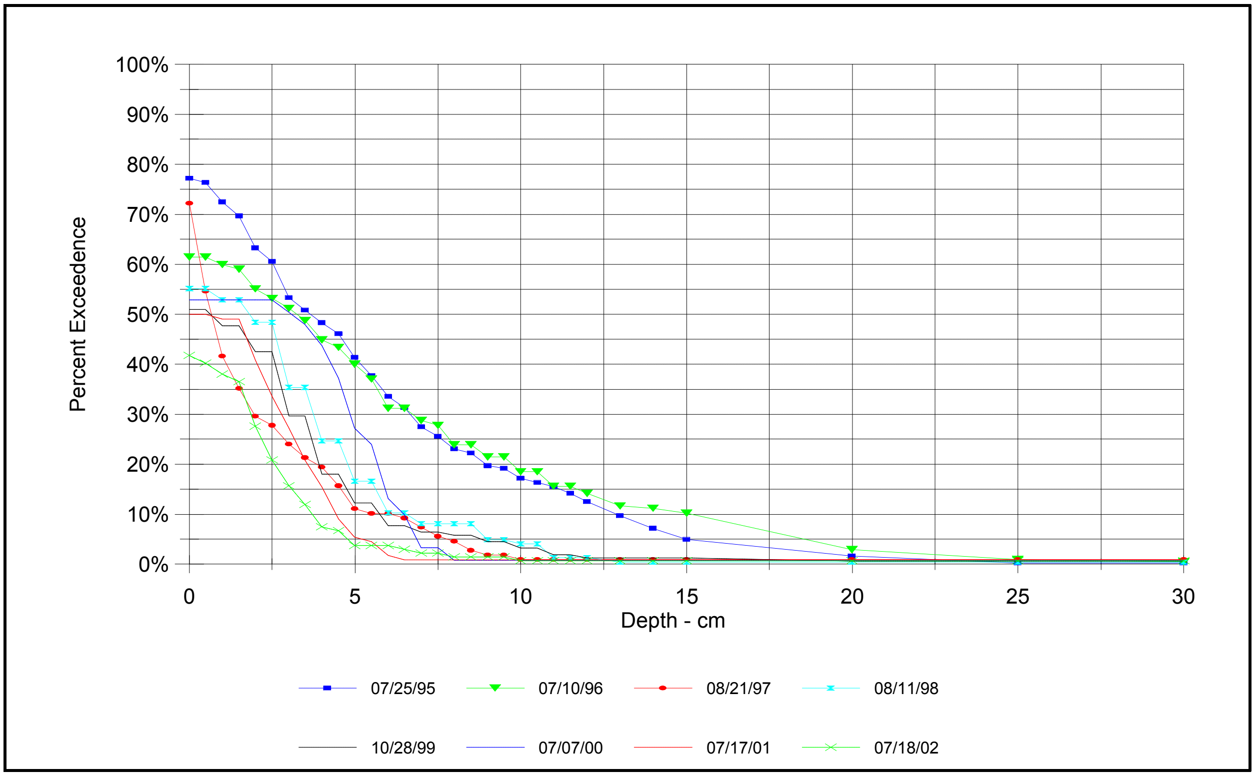

Figure 3.41. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 132 (M-6) Expressed in cm

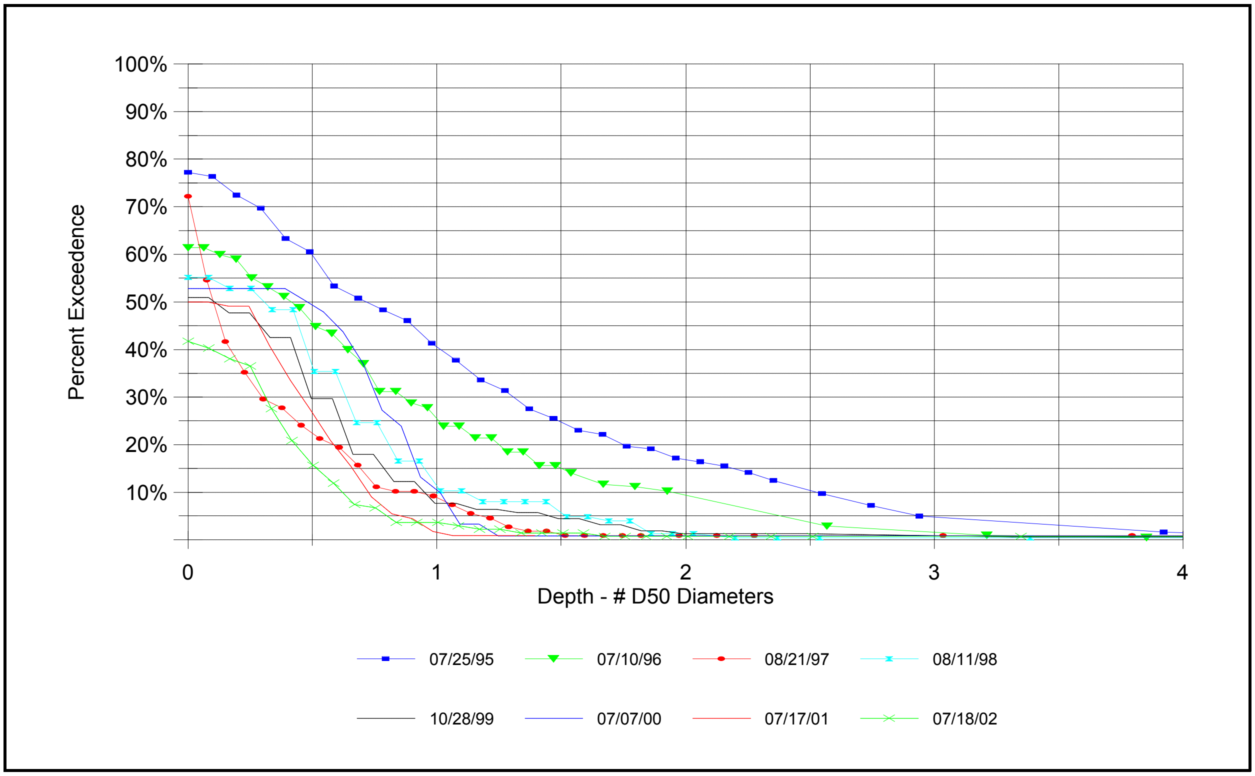

Figure 3.42. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 132 (M-6) Expressed in d50 Cobble Size

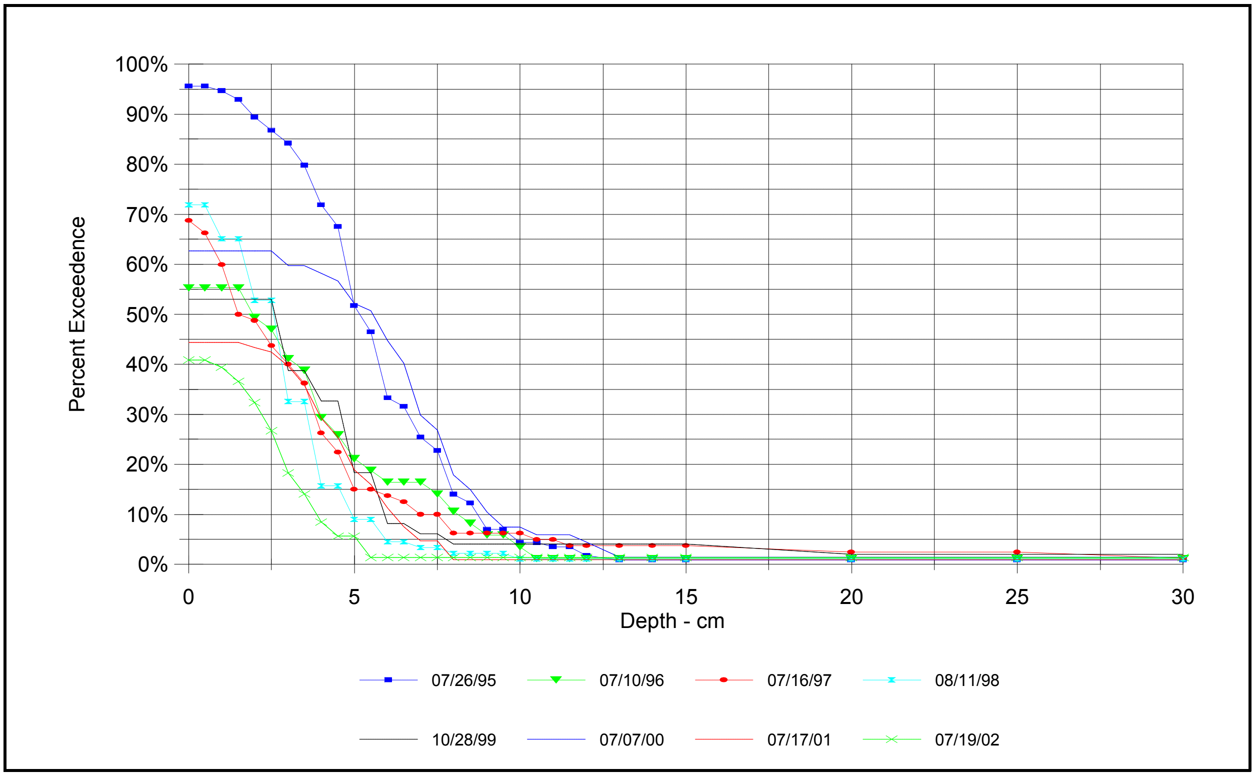

Figure 3.43. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 131 (M-4) Expressed in cm

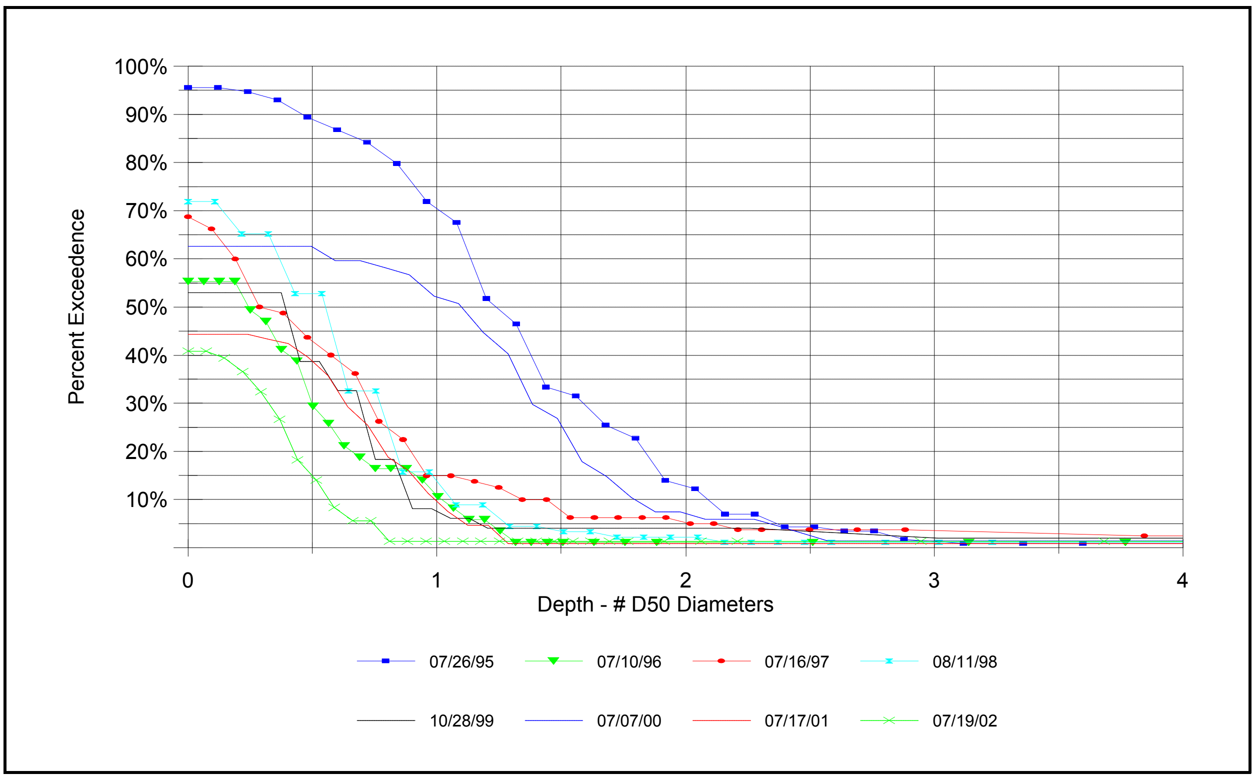

Figure 3.44. Frequency Distribution of Depth of Open Interstitial Space for Cobble Bar 131 (M-4) Expressed in d50 Cobble Size

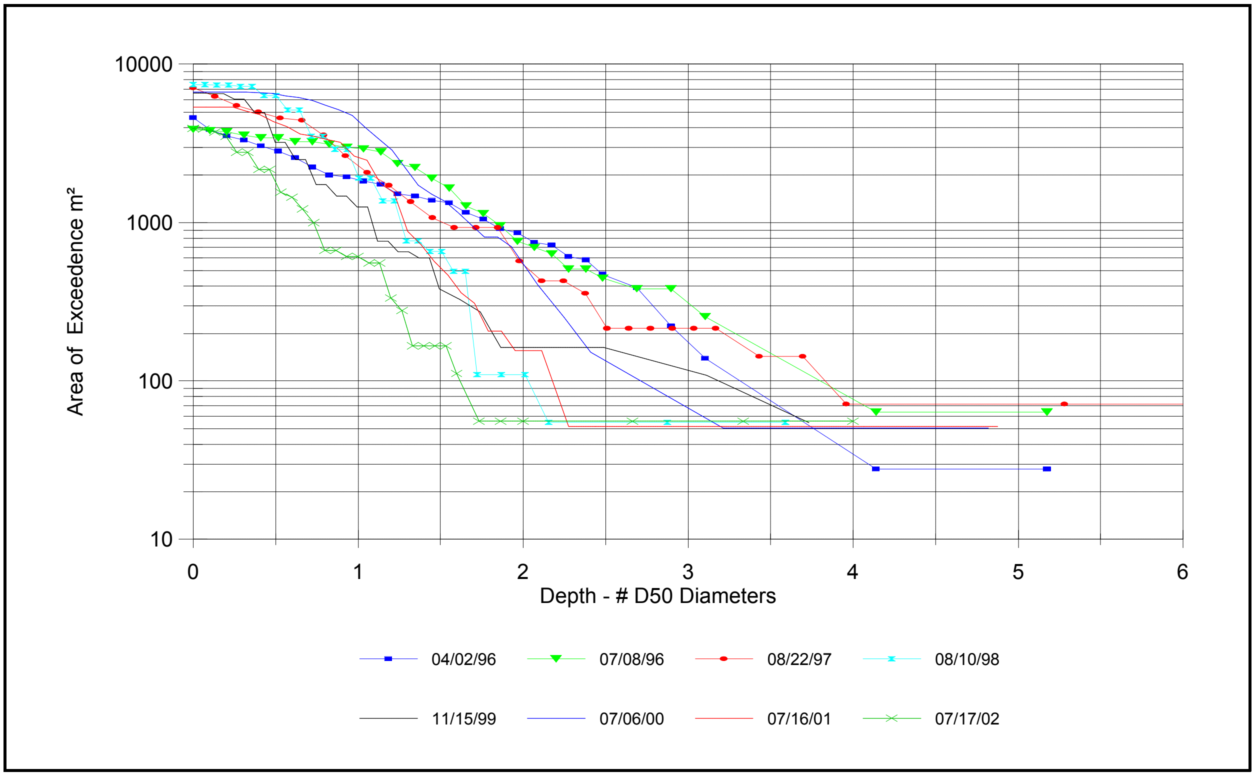

Figure 3.45. Area of Depth of Open Interstitial Space Exceedence for 173.7

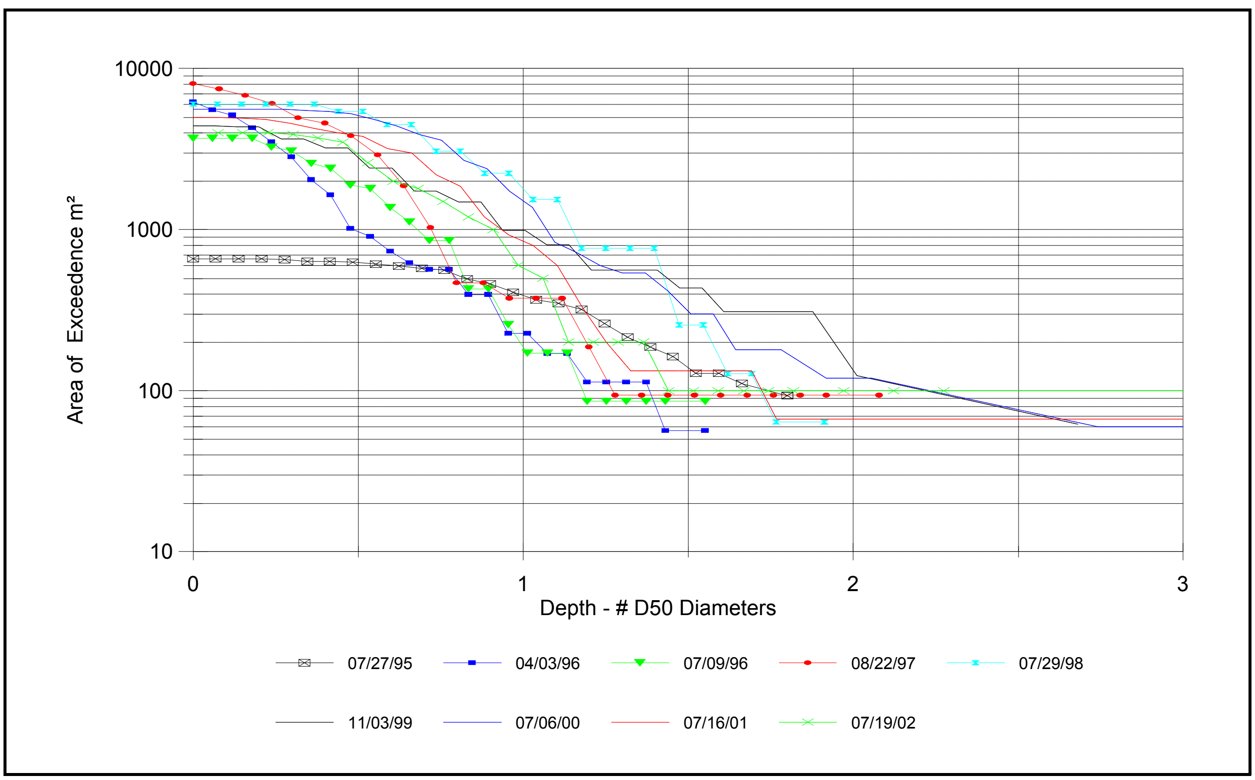

Figure 3.46. Area of Depth of Open Interstitial Space Exceedence for 168.4

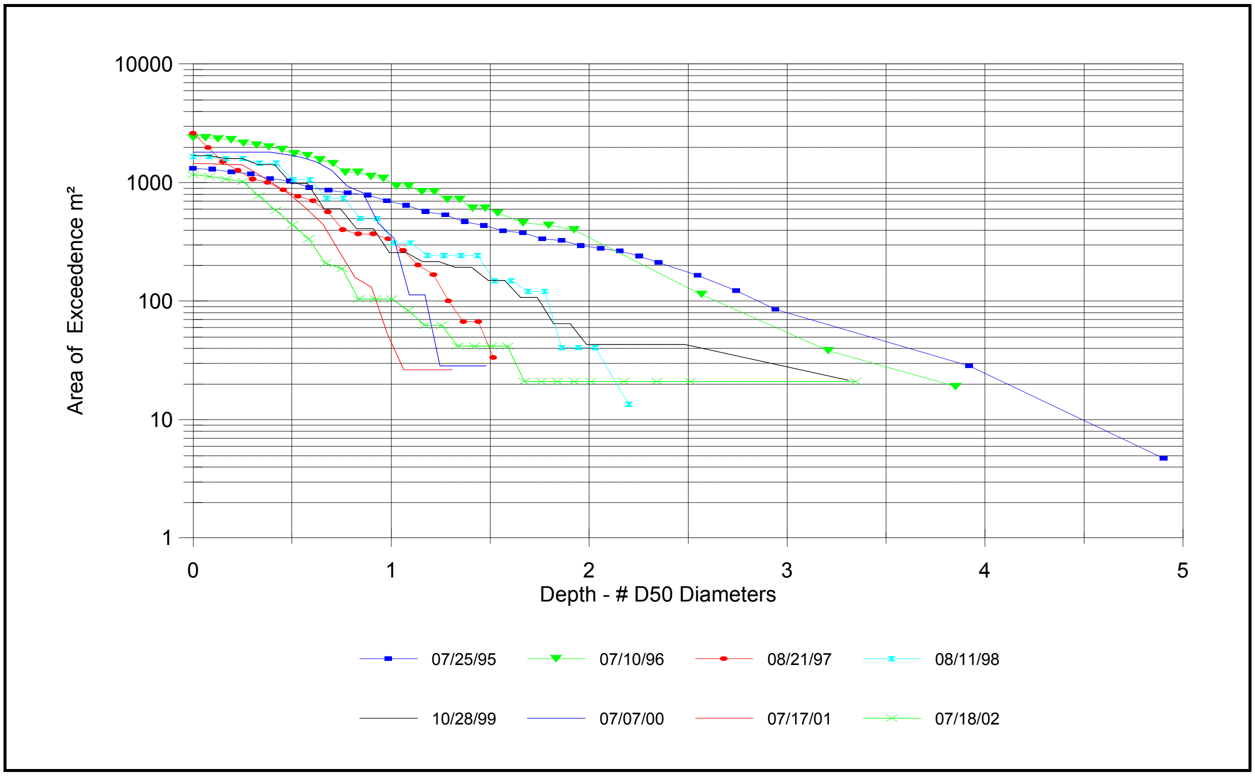

Figure 3.47. Area of Depth of Open Interstitial Space Exceedence for 132 (M-6)

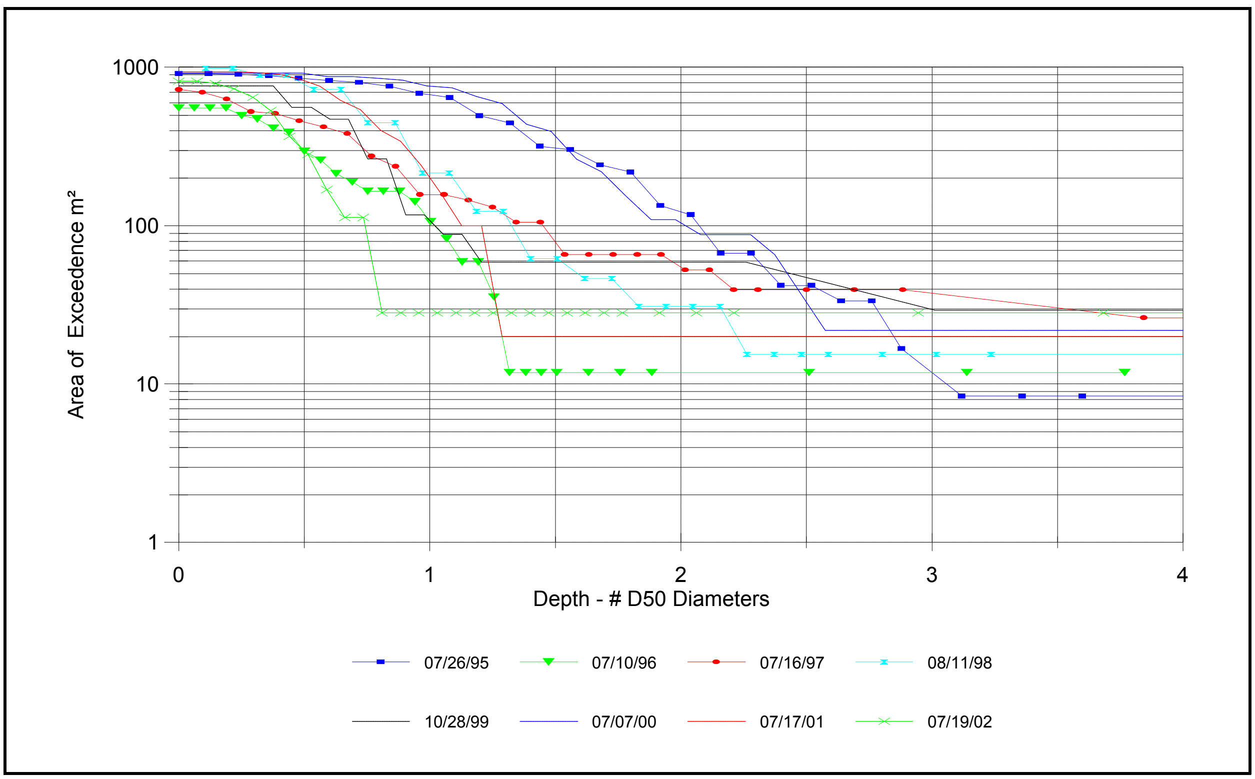

Figure 3.48. Area of Depth of Open Interstitial Space Exceedence for 131 (M-4)

$Gain_0 = Bluff_0 – Animas_{-1} – Archuleta_{-2}$

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 1999 Annual Monitoring Report described an analysis that estimated the average daily turbidity that could be used to estimate storm event days and produce similar results to the flow based algorithm described in the previous paragraph. This analysis determined that 2600 NTU's was a good approximation. The Shiprock turbidity data was used to determine that there were 13-days where the average daily turbidity was greater than or equal to 2600 NTU's between July 25, 2001 and February 28, 2002. The flow based calculation produced 6-days. Five of these days are concurrent or within 1-day. The same analysis is shown for 2002. The results are summarized in Table 3.6.

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
2000	6	8	4
2001	13	6	5
2002**	10	8	6

* Concurrent or with 1-day, **7/25/2002 to 9/19/2002

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 4.1 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 2001 and 2002 StowAway temperature data is shown in Figure 4.1 and 4.2. Maximum, minimum and average plots are shown for Archuleta and Montezuma Creek in Figures 4.3 to 4.6. The new equipment is operating fairly well and is providing a more consistent and reliable record. An exception to this is that the StowAway at Farmington which stopped recording in November 2001. It was tested and restarted in March 2002 with no obvious problems. However, it still was not properly recording temperature and was finally replaced in October 2002.

Table 4.1. Water Temperature Monitoring Locations and Period of Record

Location	RM	Period of Record
Near Navajo Dam	225	7/9/1999 to 4/1/03 (in place)
Archuleta - San Juan at USGS Gage Location	218.6	7/23/92 to 4/1/03 (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 11/4/01, 10/3/02 to 4/1/03 (in place)
Shiprock - San Juan at USGS Gage Location	148.0	7/8/99 to 4/1/03 (in place)
Four Corners - San Juan at USGS Gage Location	119.4	10/7/94 to 3/11/96*, 7/9/99 to 4/1/03 (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 4/1/03 (in place)
Mexican Hat - San Juan near Bluff Gage Location	52.1	7/9/99 to 3/27/02 , 9/18/02 to 4/1/03
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 4/1/03 (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	1991-2000
Animas River @ Farmington	9364500	1958 -1992	1991-2000
San Juan River @ Farmington	9365000	1974 -1991	1991-2000
LaPlata River near Farmington	9367500	1977-1991	1994-2000
San Juan River @ Shiprock	9368000	1958 -1992	1991-2000
Mancos River near Four Corners	9371005		1991-2000
San Juan River @ Four Corners	9371010	1977-1990	1991-2000
San Juan River @ Montezuma Creek	9378610		1991-2000
San Juan River @ Bluff	9379495		1991-2000
San Juan River near Bluff (@ Mex. Hat)	9379500	1974 -1993	1991-2000

Table 4.3. San Juan River Monitoring Program Water Quality Parameters

Quarterly	Detection	Annually	Detection
Arsenic (total & dissolved)	*0.5 : g/L*	Aluminum (total & dissolved)	*0.2 mg/L*
Calcium (dissolved)	*0.2 mg/L*	Barium (total & dissolved)	*20 : g/L*
Copper (total & dissolved)	*0.5 : g/L*	Manganese (total & dissolved)	*30 : g/L*
Lead (total & dissolved)	*40 : g/L*	Nickel (total & dissolved)	*50 : g/L*
Magnesium (dissolved)	*0.2 mg/L*	Potassium (total & dissolved)	*2 mg/L*
Mercury (total & dissolved)	*0.2 : g/L*	Strontium (total & dissolved)	*50 : g/L*
Sodium (dissolved)	*2 mg/L*	Orthophosphate (total & dissolved)	*5 mg/L*
Selenium (total, dissolved, & total recoverable)	*1 : g/L*	Chloride (dissolved)	*10 mg/L*
Zinc (total & dissolved)	*10 : g/L*	Ammonia (dissolved)	*50 : g/L*
Alkalinity (HCO_3)	*2 mg/L*	Nitrate (dissolved)	*20 : g/L*
Hardness	*1 mg/L*	Nitrite (dissolved)	*10 : g/L*
TDS	*10 mg/L*	Silica (total & dissolved)	*1 mg/L*
TSS	*5 mg/L*	Sulfate (dissolved)	*100 mg/L*
Turbidity	*0.1 NTU*		

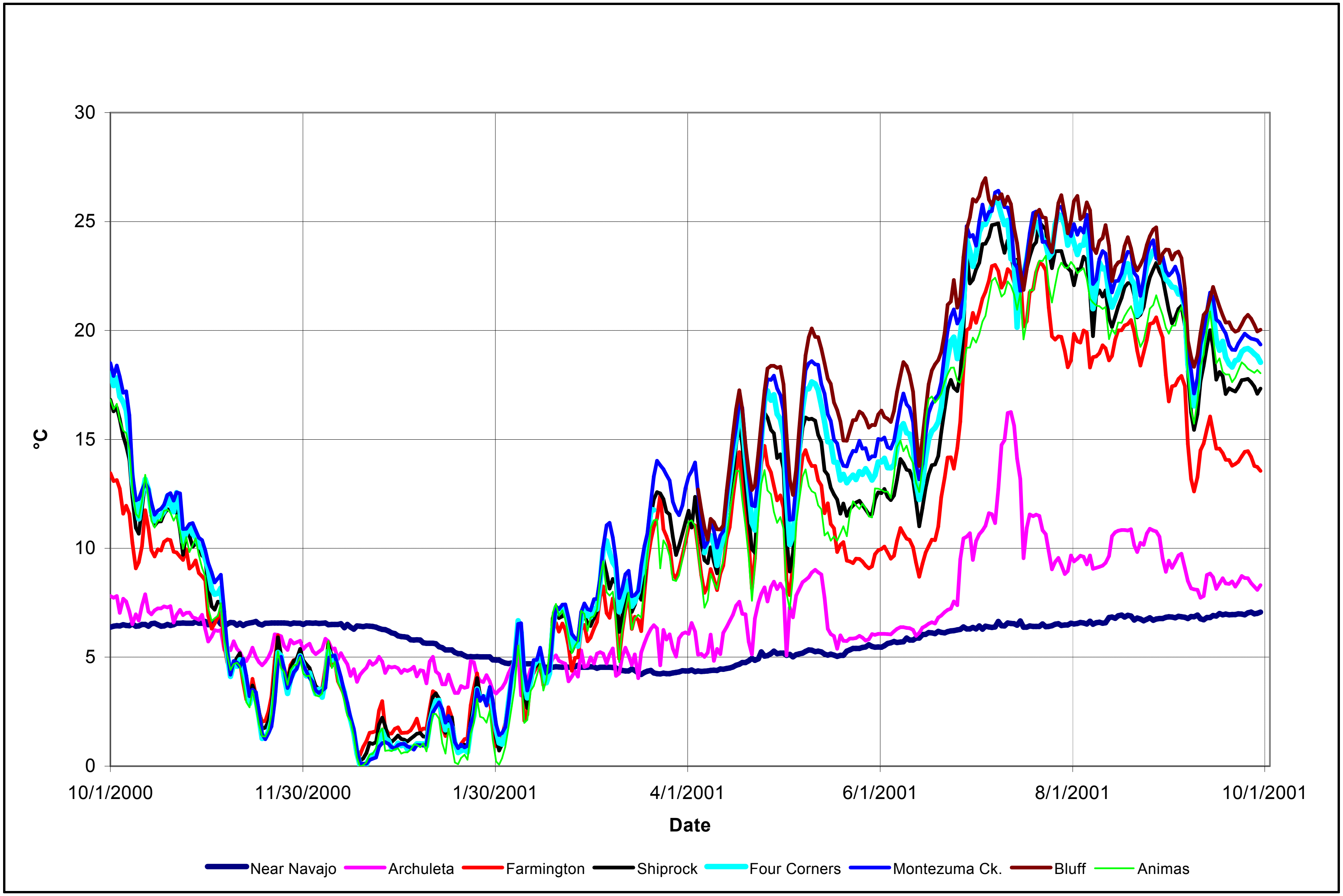

Figure 4.1. San Juan Basin Average Water Temperature Data, 2001

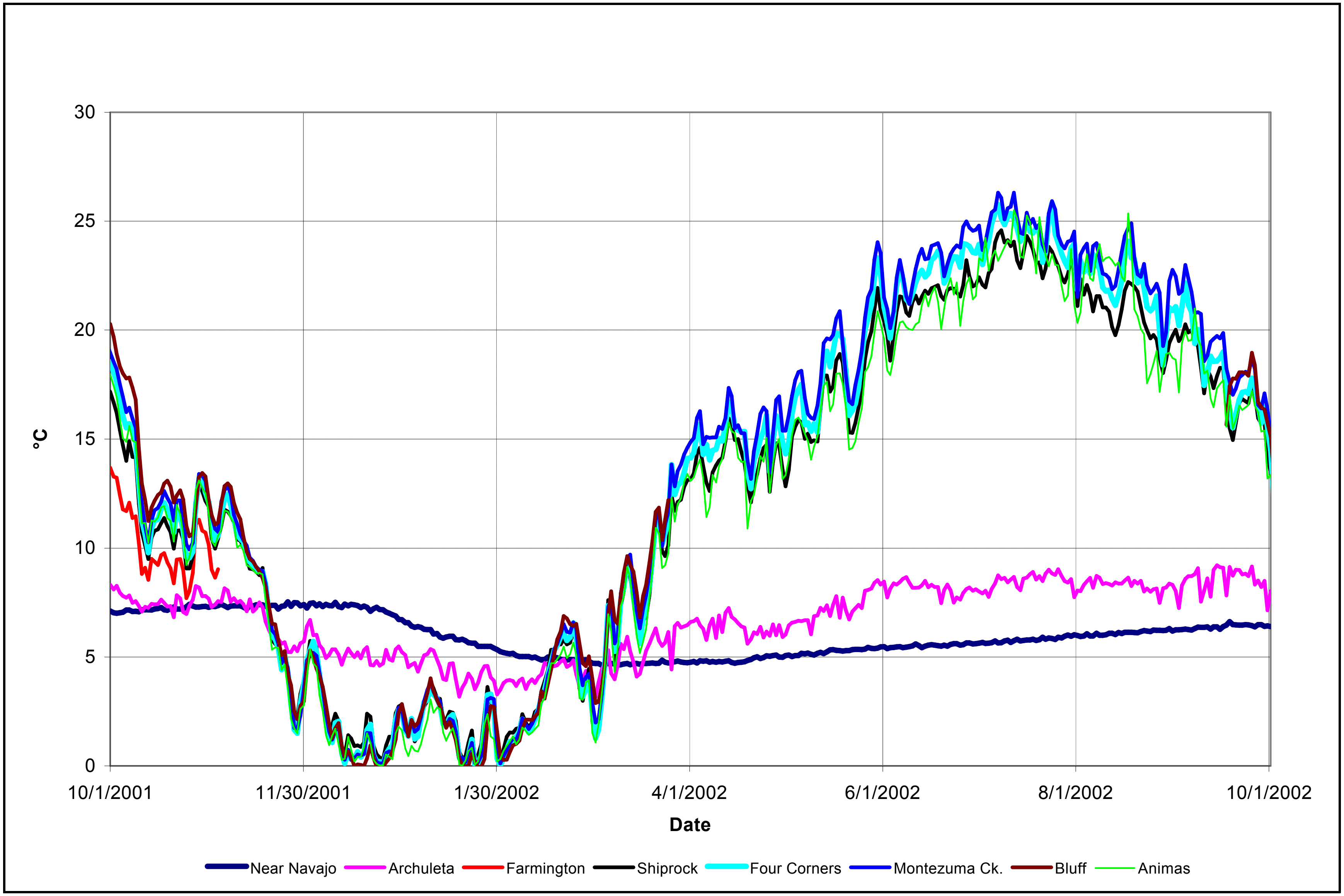

Figure 4.2. San Juan Basin Average Water Temperature Data, 2002

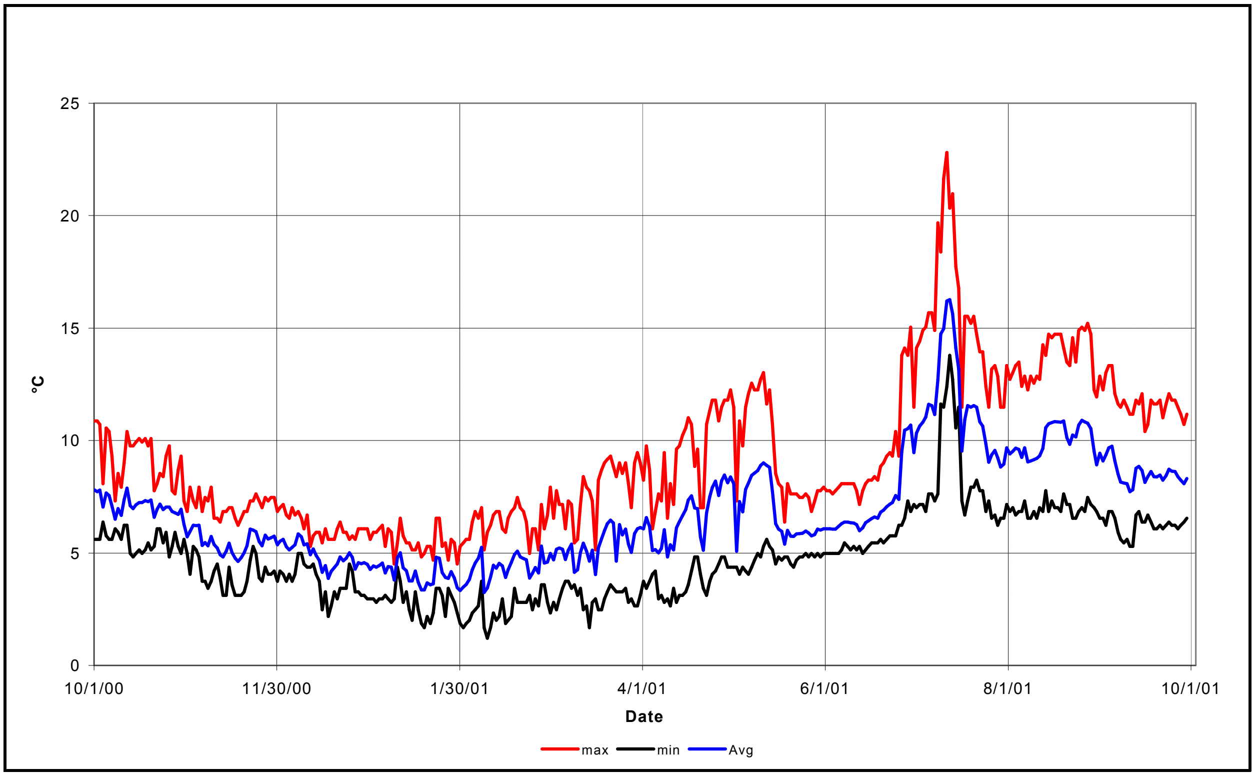

Figure 4.3 Archuleta Maximum, Minimum and Average 2001 Water Temperatures

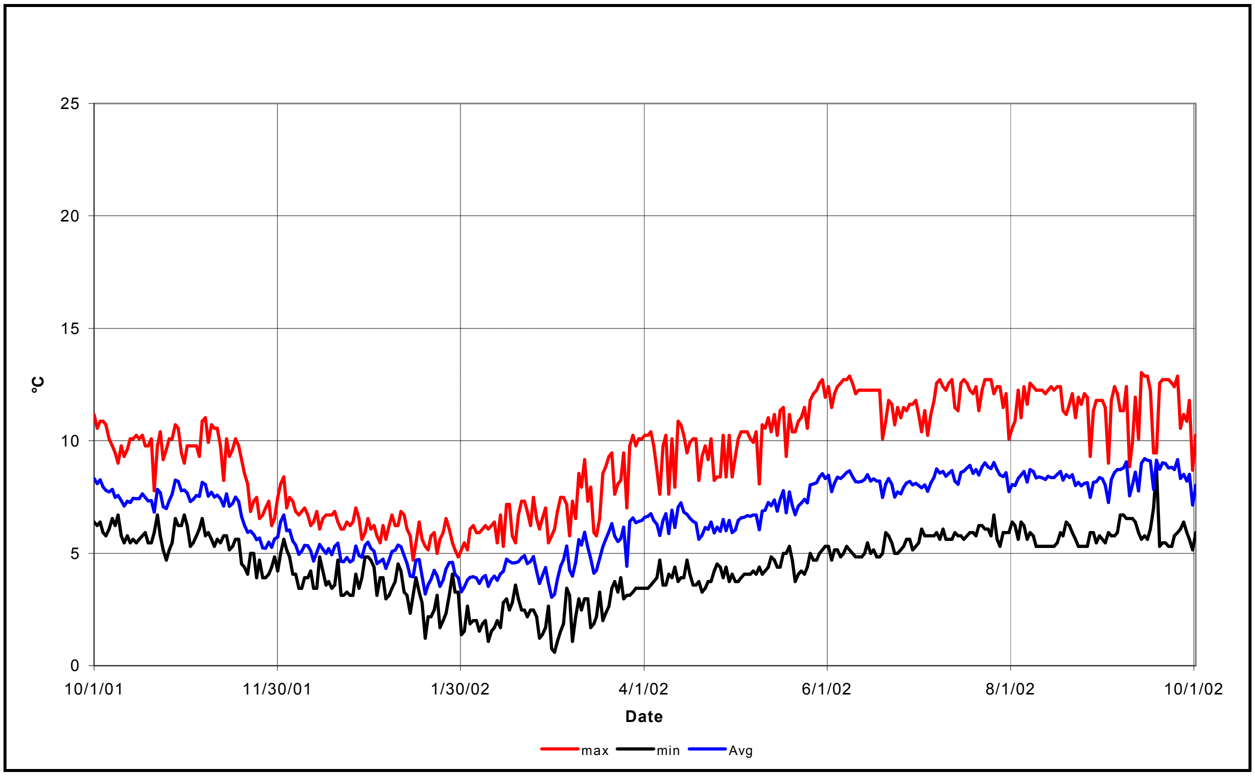

Figure 4.4 Archuleta Maximum, Minimum and Average 2002 Water Temperatures

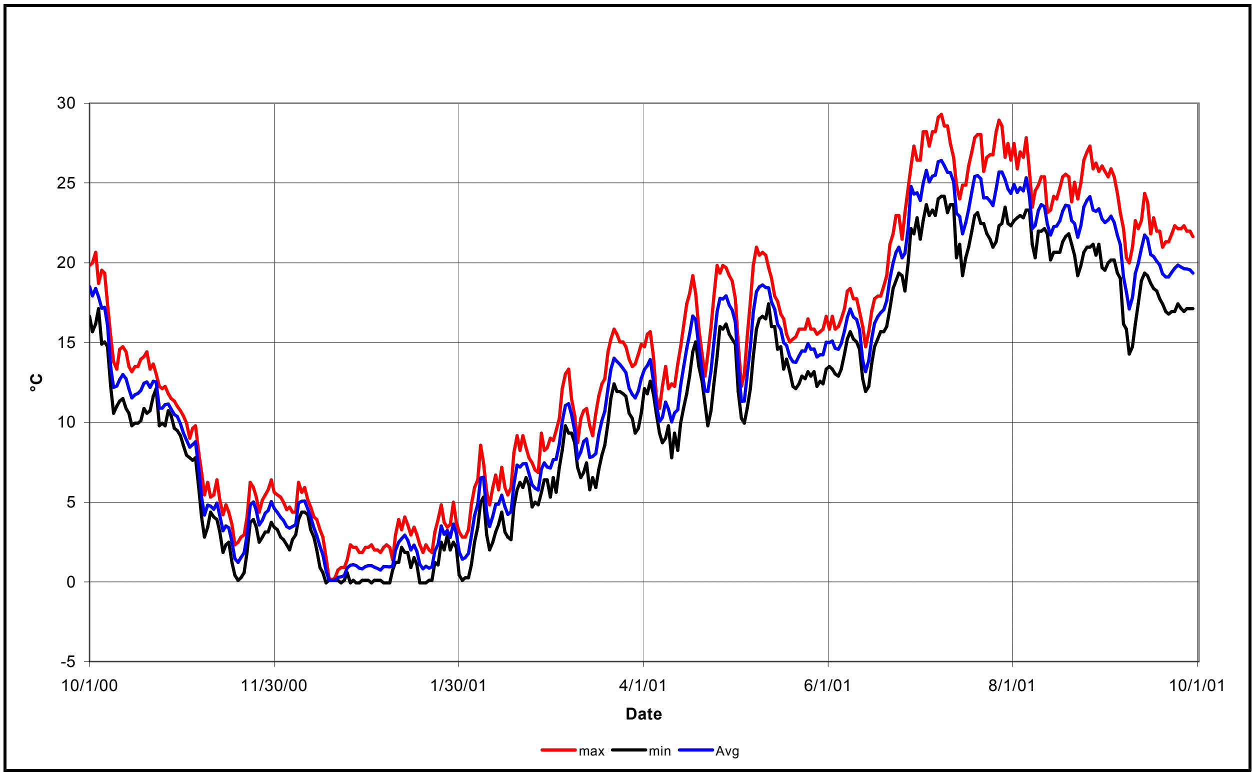

Figure 4.5. Montezuma Creek Maximum, Minimum and Average 2001 Water Temperatures

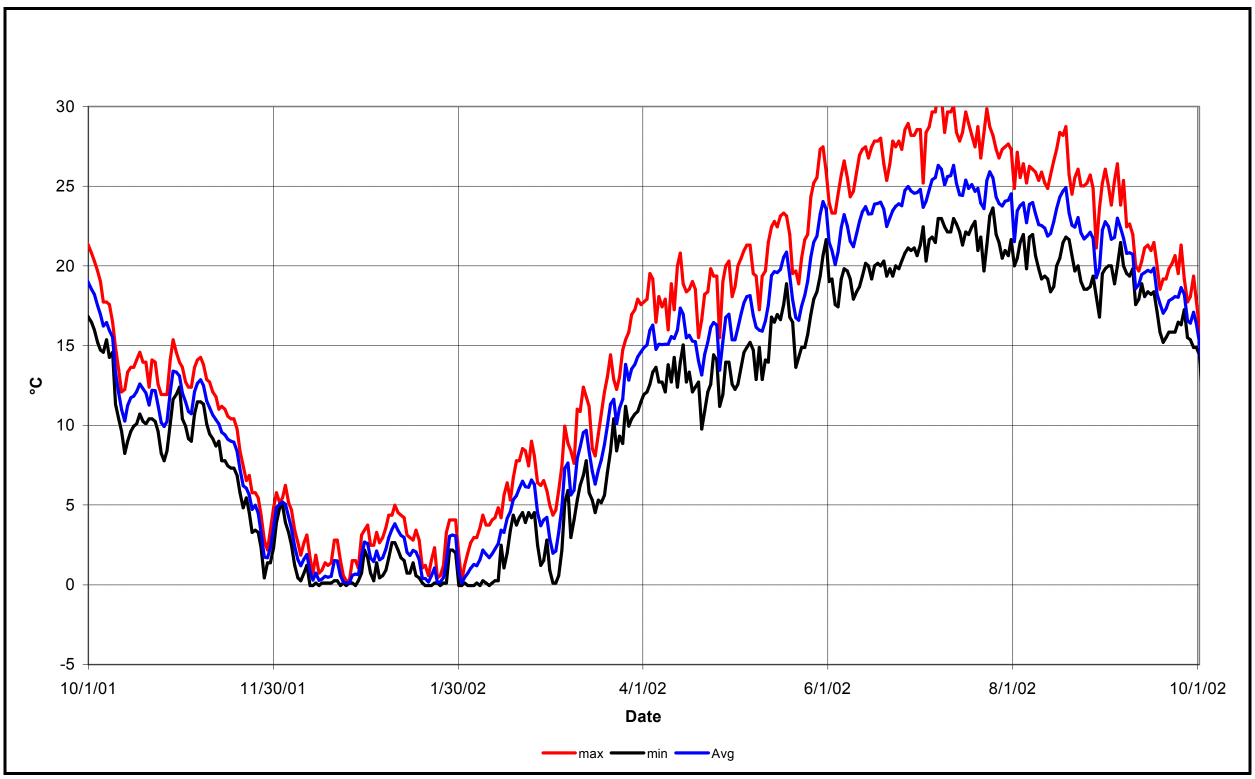

Figure 4.6. Montezuma Creek Maximum, Minimum and Average 2002 Water Temperatures

Water Chemistry

Tables 4.4 through 4.13 summarize the water quality data for the 10 permanent stations, comparing the 1994 -2000 statistics to those for 2001 as well as the 1994-2001 to those for 2002. In each case the minimum, maximum, mean and standard deviation is given for each parameter in Table 4.3. When values fall below detection, they are shown at ½ detection limit.

Table 4.4. Water Chemistry Data for San Juan River at Archuleta Bridge

San Juan River at Archuleta Bridge	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	39	43	99	73.8	9.2	4	79	124	93	20.9
Alkalinity (mg/l)	39	43	99	74.4	9.3	4	79	124	93	20.9
Arsenic dissolved (µg/l)	67	0.3	2.5	1.9	0.8	4	0.5	0.9	0.7	0.2
Arsenic total (µg/l)	67	0.5	642	11.8	78.2	4	0.7	1.3	1	0.3
Calcium dissolved (mg/l)	39	25.1	33.6	29	2.5	4	29.8	33	31.6	1.6
Copper dissolved (µg/l)	39	0.9	21	3.5	3.4	4	1.1	1.6	1.4	0.2
Copper total (µg/l)	39	1	41	6.9	9.5	4	1.2	1.4	1.3	0.1
Hardness ((mg/l)	39	83	112	95.4	8.1	4	98	108	103	4.4
Mercury dissolved (µg/l)	67	0.1	0.5	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	67	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	39	4.9	6.9	5.6	0.5	4	5.6	6.2	5.9	0.3
Sodium dissolved (mg/l)	16	10.7	15.3	12.6	1.1	4	13.5	14.4	13.9	0.4
Lead dissolved (µg/l)	67	0.1	5.7	0.6	0.8	4	0.1	0.1	0.1	0
Lead total (µg/l)	67	0.1	19.2	1.3	2.5	4	0.1	0.3	0.2	0.1
Selenium dissolved (µg/l)	67	0.5	0.5	0.5	0	4	0.5	0.5	0.5	0
Selenium total (µg/l)	67	0.5	3	0.5	0.3	4	0.5	1	0.6	0.3
Selenium total recoverable (µg/l)	17	0.5	0.5	0.5	0	4	0.5	1	0.6	0.3
Total dissolved solids (mg/l)	37	90	280	156.8	38.8	4	150	170	157.5	9.6
Total suspended solids (mg/l)	66	1	57	8.4	10	4	2	22	8.5	9.4
Turbidity (NTU)	64	0	33	5.4	5.2	4	2	7	4.3	2.2
Zinc dissolved (µg/l)	67	5	70	7.6	8.9	4	5	10	8.8	2.5
Zinc total (µg/l)	67	5	360	25.2	51.8	4	5	30	13.8	11.1
Temperature (°C)	67	3.4	19.9	8.1	2.8	4	4.6	11.5	7.1	3.1
pH	67	7.2	9.1	8.2	0.4	4	7.5	8.7	8.2	0.5
Conductance (µmhos/cm)	67	199	1212	251.8	121.4	4	244	256	247.3	5.9
Redox Potential (mv)	67	223	527	380.2	71.5	4	358	483	432.3	54.8
Oxygen dissolved (mg/l)	66	5.4	14.3	10.5	1.5	4	9.8	11	10.6	0.6

Table 4.5. Water Chemistry Data for Animas River at Farmington

Animas River at Farmington	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	38	43	177	120.2	35.8	4	66	164	125.3	42.8
Alkalinity (mg/l)	38	43	177	120.8	35.8	4	66	164	128.3	43.1
Arsenic dissolved (µg/l)	67	0.3	2.5	1.8	0.8	4	0.3	0.7	0.4	0.2
Arsenic total (µg/l)	67	0.5	13	2.5	1.8	4	0.8	2.3	1.3	0.7
Calcium dissolved (mg/l)	38	27.6	103	70.5	23.2	4	29.9	102	73.7	31.5
Copper dissolved (µg/l)	38	1	9	3.7	2.1	4	1.2	3.9	2.1	1.2
Copper total (µg/l)	38	1.5	68	13.8	14.2	4	2.3	12.8	6.3	4.7
Hardness ((mg/l)	38	85	319	222.9	74.9	4	92	325	234	102.8
Mercury dissolved (µg/l)	67	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	67	0.1	0.9	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	38	3.8	19.2	11.4	4.2	4	4.1	17	12.1	5.9
Sodium dissolved (mg/l)	15	6	40.9	25.9	11.9	4	4.9	45.2	26.4	16.6
Lead dissolved (µg/l)	67	0.1	4.5	0.5	0.6	4	0.1	1.5	0.5	0.7
Lead total (µg/l)	67	0.5	80	14.3	19	4	2	27.5	9.6	12
Selenium dissolved (µg/l)	67	0.5	3	0.6	0.3	4	0.5	0.5	0.5	0
Selenium total (µg/l)	67	0.5	4	0.6	0.5	4	0.5	0.5	0.5	0
Selenium total recoverable (µg/l)	17	0.5	1	0.5	0.1	4	0.5	1	0.6	0.3
Total dissolved solids (mg/l)	37	110	520	328.1	124.5	4	140	490	352.5	152.8
Total suspended solids (mg/l)	66	1	2,170	139.3	312.4	4	32	100	67	27.8
Turbidity (NTU)	64	0	1,240	84.6	219.5	4	11	120	50	48
Zinc dissolved (µg/l)	67	5	40	10.2	7.7	4	10	30	15	10
Zinc total (µg/l)	67	5	430	87.8	86.5	4	20	120	67.5	49.9
Temperature (°C)	67	-0.2	27.3	11.6	6.9	4	4.2	22	10.9	7.8
pH	67	7.5	8.9	8.2	0.3	4	7.3	8.8	8.1	0.6
Conductance (µmhos/cm)	67	196	969	550.5	182.2	4	200	771	548.5	251.3
Redox Potential (mv)	67	253	545	397.7	64.9	4	389	518	437.3	56.3
Oxygen dissolved (mg/l)	66	3.7	13.2	9.5	2.1	4	7.8	10.7	9.6	1.3

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

San Juan River at Farmington Bridge	1994-1999					2000				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	37	49	143	102.2	21.4	4	76	132	110.5	24.2
Alkalinity (mg/l)	37	49	143	102.5	21.1	4	76	132	110.5	24.2
Arsenic dissolved (µg/l)	67	0.3	5	2	0.9	4	0.6	0.7	0.6	0.1
Arsenic total (µg/l)	67	0.5	7	2.5	1.2	4	1.3	1.9	1.6	0.3
Calcium dissolved (mg/l)	37	28.8	83.5	53.5	14.3	4	31.2	71.7	58.1	18.8
Copper dissolved (µg/l)	37	0.8	10	3.7	2.4	4	1.8	5.1	3.1	1.5
Copper total (µg/l)	37	2.5	50	15.6	12.2	4	5.9	106	35.4	47.4
Hardness ((mg/l)	37	91	265	168.9	45.2	4	99	227	182.8	58.8
Mercury dissolved (µg/l)	67	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	67	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	37	4.6	13.9	8.6	2.4	4	5.1	11.5	9.1	2.9
Sodium dissolved (mg/l)	14	12.2	46.7	31.5	10.1	4	11	38.8	28.1	12.2
Lead dissolved (µg/l)	67	0.1	4	0.5	0.6	4	0.1	0.6	0.4	0.2
Lead total (µg/l)	67	0.5	105	12	16.3	4	4.1	32.8	16.2	12.9
Selenium dissolved (µg/l)	67	0.5	2	0.5	0.2	4	0.5	0.5	0.5	0
Selenium total (µg/l)	67	0.5	2.5	0.6	0.3	4	0.5	0.5	0.5	0
Selenium total recoverable (µg/l)	17	0.5	0.5	0.5	0	4	0.5	0.5	0.5	0
Total dissolved solids (mg/l)	37	140	450	287.3	81.5	4	90	360	240	135.9
Total suspended solids (mg/l)	66	2	2,660	245.3	390.7	4	76	200	158	55.7
Turbidity (NTU)	64	2	7,400	215.9	945.7	4	33	171	87.8	59.9
Zinc dissolved (µg/l)	67	5	30	7.9	5.9	4	10	30	17.5	9.6
Zinc total (µg/l)	67	5	320	63.8	57.5	4	30	120	67.5	41.1
Temperature (°C)	67	-0.3	24.3	10.6	6.3	4	2.4	20.8	9.8	7.9
pH	67	7.2	8.8	8.1	0.3	4	7.5	8.6	8.1	0.5
Conductance (µmhos/cm)	67	203	704	437.9	121.4	4	222	540	390	143.9
Redox Potential (mv)	67	252	535	403.3	59.7	4	381	496	436.3	47.2
Oxygen dissolved (mg/l)	66	0	12.5	8.9	2.2	3	7.8	9.8	9	1

Table 4.7. Water Chemistry Data for La Plata River near Farmington

La Plata River near Farmington	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	27	111	370	232.8	53.2	2	231	269	250	26.9
Alkalinity (mg/l)	27	111	370	232.9	53.1	2	231	269	250	26.9
Arsenic dissolved (µg/l)	56	0	5	2.3	0.9	2	0.5	1.5	1	0.7
Arsenic total (µg/l)	56	0.5	29	4.1	5.2	2	4	4	4	0
Calcium dissolved (mg/l)	27	65.4	507	187	97.3	2	164	227	195.5	44.5
Copper dissolved (µg/l)	27	1	20	8.6	5.6	2	3	6	4.5	2.1
Copper total (µg/l)	27	1.5	136	21.7	27.5	2	5	17	11	8.5
Hardness ((mg/l)	27	279	2,120	826.8	417.3	2	763	955	859	135.8
Mercury dissolved (µg/l)	56	0.1	0.1	0.1	0	2	0.1	0.1	0.1	0
Mercury total (µg/l)	56	0.1	1.7	0.1	0.3	2	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	27	18.1	208	87.3	44	2	85.9	94.2	90.1	5.9
Sodium dissolved (mg/l)	7	56.7	546	249.8	188.9	2	94.1	262	178.1	118.7
Lead dissolved (µg/l)	56	0.1	1	0.4	0.2	2	0.1	0.1	0.1	0
Lead total (µg/l)	56	0.3	408	16.2	57.3	2	1.6	10.1	5.9	6
Selenium dissolved (µg/l)	56	0.5	4	1.2	0.9	2	0.5	0.5	0.5	0
Selenium total (µg/l)	56	0.5	10	1.5	1.7	2	0.5	1	0.8	0.4
Selenium total recoverable (µg/l)	11	0.5	2	1.1	0.6	2	1	2	1.5	0.7
Total dissolved solids (mg/l)	27	80	3,780	1,460.7	857.9	2	1,260	2,190	1,725	657.6
Total suspended solids (mg/l)	56	2	65,600	1,913.2	9,164.8	2	104	678	391	405.9
Turbidity (NTU)	56	0	18,900	534.1	2,547	2	100	520	310	297
Zinc dissolved (µg/l)	56	5	20	6.8	4.1	2	5	10	7.5	3.5
Zinc total (µg/l)	56	5	1,850	79.5	259.3	2	10	70	40	42.4
Temperature (°C)	56	-0.3	32.2	13	9	2	7.4	23.9	15.6	11.7
pH	56	7	8.5	8.1	0.3	2	7.8	8.3	8	0.4
Conductance (µmhos/cm)	56	274	4,190	1,743.3	789.6	2	1,425	2,590	2,007.5	823.8
Redox Potential (mv)	56	239	498	391.1	61.4	2	438	442	440	2.8
Oxygen dissolved (mg/l)	55	3.1	12.8	8.8	2.2	2	7.1	10.1	8.6	2.2

Table 4.8. Water Chemistry Data for San Juan River at Shiprock Bridge

San Juan River at Shiprock Bridge 1994-2000						2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	71	17	165	108.4	28.5	8	78	141	119.1	26.2
Alkalinity (mg/l)	71	17	166	109.4	28.9	8	78	141	119.5	26.5
Arsenic dissolved (µg/l)	130	0.5	5	2	0.8	8	0.6	0.8	0.7	0.1
Arsenic total (µg/l)	129	0.5	44	4	5.6	8	0.3	3.3	1.7	1.1
Calcium dissolved (mg/l)	71	30.8	96.3	59.9	16.2	8	31.9	79	64.6	20.4
Copper dissolved (µg/l)	71	1	18	4.4	3.1	8	1.3	2	1.5	0.3
Copper total (µg/l)	71	2.5	155	26.9	30.3	8	2.8	15.9	7.7	5.2
Hardness ((mg/l)	71	98	317	195.1	54.9	8	102	255	208.5	66.3
Mercury dissolved (µg/l)	130	0.1	0.3	0.1	0	8	0.1	0.1	0.1	0
Mercury total (µg/l)	130	0.1	1.6	0.1	0.2	8	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	71	5.2	18.6	11.1	3.7	8	5.3	14.2	11.4	3.7
Sodium dissolved (mg/l)	24	13	58.5	37.9	13.7	8	11.4	47	35.5	15.3
Lead dissolved (µg/l)	130	0.1	18	0.9	2.3	8	0.1	0.9	0.3	0.4
Lead total (µg/l)	129	0.5	323	25.8	43.1	8	1.6	28.9	11.4	11.6
Selenium dissolved (µg/l)	130	0.5	1	0.5	0.1	8	0.5	1	0.6	0.2
Selenium total (µg/l)	130	0.5	3	0.7	0.4	8	0.5	7	1.3	2.3
Selenium total recoverable (µg/l)	34	0.5	2	0.6	0.3	8	0.5	0.5	0.5	0
Total dissolved solids (mg/l)	70	130	550	339.3	103.3	8	170	440	337.5	114.9
Total suspended solids (mg/l)	128	2	17,700	999.3	2,917.5	8	34	356	161.3	113.4
Turbidity (NTU)	126	3	11,100	594.3	1,766.2	8	29	190	102.1	65
Zinc dissolved (µg/l)	130	5	50	7.8	6.4	8	5	20	10	4.6
Zinc total (µg/l)	130	5	1,380	118.9	218.8	8	20	120	53.8	40.7
Temperature (°C)	130	0.1	26.1	12.3	6.9	8	3.7	22.1	11.4	7.3
pH	130	7.7	9	8.3	0.3	8	7.5	8.5	8.2	0.4
Conductance (µmhos/cm)	130	244	826	516.9	147.7	8	247	645	529.8	176.3
Redox Potential (mv)	130	250	544	409.6	63	8	431	501	463.3	26.8
Oxygen dissolved (mg/l)	128	3.6	13.9	9.6	2.3	8	8.2	11.6	10	1.4

Table 4.9. Water Chemistry Data for Mancos River near Four Corners

Mancos River near Four Corners	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	32	92	360	173.3	55.4	4	125	211	167	41.5
Alkalinity (mg/l)	32	92	360	176	54.9	4	125	211	169.3	43.5
Arsenic dissolved (µg/l)	55	0.5	5	2.1	0.9	4	0.7	1	0.9	0.1
Arsenic total (µg/l)	55	1	37	5.3	7.4	4	0.7	9	4.5	4.3
Calcium dissolved (mg/l)	32	43.6	225	138.8	53.5	4	70.6	214	157.7	62.1
Copper dissolved (µg/l)	32	1.5	20	8.6	5.6	4	2.6	4.2	3.6	0.7
Copper total (µg/l)	32	1.5	198	31.6	42.4	4	3.6	42	17.1	17.6
Hardness ((mg/l)	32	165	1,110	665.1	292.3	4	315	1,050	750.8	334.1
Mercury dissolved (µg/l)	55	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	55	0.1	2	0.1	0.3	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	32	13.7	145	77.3	40.1	4	33.7	125	86.7	45
Sodium dissolved (mg/l)	9	22	206	123.6	66.6	4	61.2	160	113.4	43.3
Lead dissolved (µg/l)	55	0.1	1	0.4	0.2	4	0.1	0.2	0.1	0.1
Lead total (µg/l)	55	0.2	78.6	10.9	19.3	4	1	19.4	8.6	8.8
Selenium dissolved (µg/l)	55	0.5	30	7.9	6.2	4	2	11	8	4.1
Selenium total (µg/l)	55	0.5	30	7.8	5.8	4	6	11	8.8	2.2
Selenium total recoverable (µg/l)	16	2	17	9.1	5.1	4	8	11	9.5	1.3
Total dissolved solids (mg/l)	31	240	2,100	1,219.7	563.6	4	600	1,770	1,337.5	554.8
Total suspended solids (mg/l)	54	2	33,500	1,184.1	4,626.5	4	24	1,170	482	544.9
Turbidity (NTU)	54	3	18,500	614	2,525.1	4	46	526	286	246.9
Zinc dissolved (µg/l)	55	5	40	7.3	6.1	4	5	5	5	0
Zinc total (µg/l)	55	5	2,300	95.5	311.4	4	10	80	42.5	28.7
Temperature (°C)	55	-0.3	32.3	12.3	8.5	4	0.4	20.4	10.9	9.2
pH	55	7.8	8.8	8.2	0.2	4	7.7	8.6	8.2	0.5
Conductance (µmhos/cm)	55	381	2,450	1,539.3	593.5	4	847	2,140	1,630.3	600.7
Redox Potential (mv)	55	4	548	401.5	84.3	4	433	530	462.5	45.4
Oxygen dissolved (mg/l)	54	4.8	12.7	9.4	2	4	8.2	12.5	10.2	1.8

Table 4.10. Water Chemistry Data for San Juan River at Four Corners Bridge

San Juan River at Four Corners Bridge	1994-2000					2000				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	38	67	165	113.8	22.6	4	80	140	120	27.1
Alkalinity (mg/l)	38	67	165	114.4	22.9	4	80	146	121.5	28.7
Arsenic dissolved (µg/l)	67	0.5	2.5	1.9	0.8	4	0.6	17.2	4.8	8.3
Arsenic total (µg/l)	67	0.5	19	3.5	3.2	4	0.7	2.3	1.8	0.8
Calcium dissolved (mg/l)	38	31.7	99.9	64.4	17.9	4	33.2	83.6	67.1	22.9
Copper dissolved (µg/l)	38	1	11	4.7	2.6	4	1.4	16.2	5.2	7.3
Copper total (µg/l)	38	2.5	130	24.8	25.6	4	3.7	13	8.8	4.1
Hardness ((mg/l)	38	103	340	218	66.1	4	107	279	222.5	78
Mercury dissolved (µg/l)	67	0.1	0.3	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	67	0.1	0.8	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	38	5.5	23.8	13.9	5.4	4	5.8	17	13.3	5.1
Sodium dissolved (mg/l)	15	14	60.1	42.7	14.6	4	12.6	59	42.6	20.8
Lead dissolved (µg/l)	67	0.1	7	0.6	0.9	4	0.1	14.4	3.8	7.1
Lead total (µg/l)	67	0.5	271	22	44.1	4	1.5	18.8	8.8	7.4
Selenium dissolved (µg/l)	67	0.5	2	0.8	0.5	4	0.5	18	5.3	8.5
Selenium total (µg/l)	67	0.5	4	1	0.7	4	0.5	1	0.6	0.3
Selenium total recoverable (µg/l)	17	0.5	2	0.9	0.4	4	0.5	1	0.6	0.3
Total dissolved solids (mg/l)	37	110	640	383.8	129.5	4	180	490	337.5	146.4
Total suspended solids (mg/l)	67	2	11,700	703.9	1,912.3	4	42	488	266.5	183.1
Turbidity (NTU)	65	2	60,500	1,318	7,560.3	4	22	498	198.8	207.1
Zinc dissolved (µg/l)	67	5	30	7	4.8	4	5	30	13.8	11.1
Zinc total (µg/l)	67	5	920	83.5	137.2	4	20	70	45	23.8
Temperature (°C)	67	0	26.3	12.3	7.4	4	0.6	21.4	10.5	8.7
pH	67	7.5	8.8	8.2	0.3	4	7.6	8.5	8.1	0.4
Conductance (µmhos/cm)	67	251	870	576.2	173.9	4	266	741	585	215.8
Redox Potential (mv)	67	256	592	410.6	63.4	4	428	547	469.8	53.8
Oxygen dissolved (mg/l)	66	4.3	12.7	9.3	2.1	4	7.9	10.5	9.4	1.2

Table 4.11. Water Chemistry Data for San Juan River at Montezuma Creek Bridge

San Juan River at Montezuma Creek Bridge	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	35	59	192	122.9	28.7	4	79	154	127	33.7
Alkalinity (mg/l)	35	59	192	123.5	29	4	79	156	127.5	34.2
Arsenic dissolved (µg/l)	63	0.5	2.5	1.9	0.8	4	0.7	1.4	1	0.3
Arsenic total (µg/l)	63	0.5	21	3.4	3.5	4	1.2	4.8	3	1.5
Calcium dissolved (mg/l)	35	33.9	132	73.1	23.7	4	33.9	90.7	75.6	27.8
Copper dissolved (µg/l)	35	1.5	15	4.8	3.3	4	1.6	2	1.8	0.2
Copper total (µg/l)	35	1.5	120	23.5	27.3	4	3.3	22	14.5	8.3
Hardness ((mg/l)	35	111	465	264.2	94.8	4	110	322	265.8	103.9
Mercury dissolved (µg/l)	63	0.1	0.2	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	63	0.1	0.8	0.1	0.1	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	35	6.5	40.5	19.9	9	4	6.2	23.1	18.7	8.3
Sodium dissolved (mg/l)	11	16	196	54.9	49.3	4	12.8	67.7	49	24.6
Lead dissolved (µg/l)	63	0.1	4	0.4	0.5	4	0.1	0.7	0.3	0.3
Lead total (µg/l)	63	0.5	129	17.2	26	4	1.4	22.4	13.2	8.7
Selenium dissolved (µg/l)	63	0.5	4	0.9	0.6	4	0.5	1	0.6	0.3
Selenium total (µg/l)	63	0.5	6	1.1	0.9	4	0.5	2	0.9	0.8
Selenium total recoverable (µg/l)	17	0.5	2	0.8	0.4	4	1	2	1.3	0.5
Total dissolved solids (mg/l)	33	170	800	44.8	164.7	4	180	570	465	190.2
Total suspended solids (mg/l)	62	2	9,100	668.9	1,489.9	4	44	760	468	354
Turbidity (NTU)	62	3	6,900	407.9	1,068.6	4	29	796	346	338.5
Zinc dissolved (µg/l)	63	5	60	7.7	7.9	4	5	20	11.3	6.3
Zinc total (µg/l)	63	5	540	80.2	106.9	4	10	90	65	37
Temperature (°C)	63	-0.2	27.8	12.7	7.5	4	1.2	19.9	10	8.1
pH	63	7.7	8.7	8.2	0.2	4	7.6	8.5	8.1	0.4
Conductance (µmhos/cm)	63	277	1,160	667	216.5	4	274	831	673.8	267.1
Redox Potential (mv)	63	250	516	404.3	63.4	4	443	520	465.3	36.7
Oxygen dissolved (mg/l)	62	5.1	12.6	9.1	2	4	7.9	10.6	9.5	1.2

Table 4.12. Water Chemistry Data for San Juan River at Bluff Bridge

San Juan River at Bluff Bridge	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	73	47	175	122.9	29.1	8	80	150	126.3	29.7
Alkalinity (mg/l)	73	47	175.	123	29.2	8	80	155	127.5	30.9
Arsenic dissolved (µg/l)	130	0.5	2.5	1.9	0.7	8	0.7	1.2	0.9	0.2
Arsenic total (µg/l)	129	0.5	20	4	4.3	8	0.9	4.5	2.6	1.4
Calcium dissolved (mg/l)	73	32.3	121	73.4	20.9	8	33.4	90.7	74	25.2
Copper dissolved (µg/l)	73	1	13	5.4	3.2	8	1.6	2.2	1.9	0.3
Copper total (µg/l)	73	1.5	200	29.8	35	8	3.4	15.8	9.5	4.8
Hardness ((mg/l)	73	106	507	267.1	88.1	8	109	323	262	94.7
Mercury dissolved (µg/l)	130	0.1	0.5	0.1	0	8	0.1	0.1	0.1	0
Mercury total (µg/l)	130	0.1	0.7	0.1	0.1	8	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	73	6.2	49.8	20.5	9.1	8	6.2	23.7	18.8	7.8
Sodium dissolved (mg/l)	26	18	83	48.5	19.6	8	12.6	59.7	44.5	20
Lead dissolved (µg/l)	130	0.1	4	0.6	0.7	8	0.1	0.8	0.2	0.3
Lead total (µg/l)	129	0.5	144	21.2	31.4	8	1.5	26.3	10.5	10
Selenium dissolved (µg/l)	130	0.5	3	0.9	0.6	8	0.5	1	0.7	0.3
Selenium total (µg/l)	130	0.5	8	1.2	1.1	8	0.5	2	0.8	0.5
Selenium total recoverable (µg/l)	34	0.5	1	0.7	0.2	8	0.5	1	0.7	0.3
Total dissolved solids (mg/l)	70	160	990	473.6	170.8	8	180	560	448.8	166.8
Total suspended solids (mg/l)	130	1	9,820	853.3	1,731.3	8	52	534	296.8	191.4
Turbidity (NTU)	128	2	7,900	561.8	1,278.3	8	39	399	223.4	134.7
Zinc dissolved (µg/l)	130	5	40	7.5	5.8	8	5	20	10	4.6
Zinc total (µg/l)	130	5	650	98	135.5	8	10	110	47.5	32.4
Temperature (°C)	130	-0.3	29.4	12.4	7.7	8	1.7	20.3	10.5	7.5
pH	130	7.7	8.6	8.2	0.2	8	7.7	8.5	8.2	0.4
Conductance (µmhos/cm)	130	275	1,145	686.2	220.1	8	270	801	657.5	239.4
Redox Potential (mv)	130	4	535	402.4	81.8	8	430	525	466.5	38.5
Oxygen dissolved (mg/l)	128	5.4	12.7	9.1	2	8	7.5	10.7	9.3	1.4

Table 4.13. Water Chemistry Data for San Juan River at Mexican Hat Bridge

San Juan River at Mexican Hat Bridge	1994-2000					2001				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev	N of cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	38	71	180	129.4	26.3	4	96	147	128.8	24.2
Alkalinity (mg/l)	38	71	180	129.4	26.3	4	96	147	128.8	24.2
Arsenic dissolved (µg/l)	67	0.5	2.5	1.9	0.7	4	0.7	1.3	0.9	0.3
Arsenic total (µg/l)	67	1	50	4.7	6.7	4	1.1	6.2	3	2.3
Calcium dissolved (mg/l)	38	32.7	112	75	22.1	4	34.9	89.2	72.4	25.5
Copper dissolved (µg/l)	38	1.6	13	5	3.2	4	1.5	2	1.8	0.2
Copper total (µg/l)	38	1.5	170	21.3	28.6	4	3.1	20.4	12.6	8
Hardness ((mg/l)	38	108	460	274.6	92.8	4	114	320	253.3	94.5
Mercury dissolved (µg/l)	67	0.1	0.1	0.1	0	4	0.1	0.1	0.1	0
Mercury total (µg/l)	67	0.1	1.1	0.1	0.2	4	0.1	0.1	0.1	0
Magnesium dissolved (mg/l)	38	6.3	43.8	21.2	9.4	4	6.5	23.7	17.6	7.6
Sodium dissolved (mg/l)	15	15	77.5	50.3	8.5	4	12.8	60.4	43.8	21.1
Lead dissolved (µg/l)	67	0.1	1	0.4	0.2	4	0.1	0.6	0.2	0.3
Lead total (µg/l)	67	0.5	327	21.2	49	4	1.3	28.4	13.4	12.2
Selenium dissolved (µg/l)	67	0.5	2	0.9	0.5	4	0.5	1	0.8	0.3
Selenium total (µg/l)	67	0.5	5	1.1	0.9	4	0.5	2	1	0.7
Selenium total recoverable (µg/l)	17	0.5	2.5	1.1	0.7	4	0.5	7	2.5	3.1
Total dissolved solids (mg/l)	37	170	800	480.3	167.6	4	180	570	440	176.4
Total suspended solids (mg/l)	67	1	16,090	1,234.9	2,649.1	4	48	1,140	534	460.3
Turbidity (NTU)	65	1	11,000	784.9	1,879.2	4	46	718	364.5	279.9
Zinc dissolved (µg/l)	67	5	100	8.7	12.7	4	5	10	7.5	2.9
Zinc total (µg/l)	67	5	1,620	103.5	217.3	4	20	110	65	42
Temperature (°C)	67	-0.3	29.8	12.6	7.9	4	3.7	21.7	11.6	8
pH	67	7.7	8.6	8.2	0.2	4	7.7	8.5	8.2	0.4
Conductance (µmhos/cm)	67	273	1,051	693.1	212.2	4	276	818	643.3	247.8
Redox Potential (mv)	67	231	537	403.3	71	4	443	512	462.3	33.3
Oxygen dissolved (mg/l)	66	5.8	12.9	9.1	2	4	7.3	10.3	9.1	1.4

CHAPTER 5: HABITAT STUDIES

HABITAT QUANTITY

Habitat quantity was determined using airborne videography as previously described by Bliesner and Lamarra (1998) and established as part of the Long Range Monitoring Program. Habitat types mapped can be seen in Table 5.1 with habitat categories summarized into seven general categories. In 2001, mapping between RM 2 and RM 180 occurred between September 28 and October 17 . Flows during the 2001 habitat mapping ranged between 550 and 800 cfs. In 2002, mapping occurred between July 28 and August 4. Flows during the 2002 habitat mapping ranged between 325 and 700 cfs.

In 2001 and 2002, the sequence of dominant to subdominant habitats types based upon the amount of surface area between RM 180 to RM 2 was exactly the same. The distributions can be seen in Figures 5.1 and 5.2. Run habitats for both 2001 and 2002 had the most surface area with 83.3 % of the total wetted area (TWA) of the San Juan River in 2001 and 82 % of TWA in 2002. Riffles had the second largest surface area (8.3% in 2001 and 9.0% in 2002), followed by shoals (5.4 % in 2001 and 6.4% in 2002) and slackwaters (2.1 % in 2001 and 1.6% in 2002). Backwaters made up only 0.22 percent of the surface area of habitats in 2001 and 0.17 % of the surface area in 2002.

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
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				

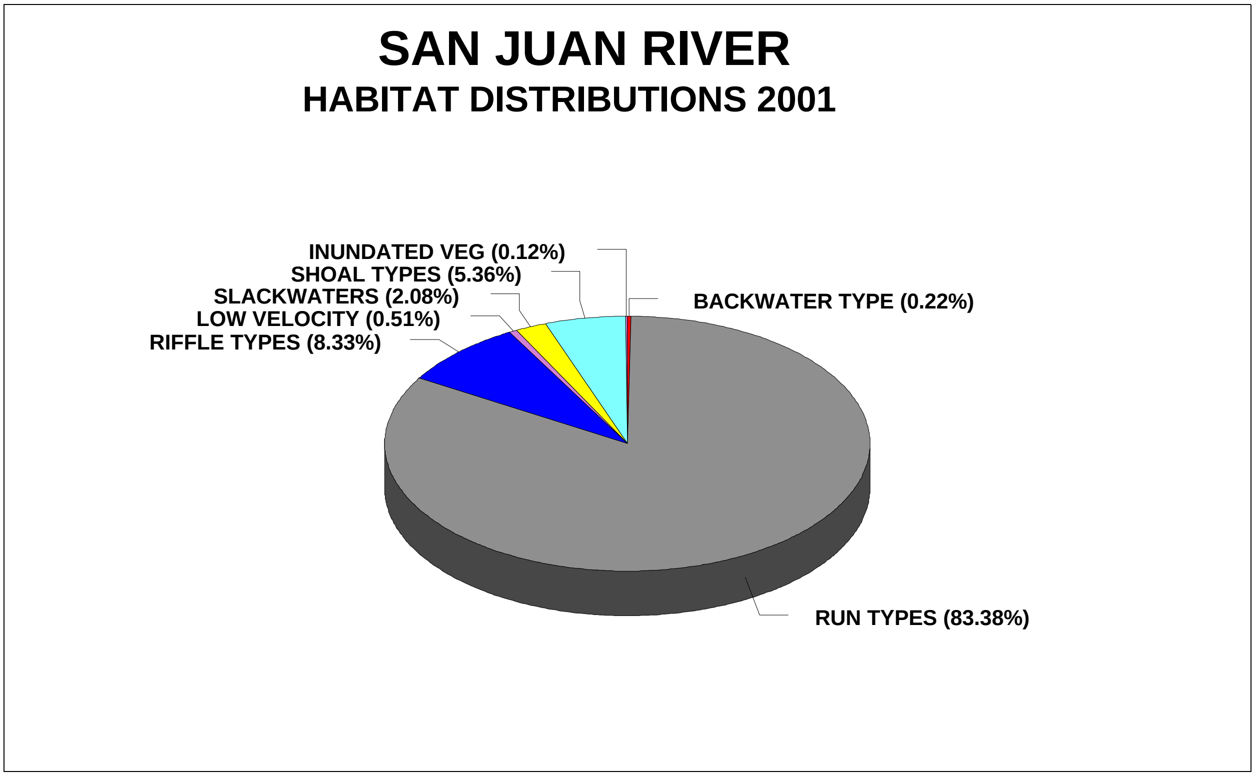

Figure 5.1. Distribution of Major Habitats in the San Juan River during the 2001 Habitat Monitoring

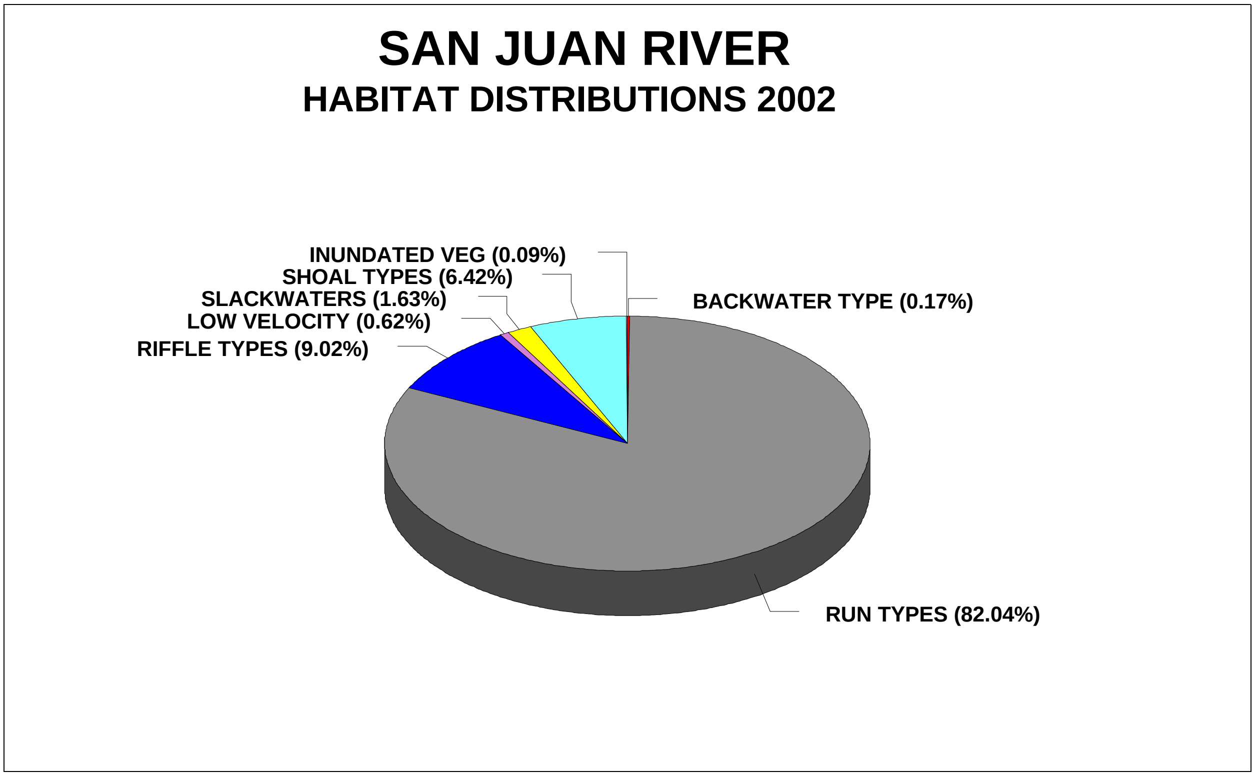

Figure 5.2. Distribution of Major Habitats in the San Juan River during the 2002 Habitat Monitoring

The spatial distribution of these same general categories can be seen in Figures 5.3 and 5.4 for 2001 and Figures 5.5 and 5.6 for 2002. Low velocity and backwater habitats were distributed throughout the river but are in highest magnitude for both years between in Reach 5 between RM 68 and RM 105 In 2001 the surface area of backwaters in this reach was 16,152 $m^{2.}$ While in 2002 the area dropped to 10,453 $m^{2.}$ In 2001, Reach 3 had the second highest surface area (8,608 $m^{2.}$) While in 2002, Reach 1 had the second largest surface area (7,057 $m^{2.}$). 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 mostly found between RM 20 and RM 80 and are associated with riffle complexes within the canyon bound reach of the river.

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 1998), 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 2001 (37,473 $m^{2.}$) And 2002 (25,993 $m^{2.}$) Compared to previous years are shown in Figure 5.7 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) between RM 2 and RM 180, there has been a decrease to 25,993 m^2 (53 backwaters) in the summer of 2002. The loss of almost 120,000 m^2, or 320 backwaters, primarily occurred in Reaches 3, 4, and 5.

HABITAT QUALITY

The depths of backwaters is an important attribute relative to use by native endangered species. In the San Juan River 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. In 2001 and 2002, sediment depth in backwaters were documented four times. These depths are shown in Figure 5.8 compared to the historical monitoring data. Sediment depths were typically lower in the spring before summer storms. On average sediment depths riverwide increased from 0.33 meters to 0.39 meters in 2001 and from 0.18 meters to 0.26 meters in 2002 (Figure 5.8). Deepest backwater sediment depths were found in Reach 1 (0.50 meters) in 2001 and in Reach 2 (0.58 meters) in 2002.

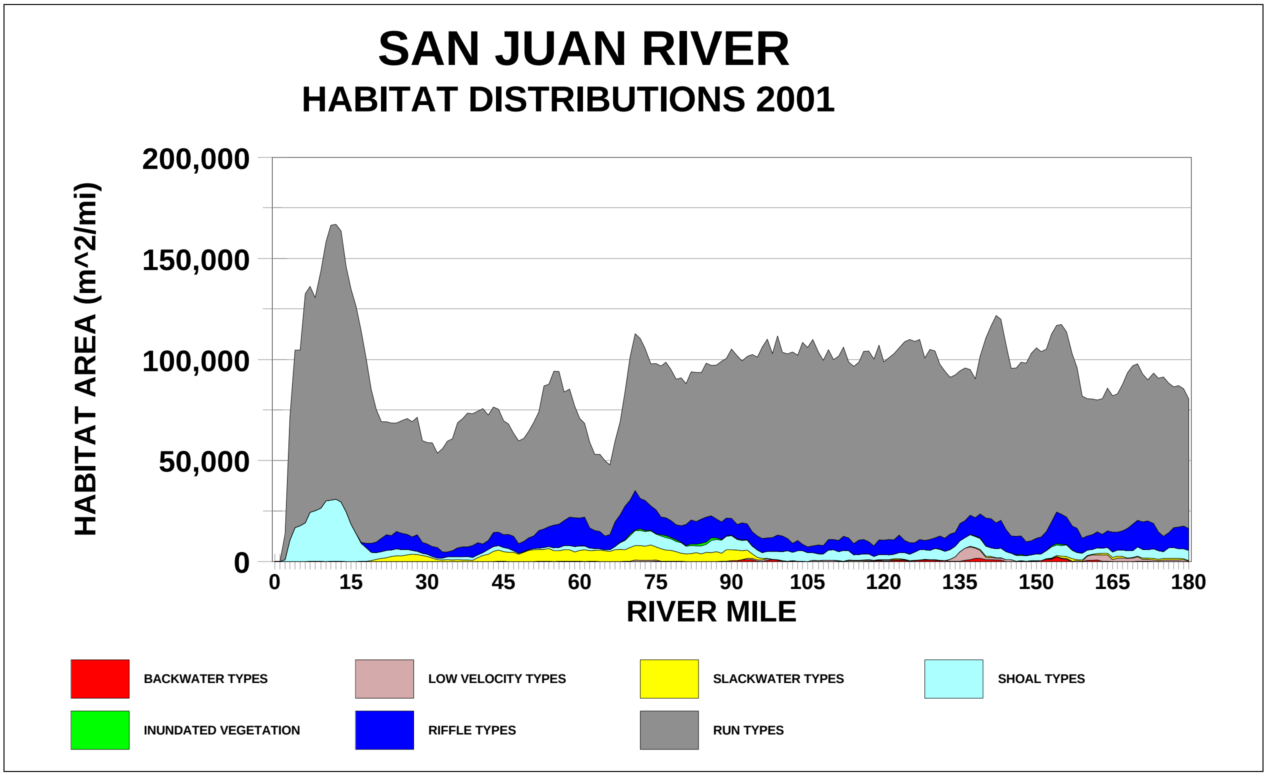

Figure 5.3. Spatial Distribution of Major Habitat Types in the San Juan River during 2001

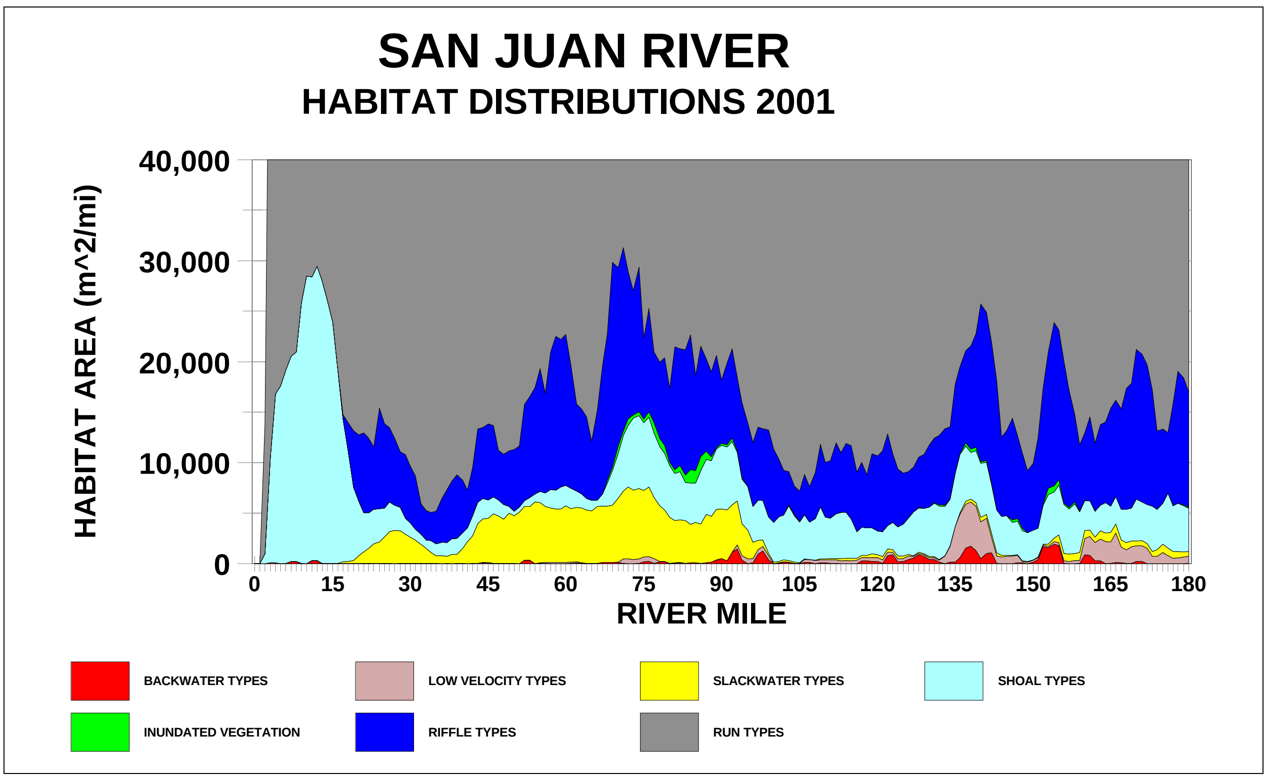

Figure 5.4. Detailed Spatial Distribution of the Major Habitat Types in the San Juan River during 2001

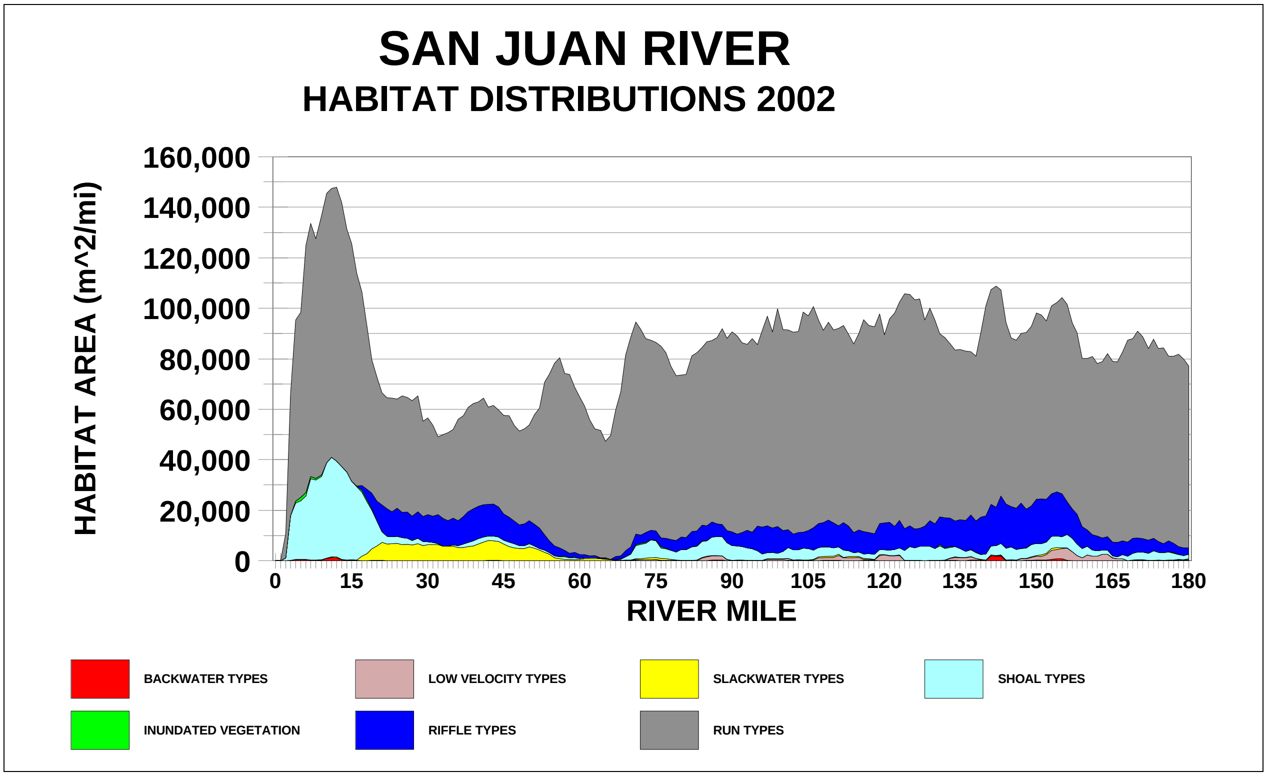

Figure 5.5. **Spatial Distribution of the Major Habitat Types in the San Juan River during 2002**

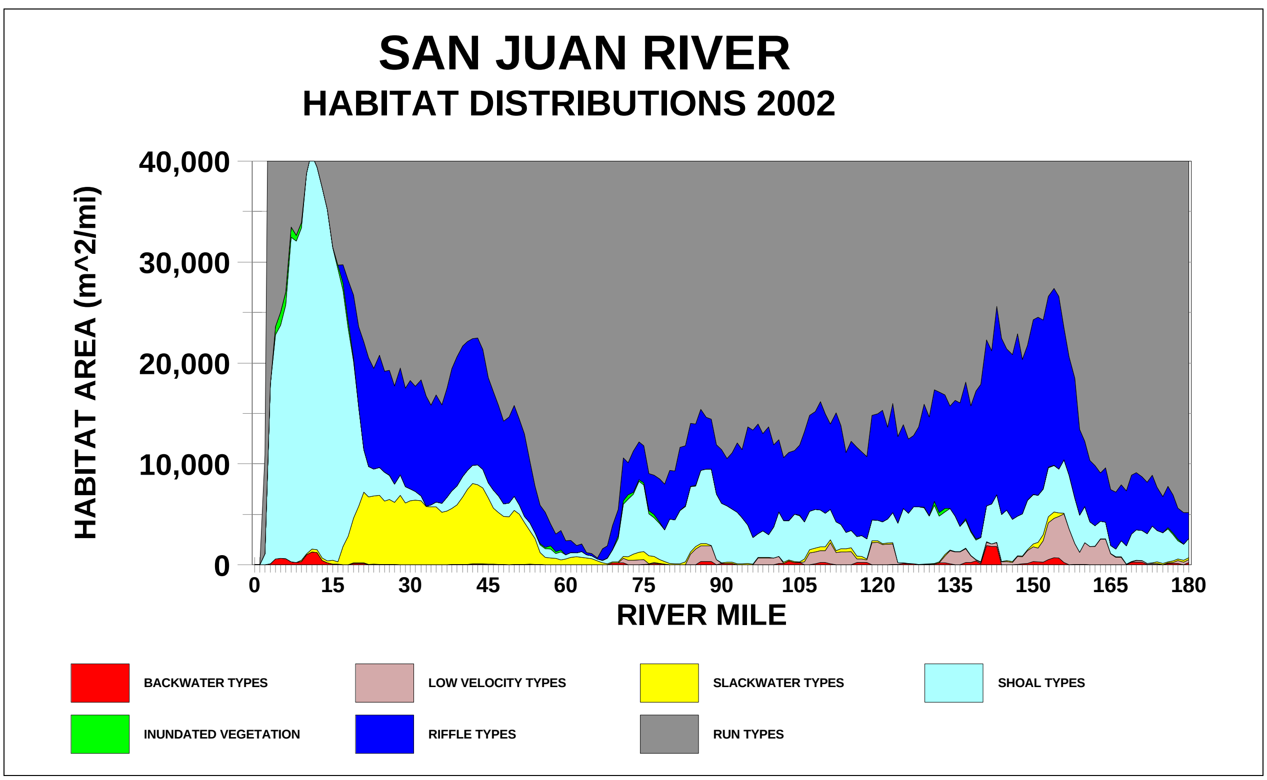

Figure 5.6. **Detailed Spatial Distribution of the Major Habitats in the San Juan River during 2002**

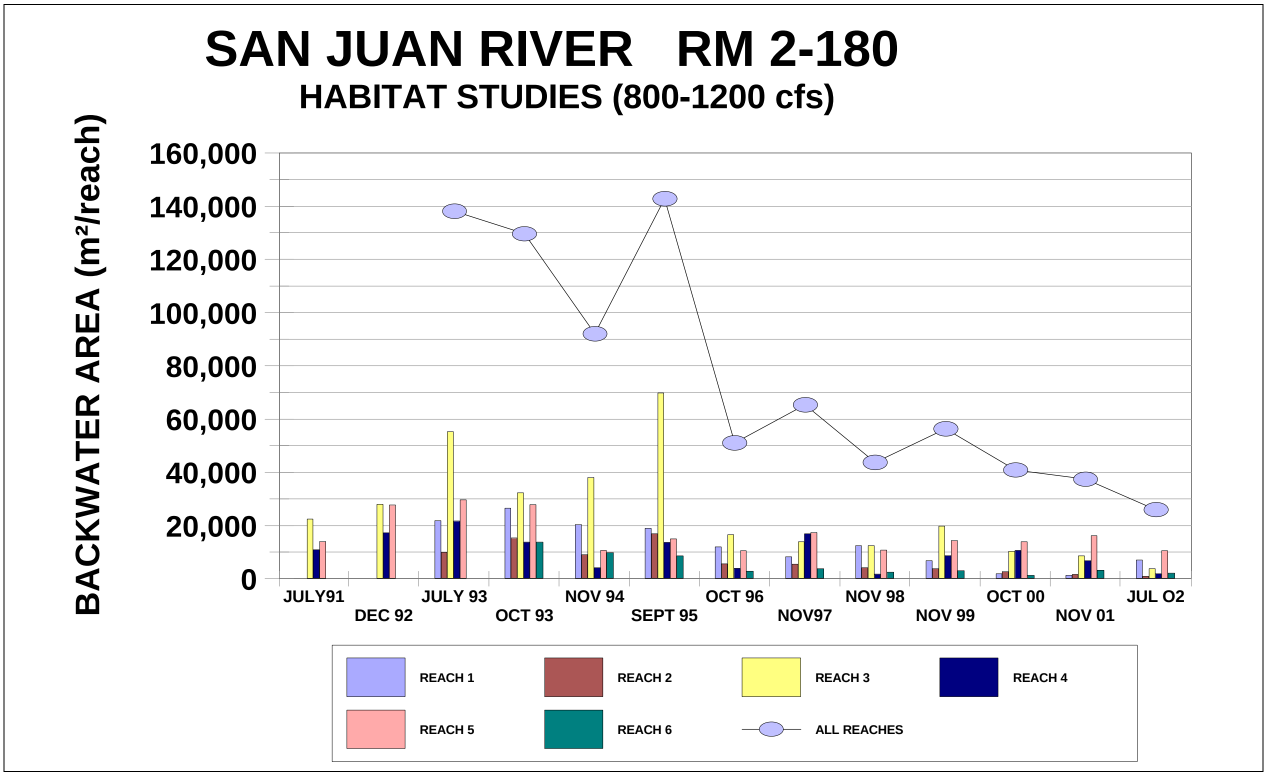

Figure 5.7. **Surface Area of Backwater Habitats in the San Juan River between RM 2 and RM 180**

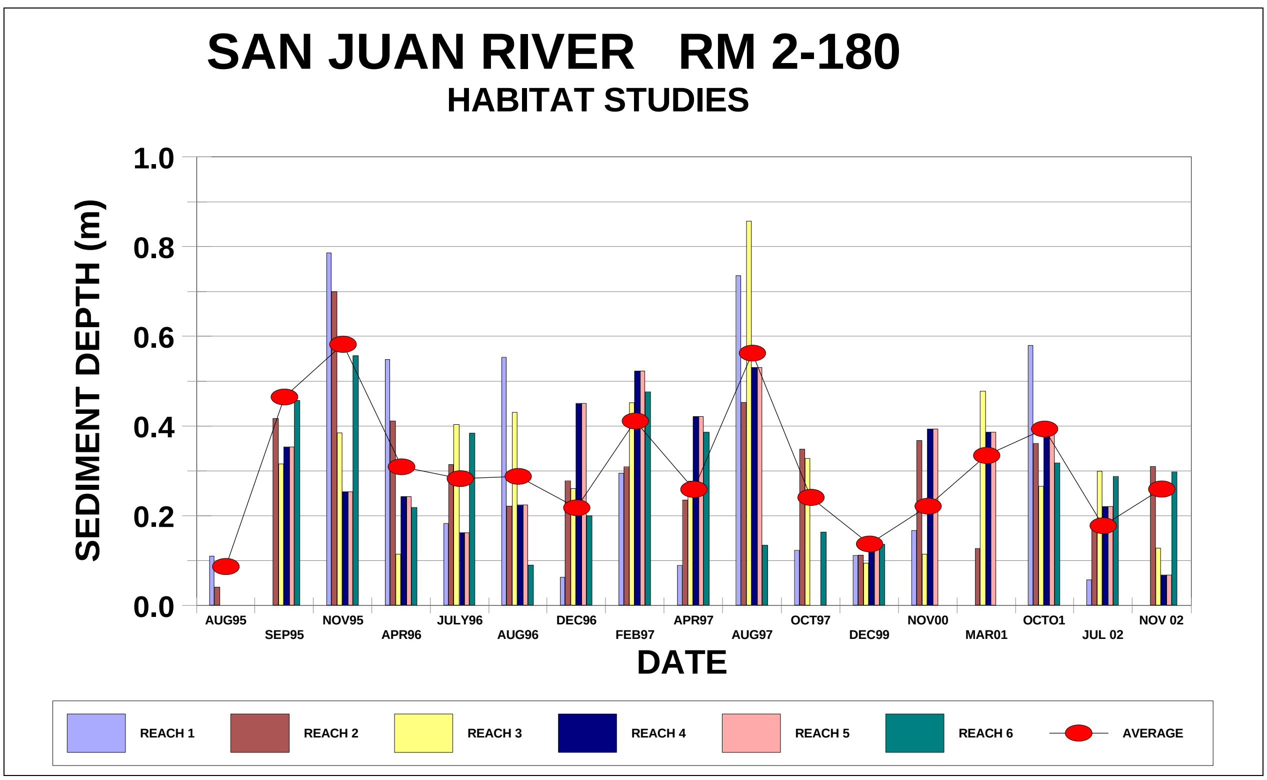

Figure 5.8. **Depth of Sediments in Backwaters in the San Juan River between RM 2 and RM 180**

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Bliesner, R., and V. Lamarra. 1999. San Juan River habitat studies, 1998 Annual Report. Keller-Bliesner Engineering and Ecosystems Research Institute for San Juan River Basin Recovery Implementation Program, Annual Research Report, Fiscal Year 1998, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

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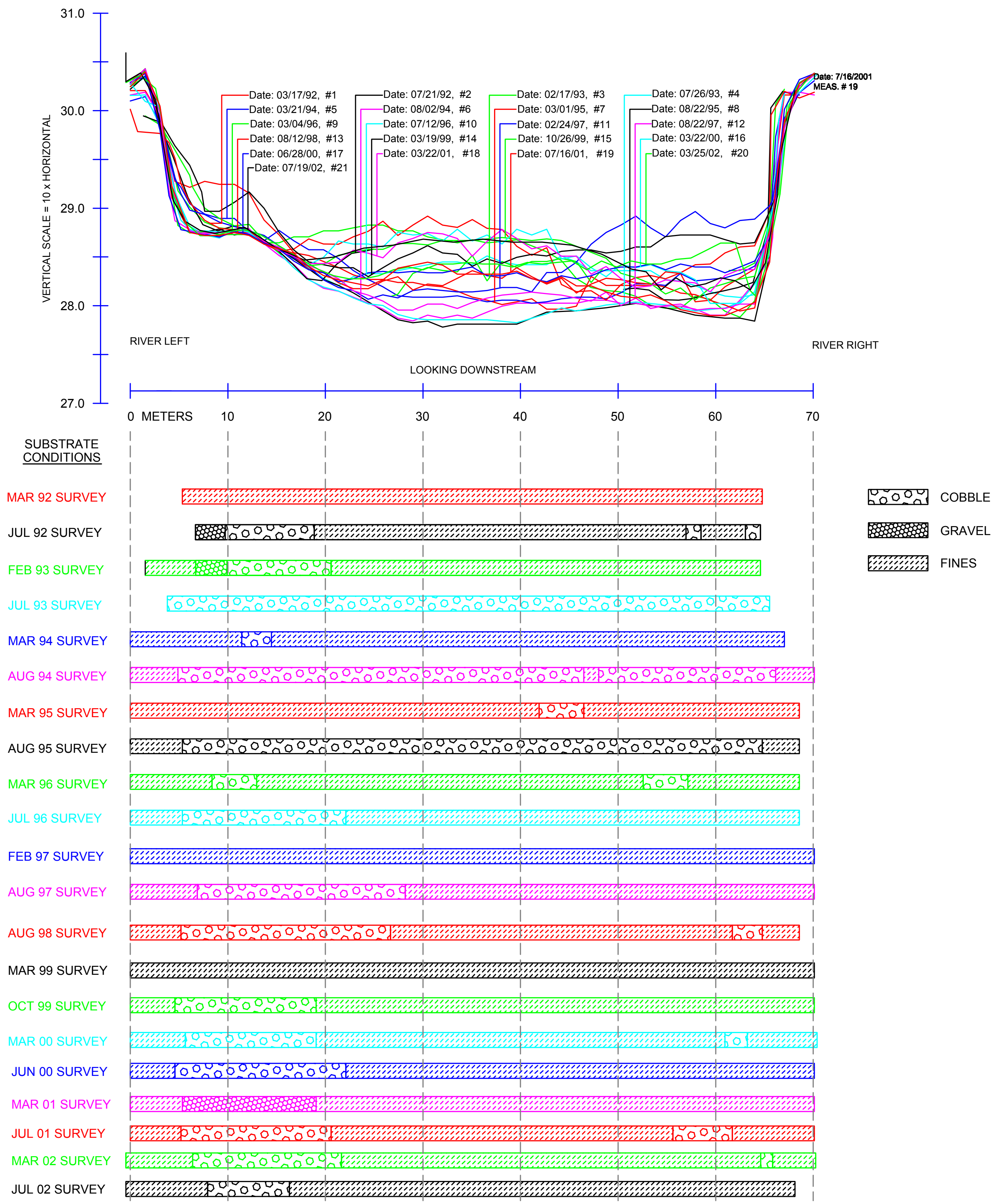
Osmundson, D.B., D.K. Scheer. 1998. Monitoring Cobble-Gravel Embeddedness in the Stream Bed of the upper Colorado River, 1996-1997. Final Report. U.S. Fish and Wildlife Service, Final Report, Grand Junction, CO.

Wolman, M.G. 1954. A method of sampling coarse river bed material. Transactions of the American Geophysical Union 35: 951-956.

APPENDIX A

San Juan River Transect Plots

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



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TRANSECT CS6-02 (RT01)
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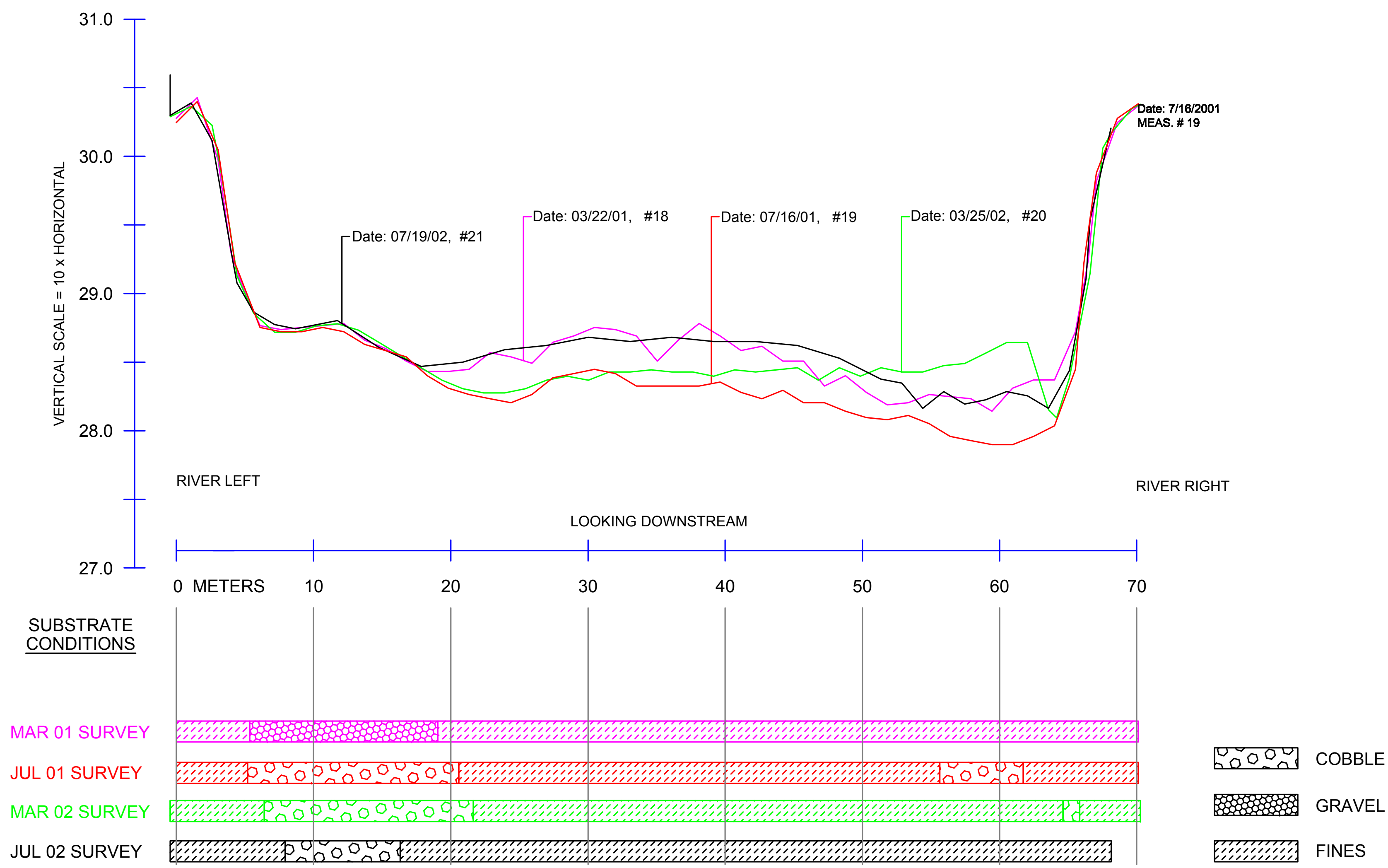
FRUITLAND QUAD.



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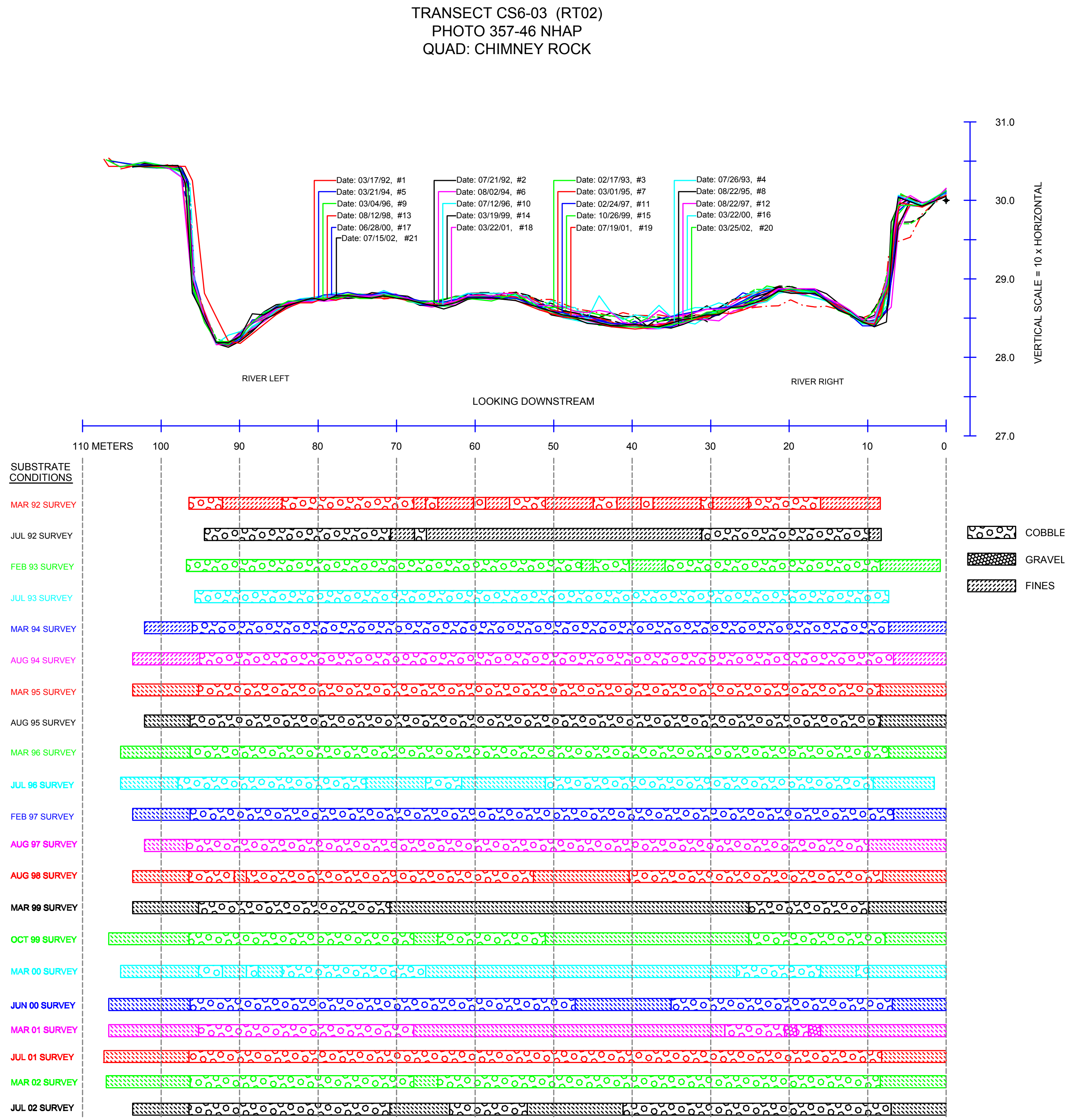

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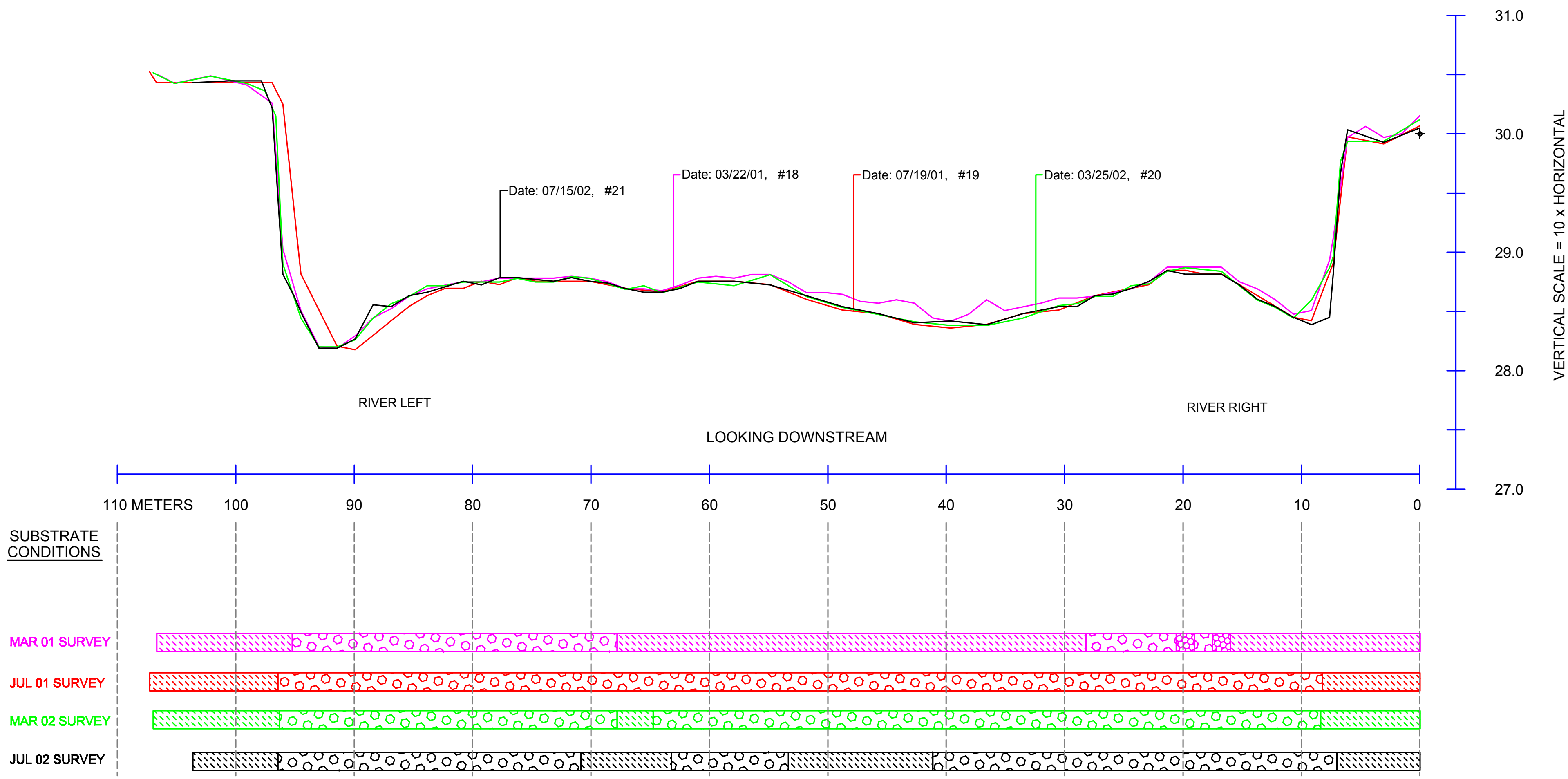
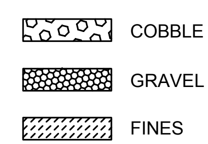
TRANSECT CS6-03 (RT02)
PHOTO 357-46 NHAP
QUAD: CHIMNEY ROCK





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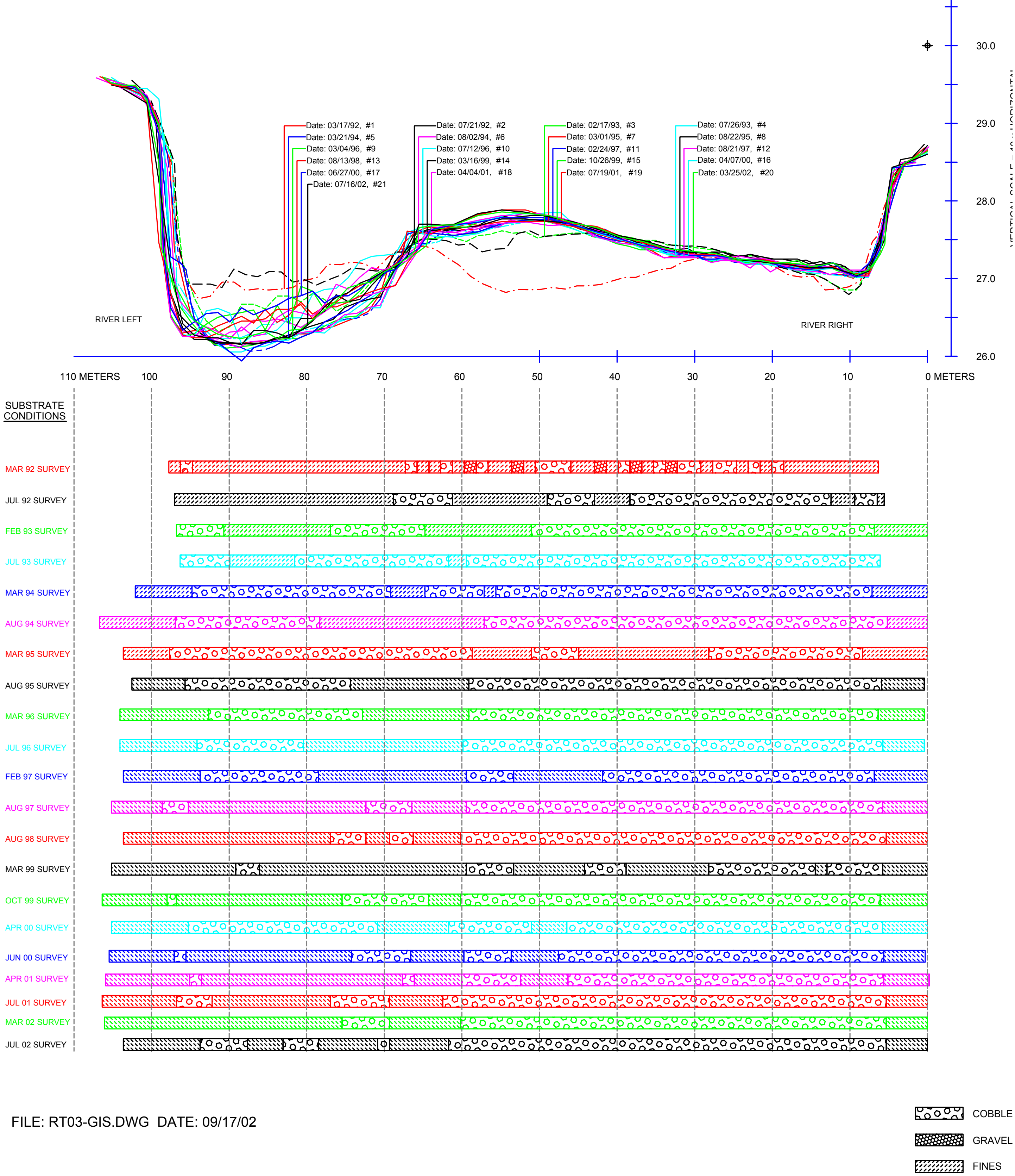
SHIPROCK QUAD.



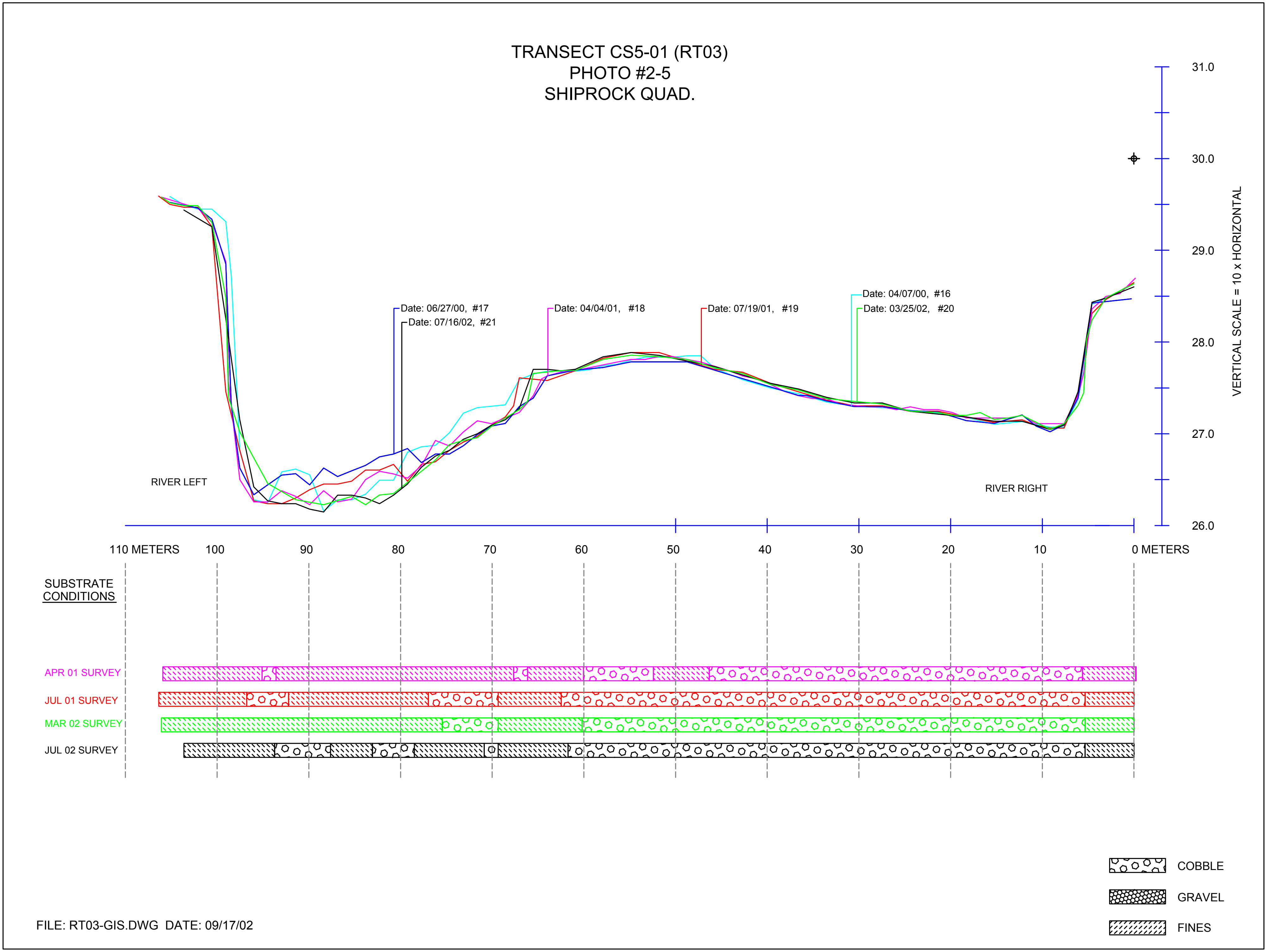

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PHOTO #2-5
SHIPROCK QUAD.
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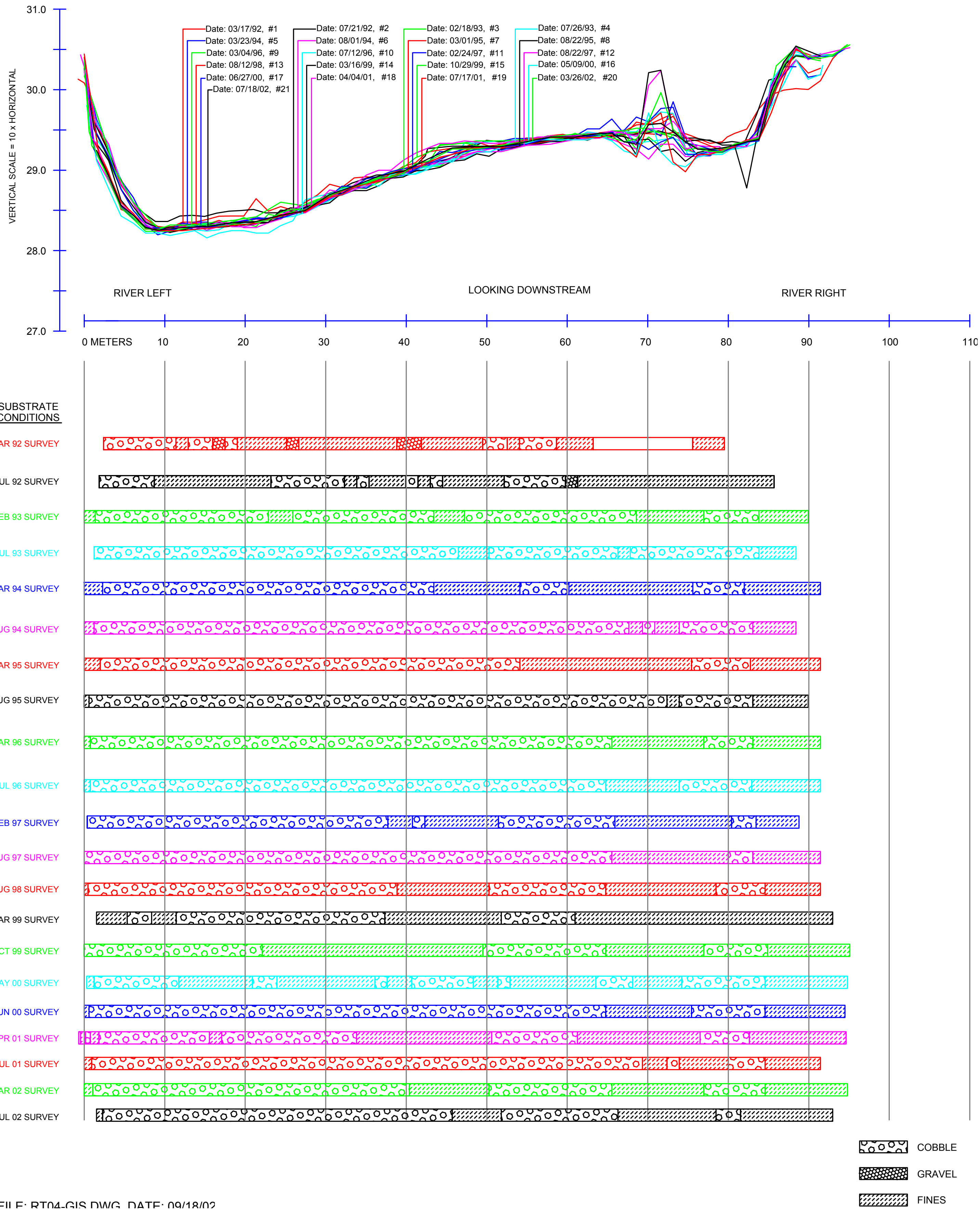
Date: 07/16/02, #21
Date: 04/04/01, #18
Date: 07/19/01, #19
Date: 04/07/00, #16
Date: 03/25/02, #20
RIVER LEFT
RIVER RIGHT
31.0
30.0
29.0
28.0
27.0
26.0
VERTICAL SCALE = 10 x HORIZONTAL
110 METERS
100
90
80
70
60
50
40
30
20
10
0 METERS
SUBSTRATE CONDITIONS
APR 01 SURVEY
JUL 01 SURVEY
MAR 02 SURVEY
JUL 02 SURVEY
COBBLE
GRAVEL
FINES
FILE: RT03-GIS.DWG DATE: 09/17/02

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



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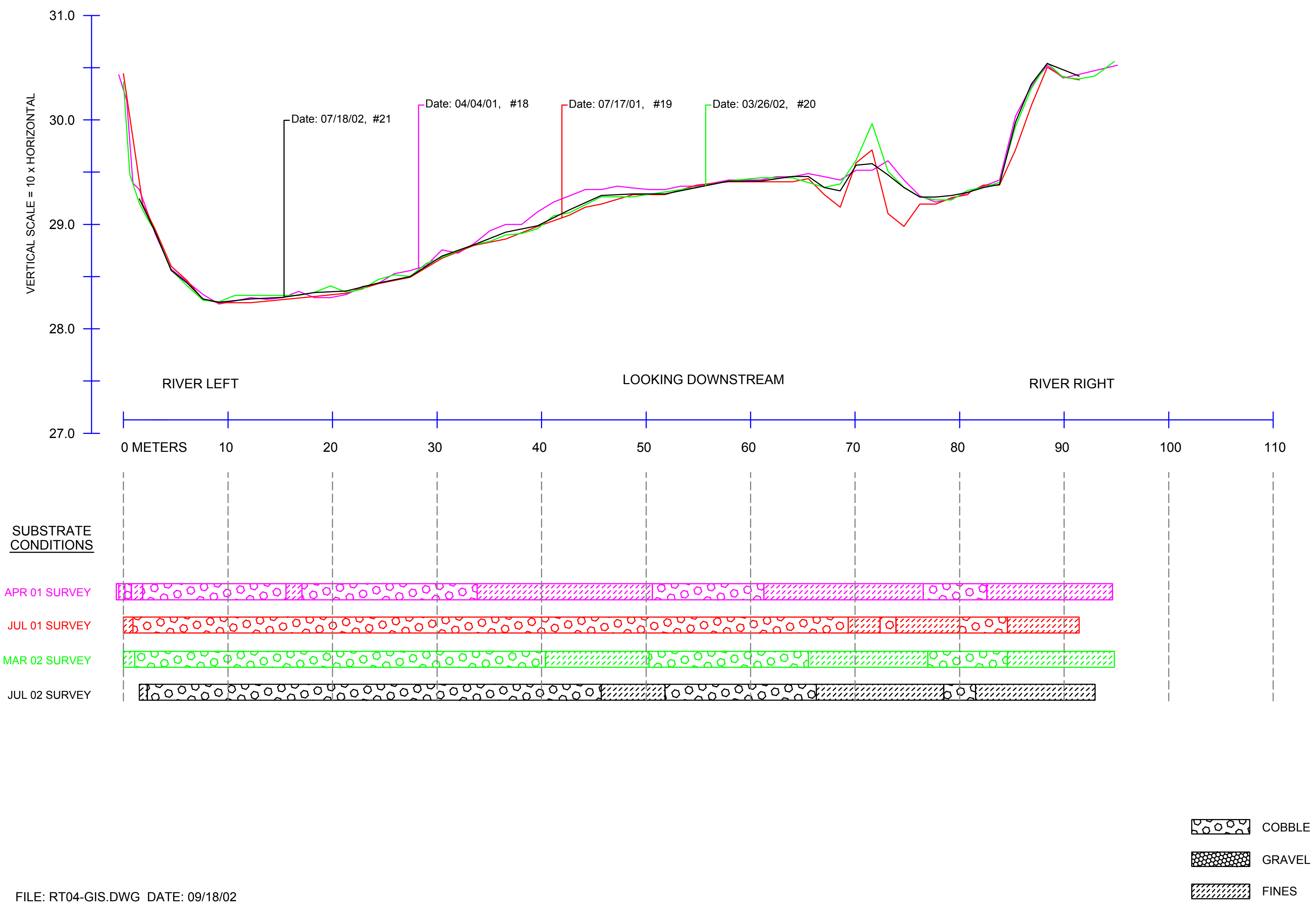

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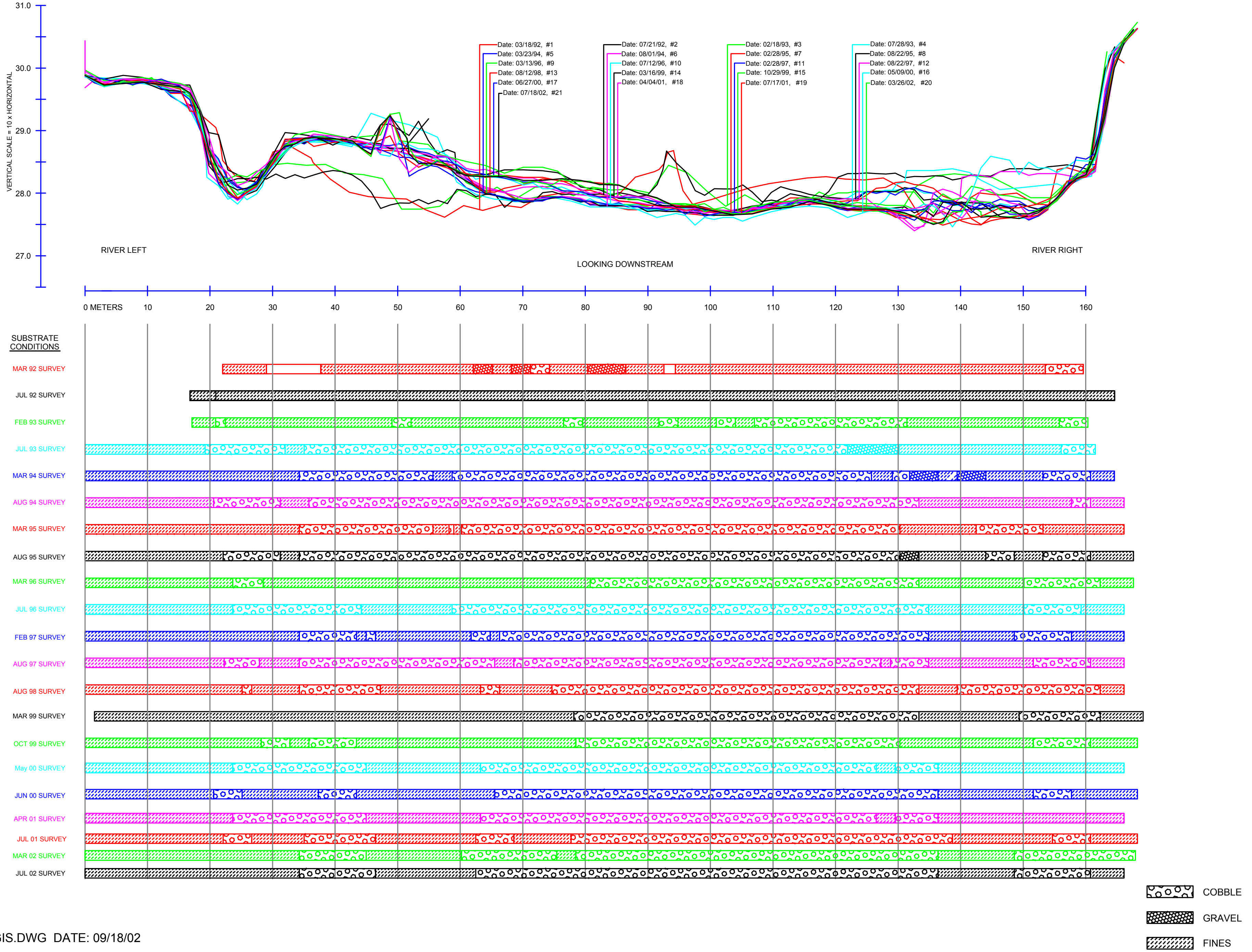
TRANSECT CS5-03 (RT05)
PHOTO 4-1
SALLIES SPRING QUAD.



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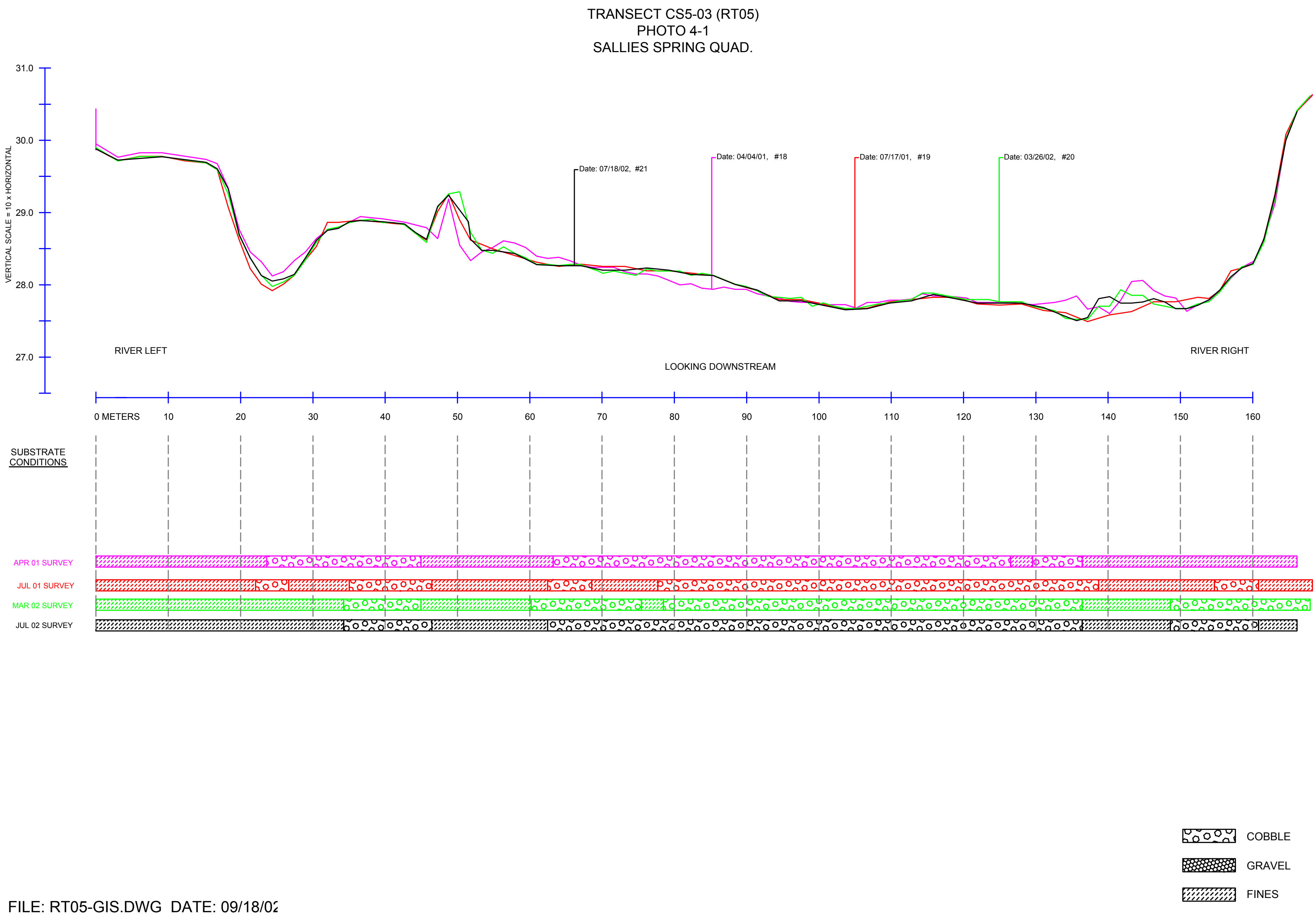

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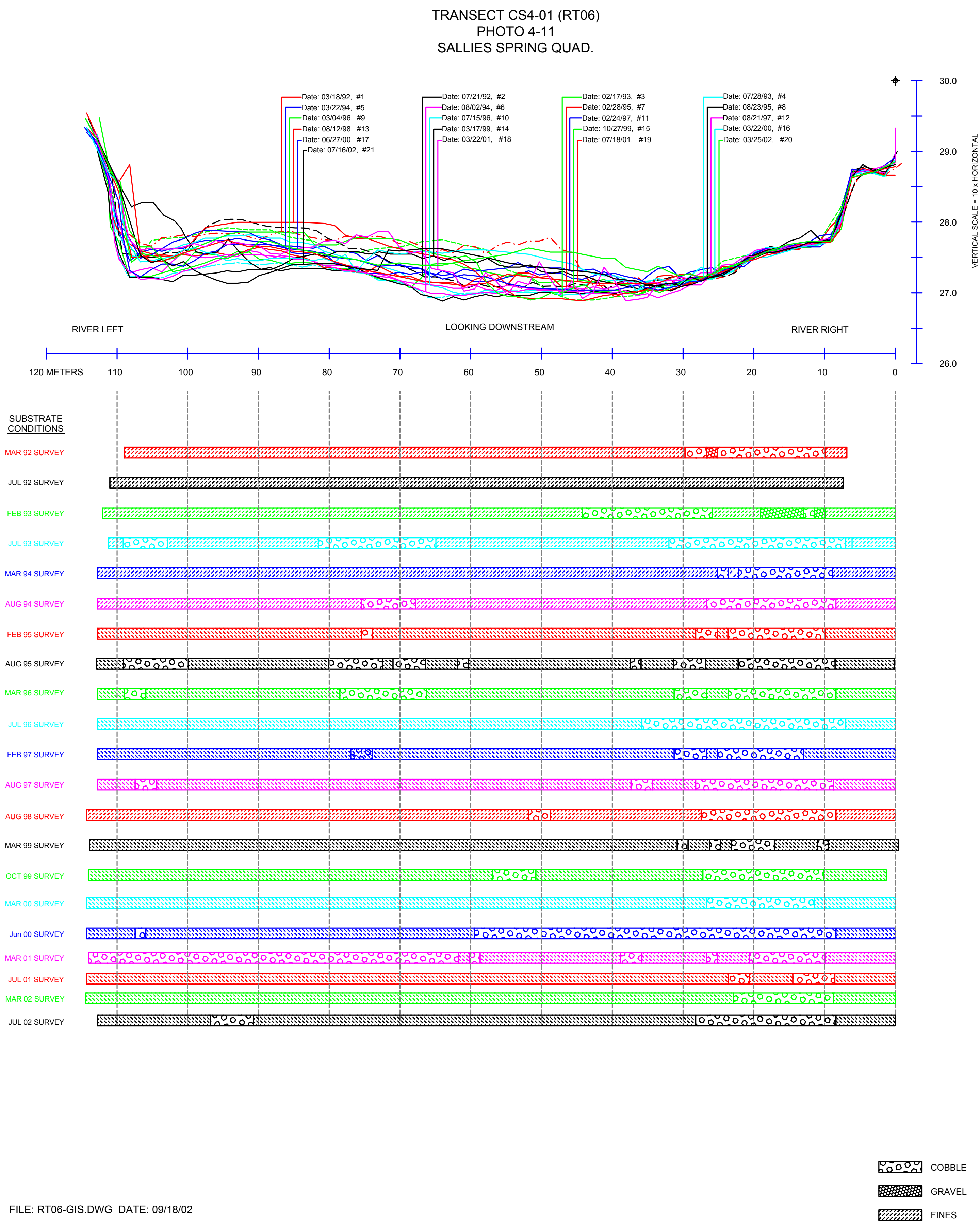

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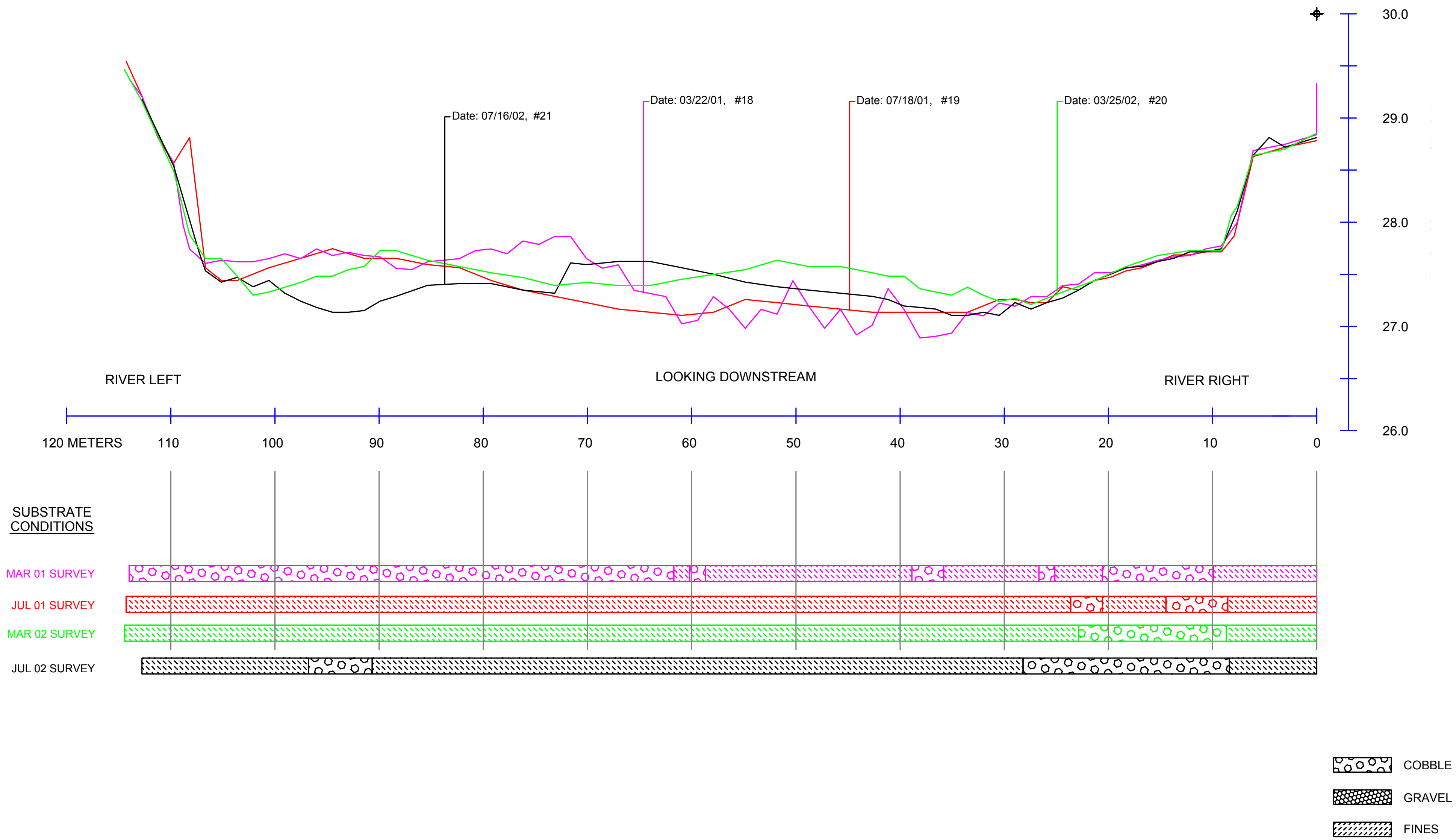

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TRANSECT RT07
PHOTO 6-1
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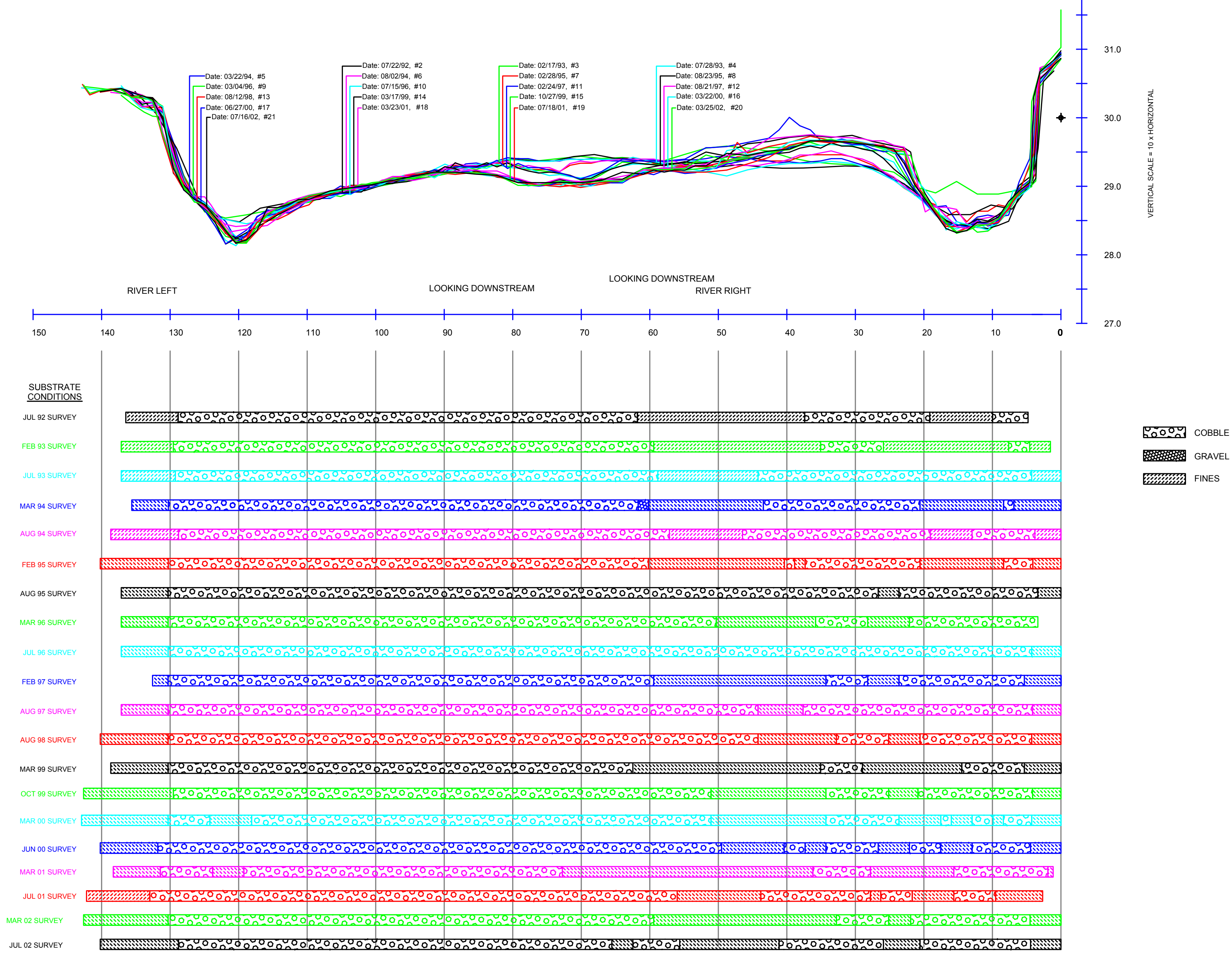

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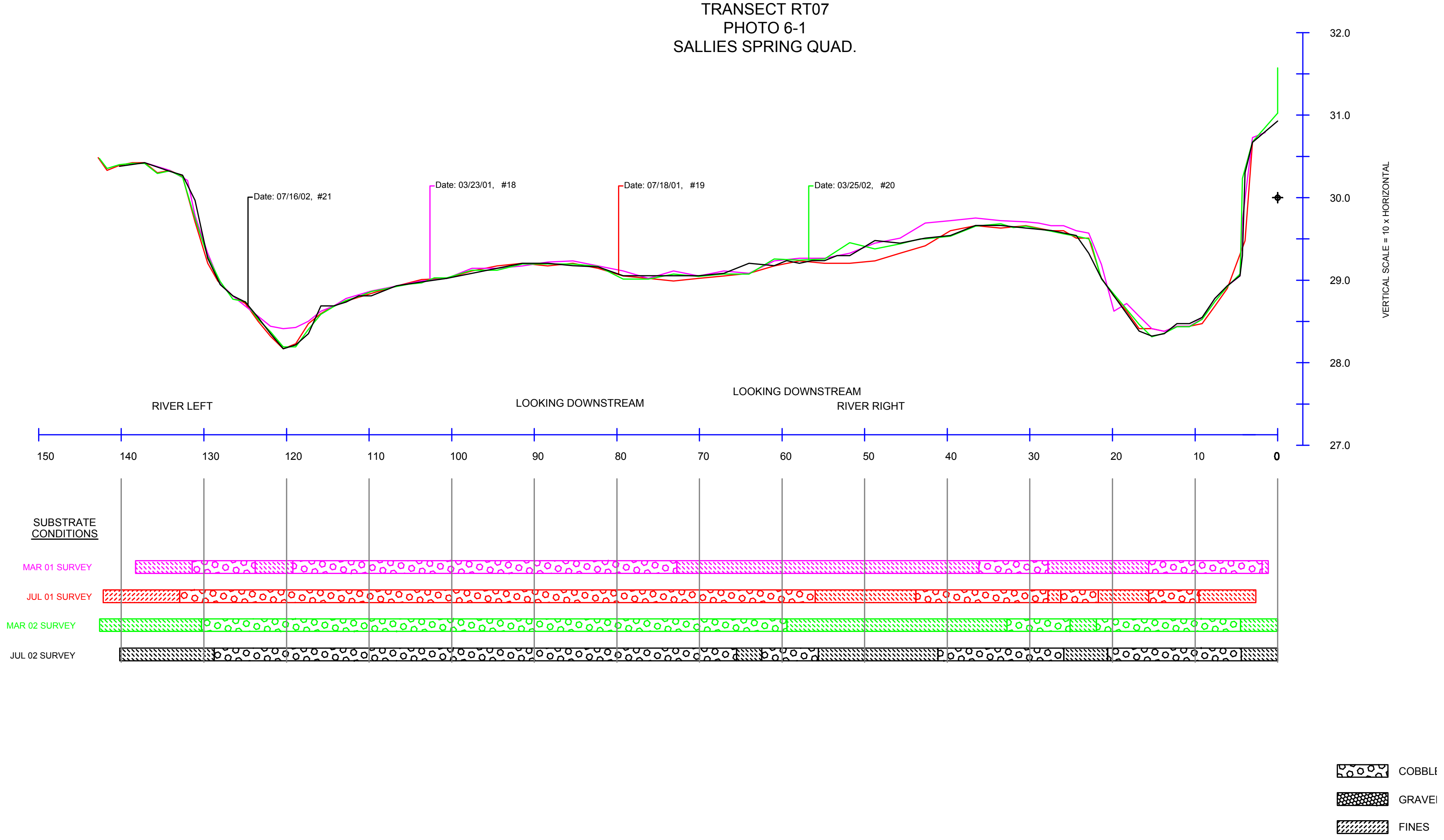

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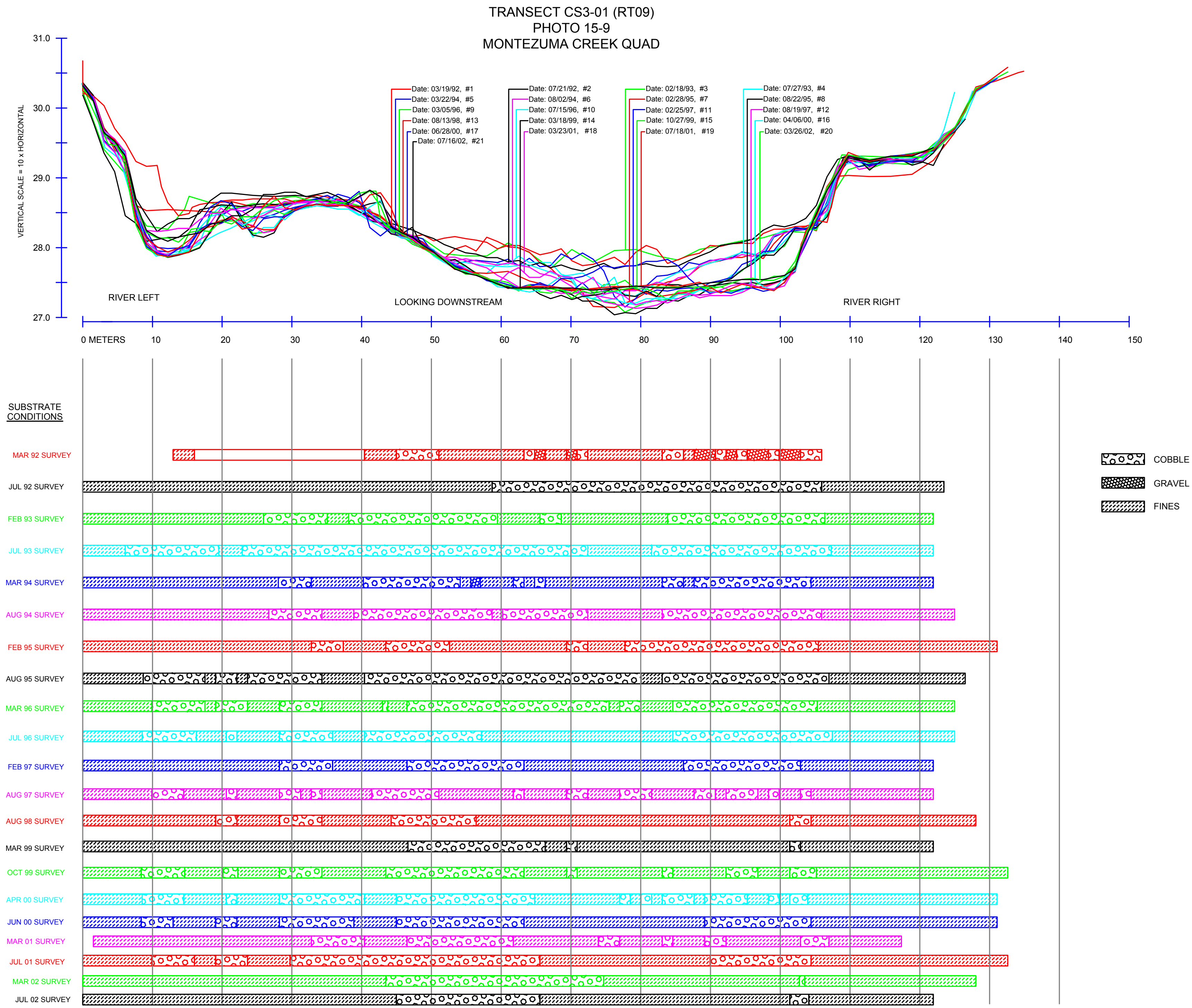
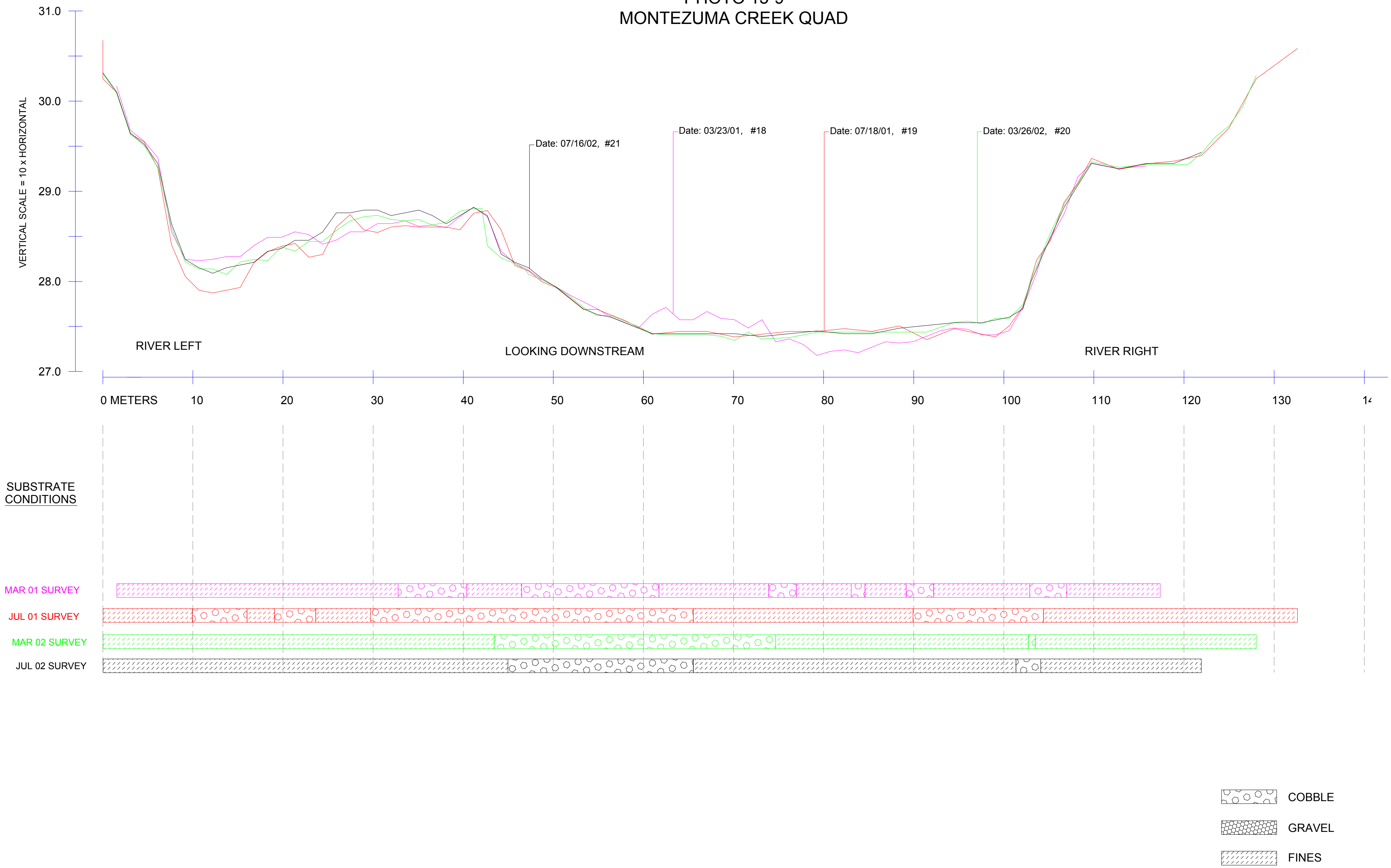


FILE: RT09-GIS.DWG DATE: 09/18/02

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



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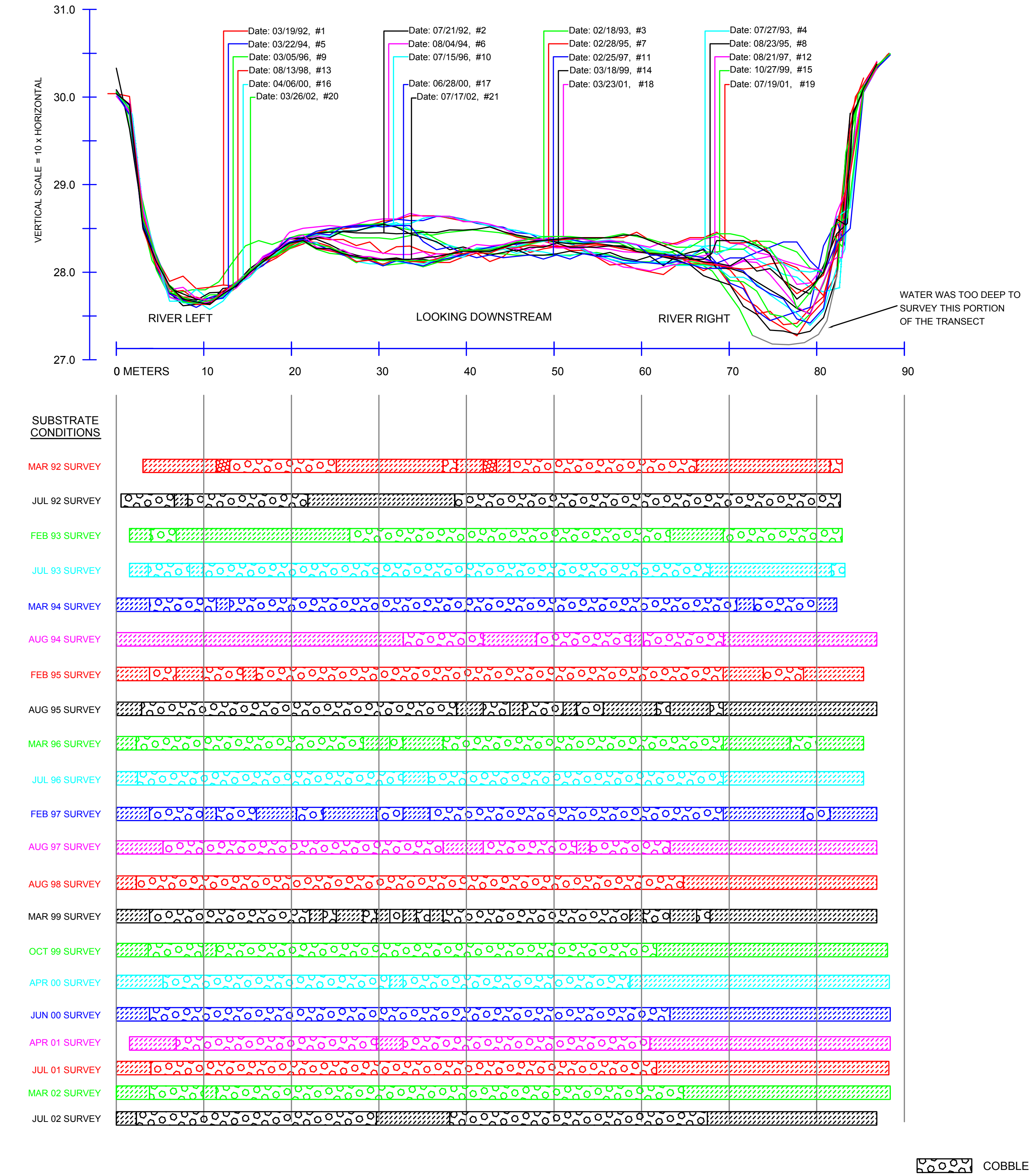
TRANSECT CS3-02 (RT10)
PHOTO 16-5
BLUFF QUAD.



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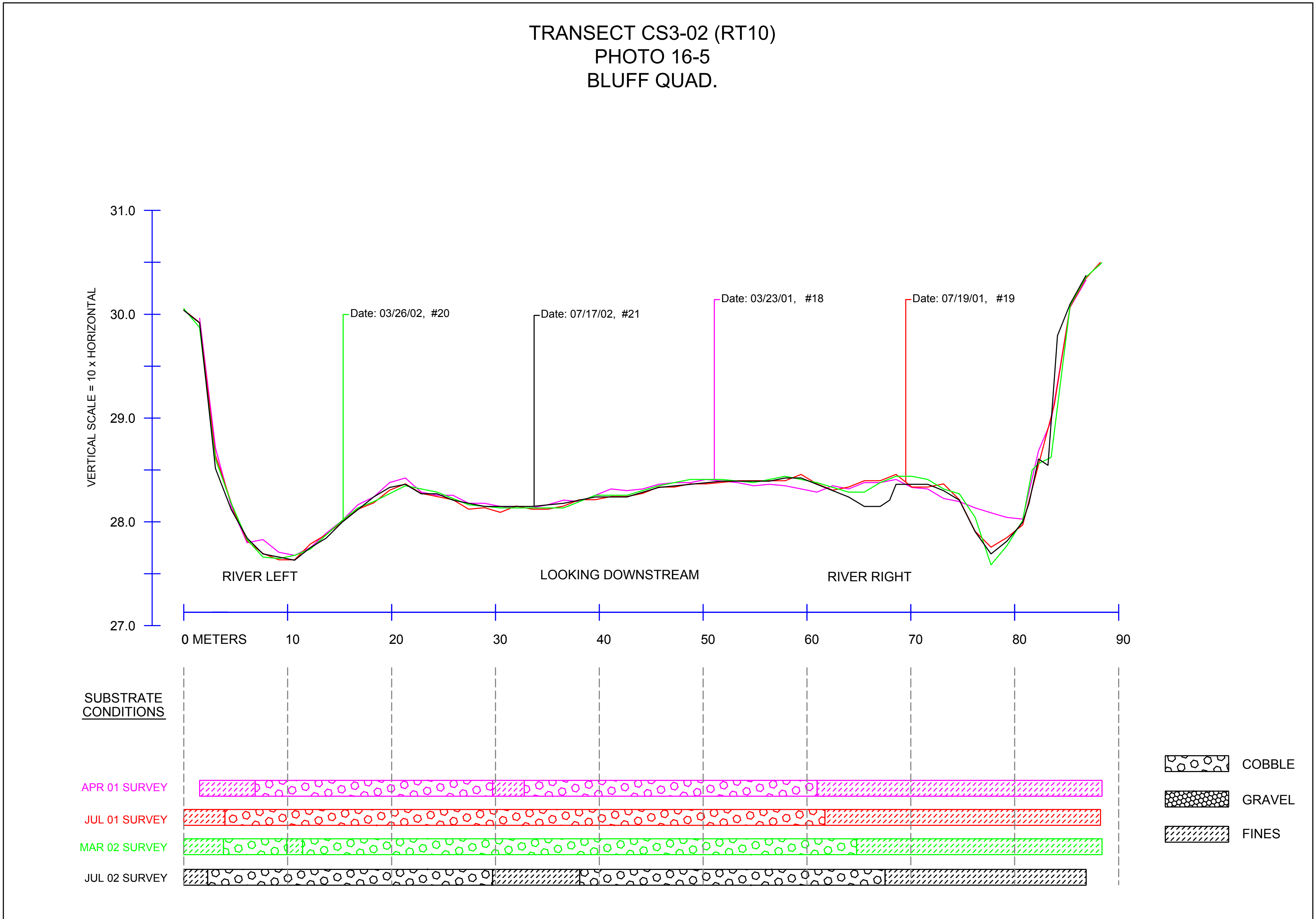

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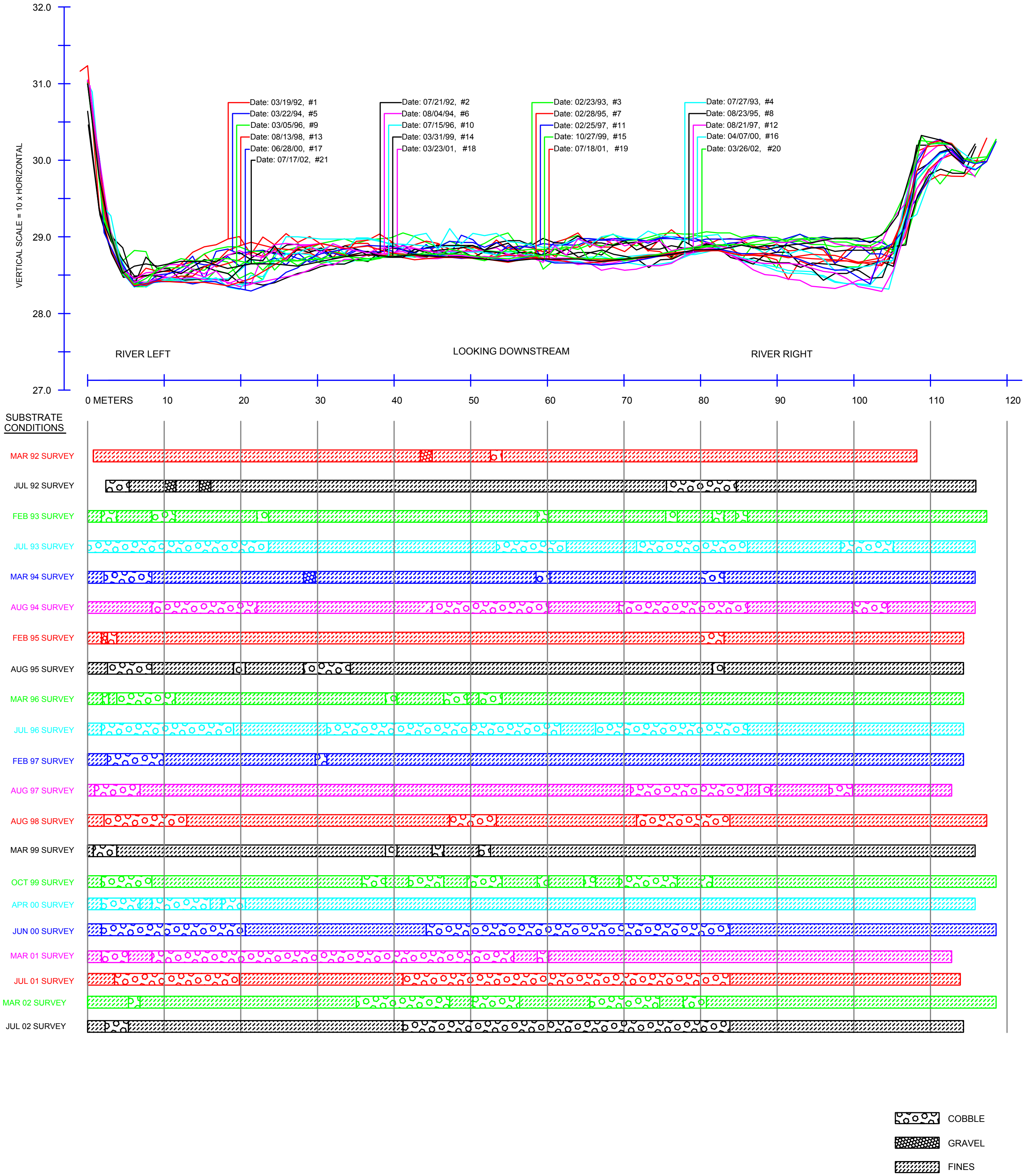
TRANSECT CS3-03 (RT11)
PHOTO 17-13
SAN JUAN HILL QUAD.



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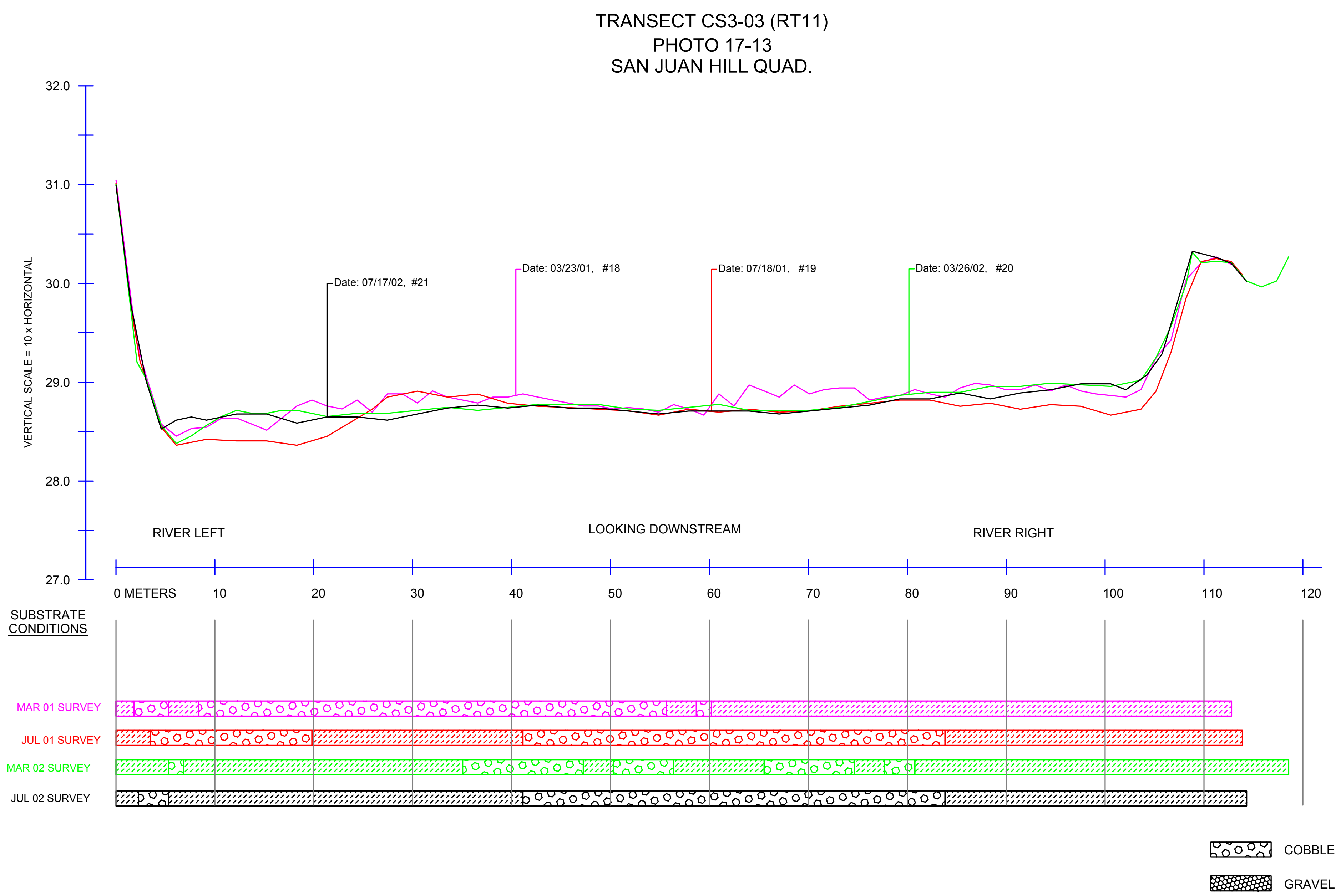
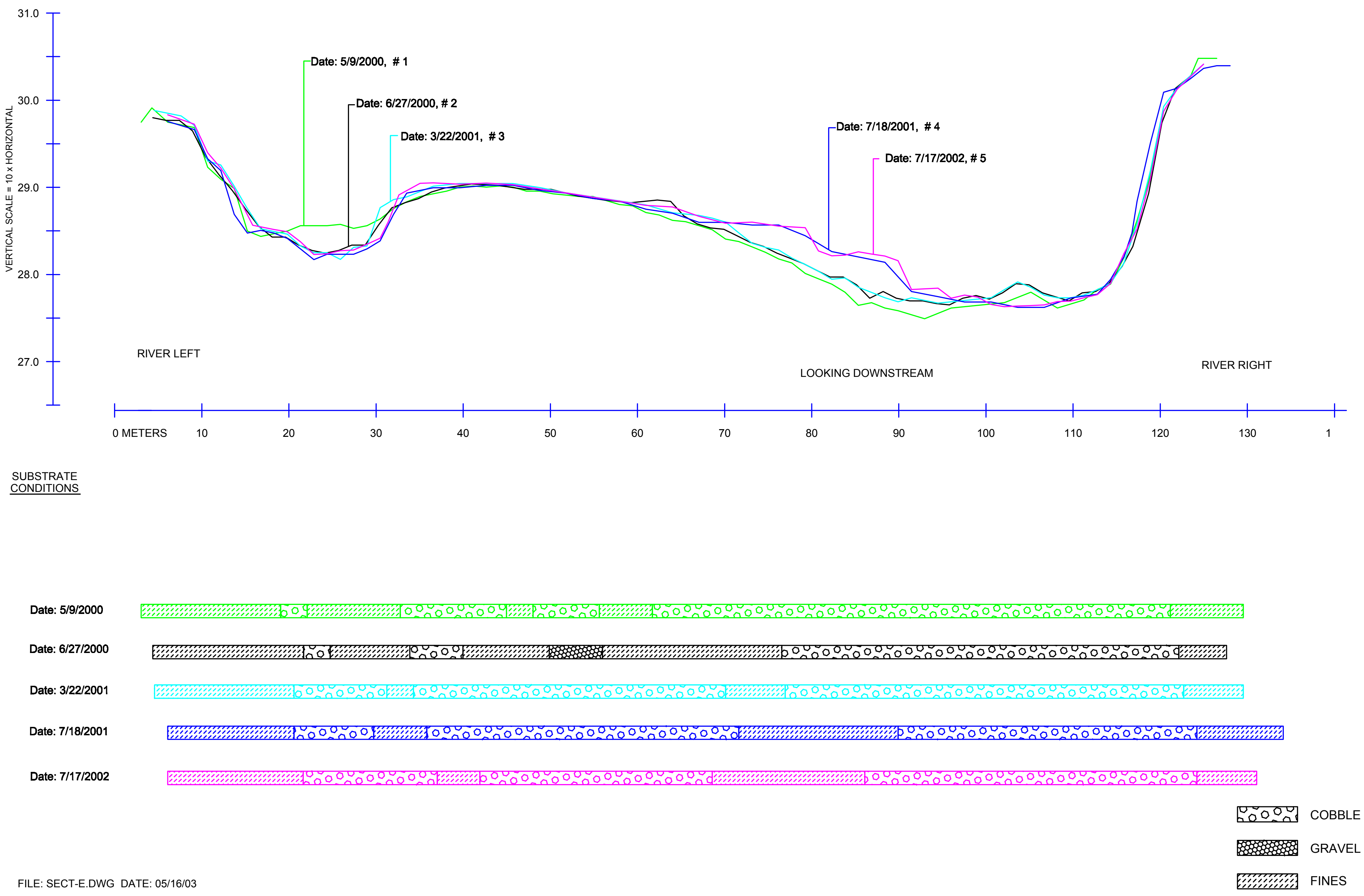


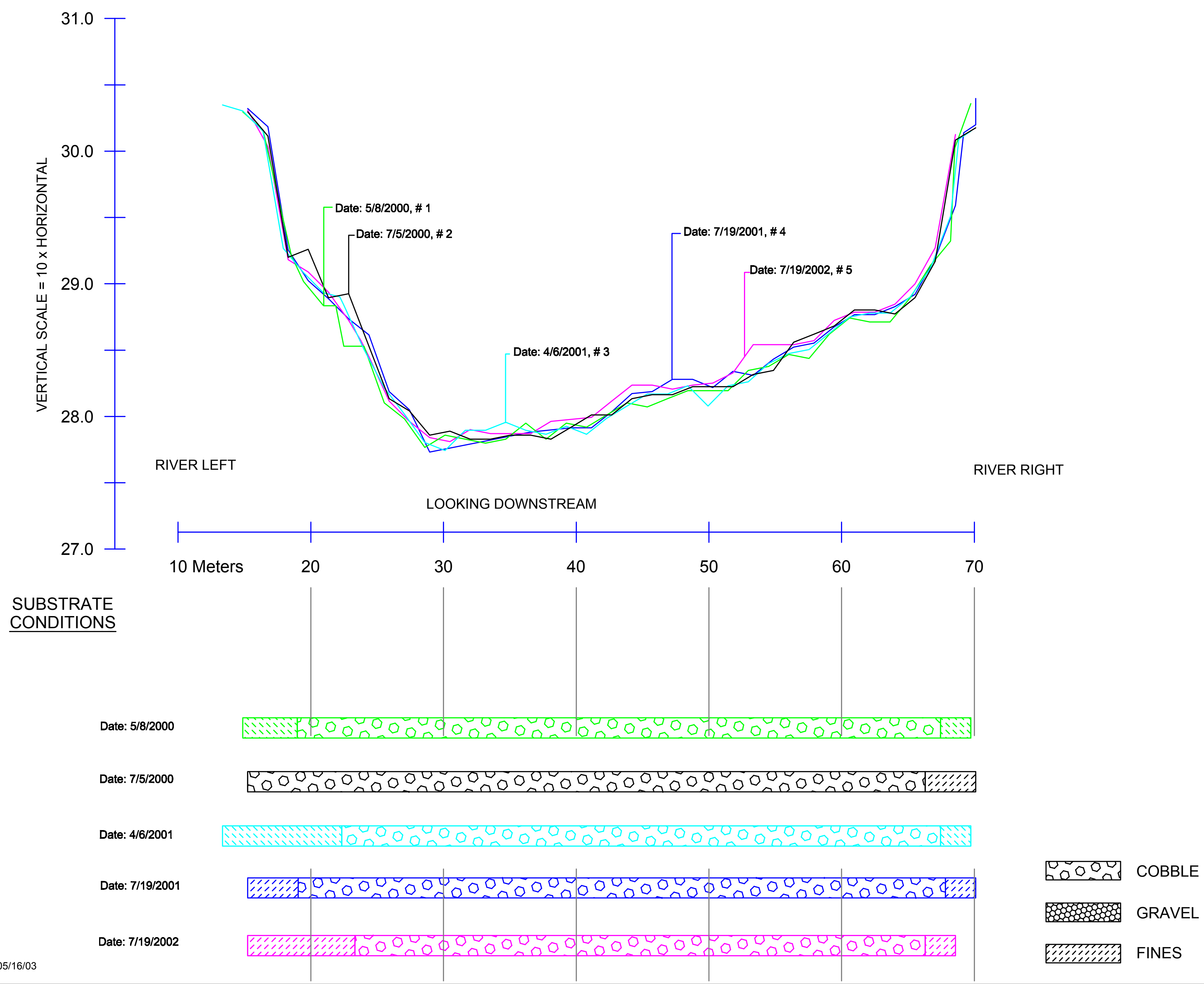
FILE: RT11-GIS.DWG DATE: 09/18/02

CS4-03 (Section-E) near Four Corners



FILE: SECT-E.DWG DATE: 05/16/03

CS6-01 (Section-T) near Farmington



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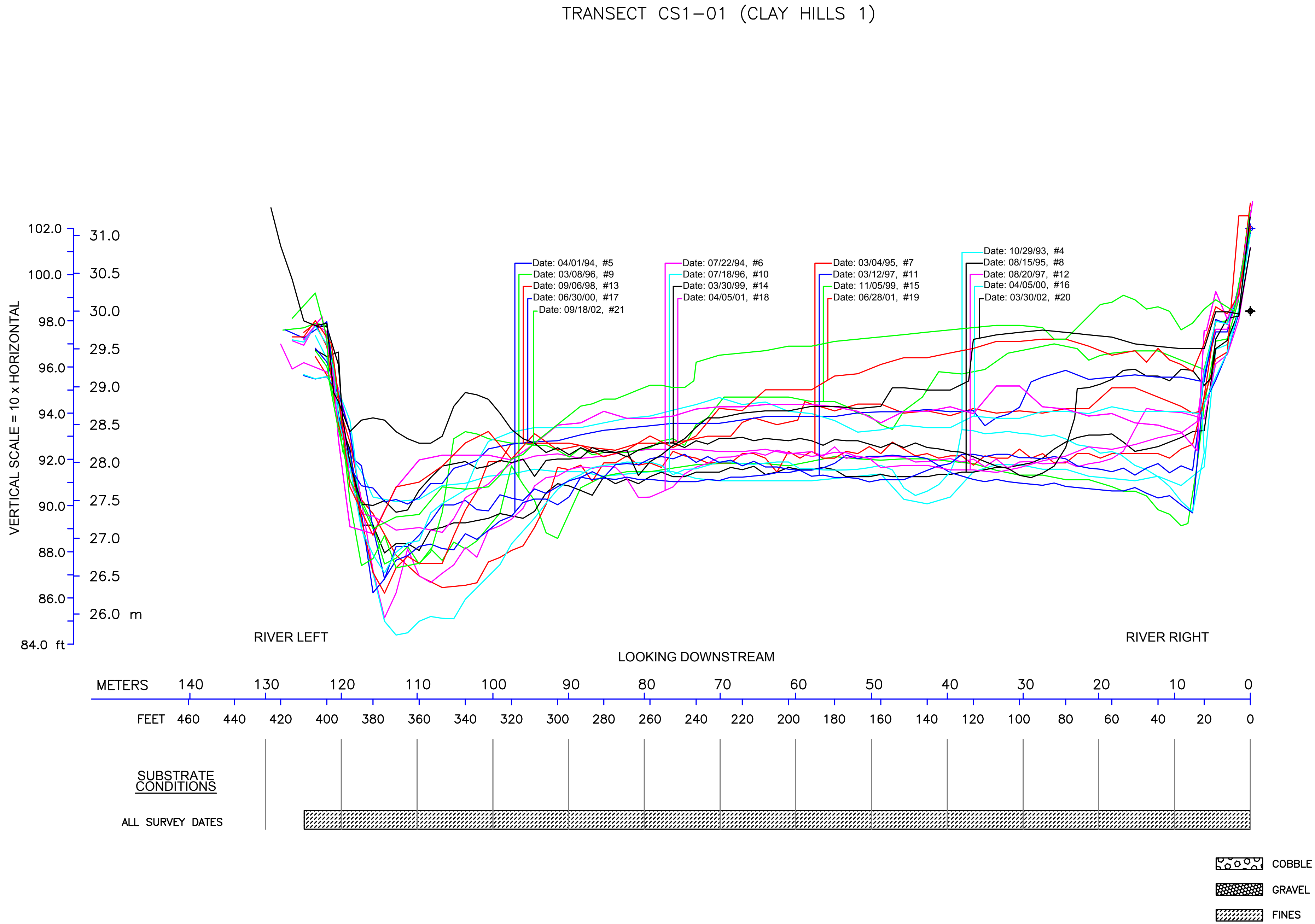

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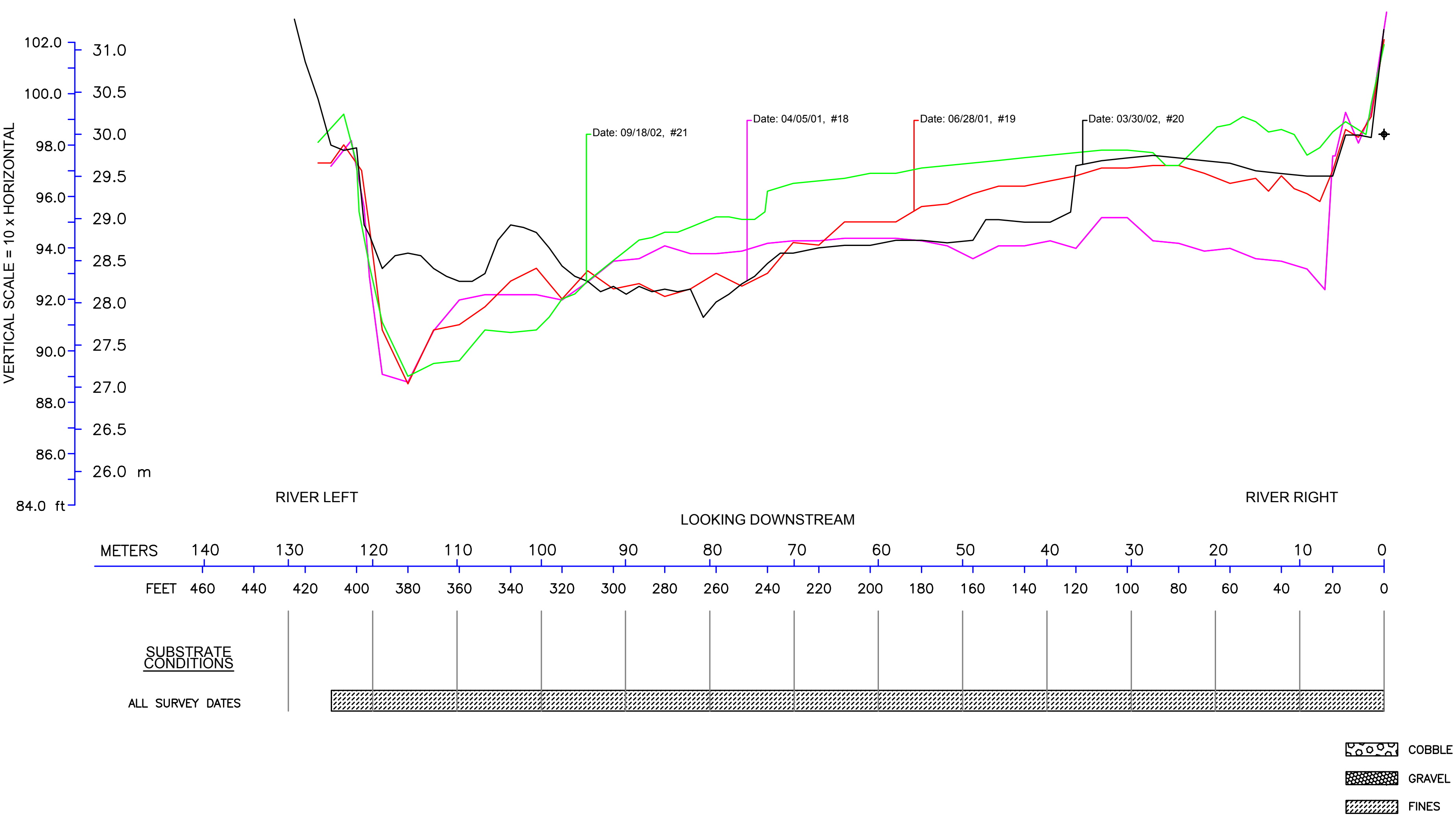

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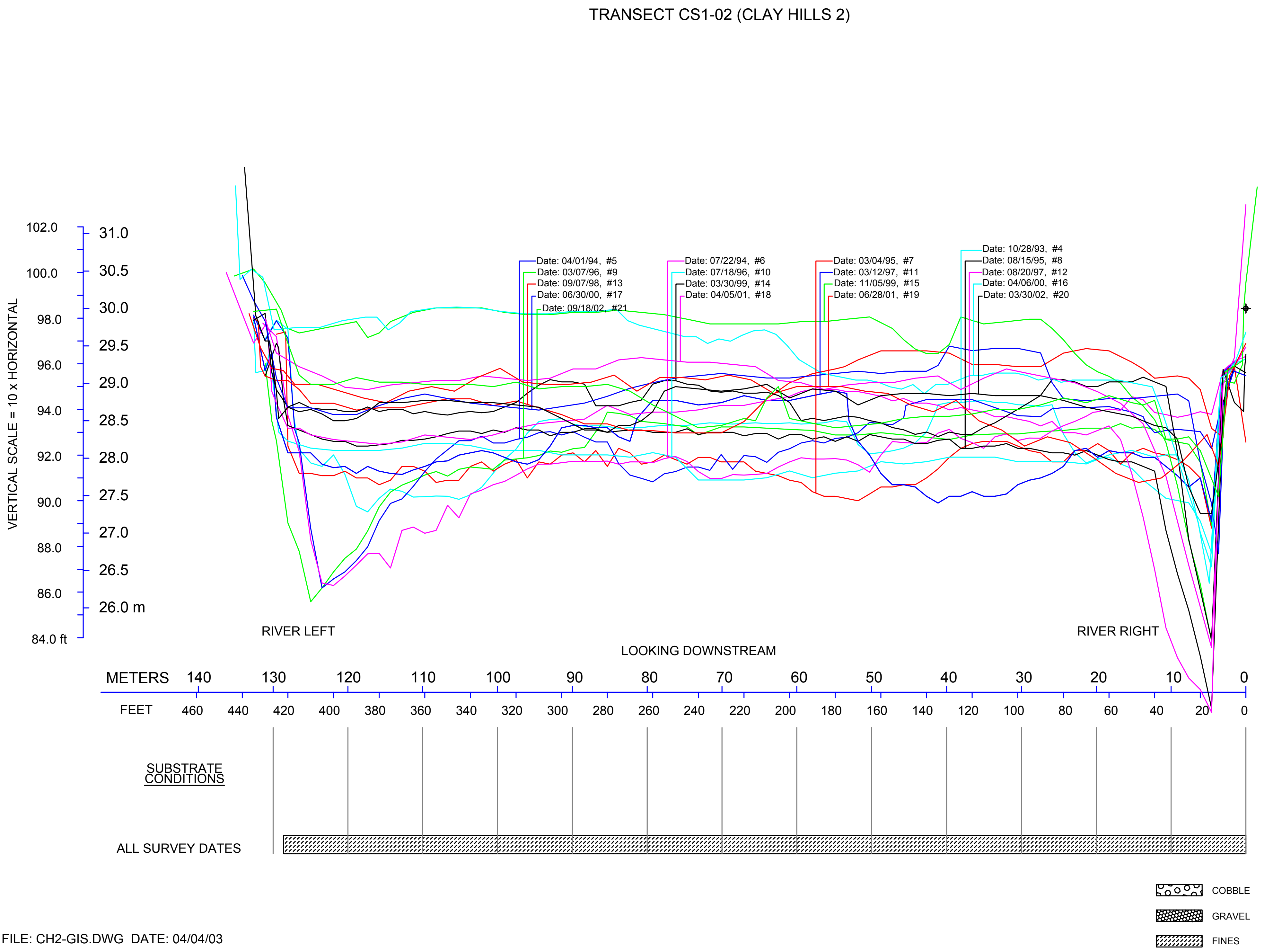

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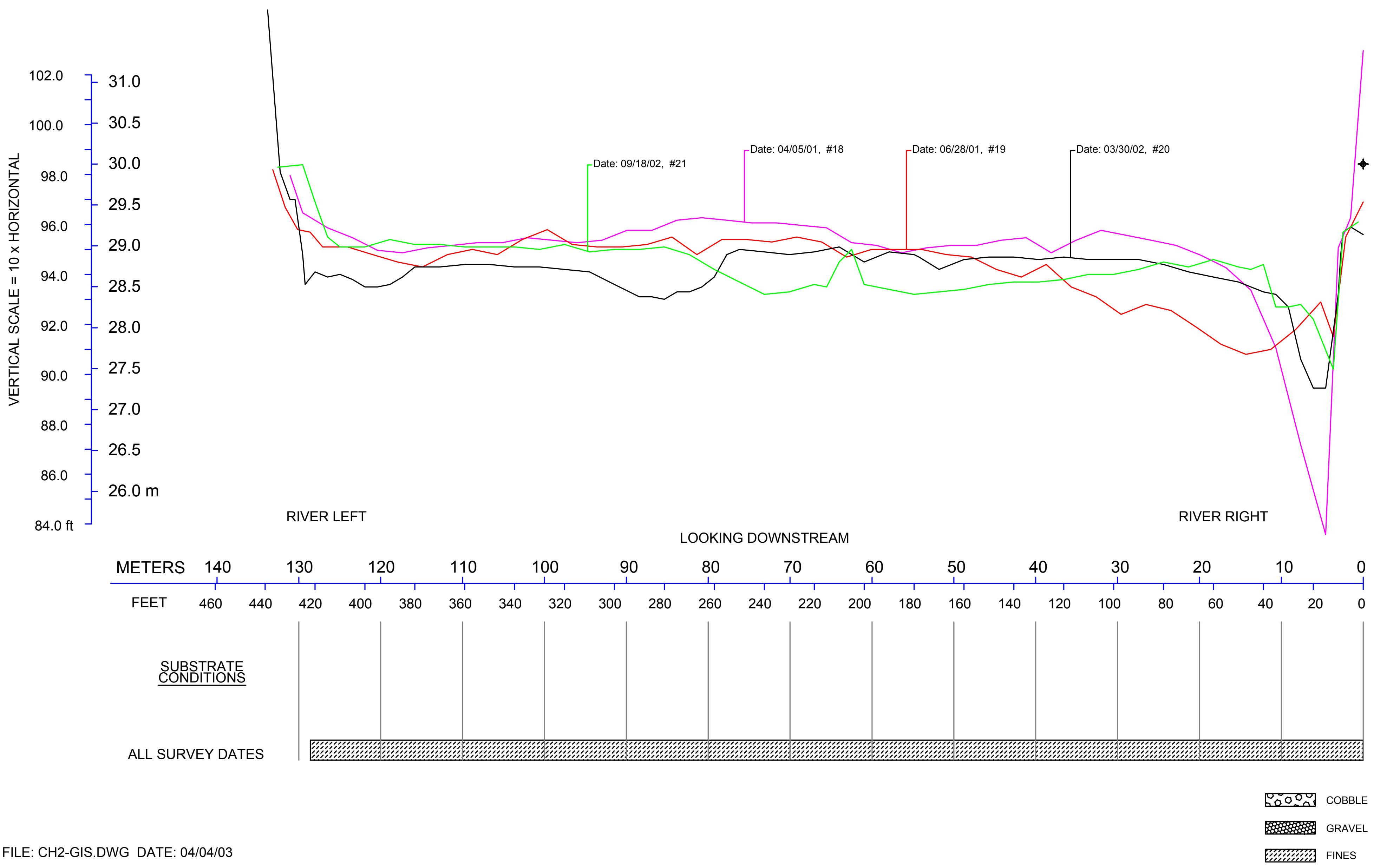

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